Australian Government

Department of the Environment and Energy

Shoalwater and Corio Bays Area

Ramsar Site

Ecological Character Description

2010

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Ecological Character Description for the Shoalwater and Corio Bays Area Ramsar Site

2010

Prepared For:	Department of Defence and Department of the Environment, Water, Heritage and the Arts
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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This report was updated by the Department of Environment and Heritage Protection (Queensland) in 2017 in consultation with the Australian Government Department of the Environment and Energy; and the Australian Government Department of Defence.

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Use of terms and information sources: All definitions and terms used in this report were correct at the time of production. Refer to the References (Section 6) for works cited and Glossary (Section 7) for a list of key terms and terminology used.

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INTRODUCTORY NOTES

This Ecological Character Description (ECD) 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 Commonwealth *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 Minister for the Environment 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 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 EPBC Act, nor replace the role of the Minister or his delegate in making an informed decision to approve an action.

This ECD 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.

List of Abbreviations

ADF	Australian Defence Force
ANZECC/ARMCANZ	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand
CAMBA	China-Australia Migratory Bird Agreement
CMS	(Convention on the) Conservation of Migratory Species
CSIRO	Commonwealth Science and Industrial Research Organisation
CQC	Central Queensland Coast (IBRA bioregion)
DEM	Digital Elevation Model
DERM	Department of Environment and Resource Management (Qld)
DEWHA	Department of the Environment, Water, Heritage and the Arts (Commonwealth)
DIWA	Directory of Important Wetlands in Australia
DoD	Department of Defence (Commonwealth)
ECC	Environmental Clearance Certificate
ECD	Ecological Character Description
EMS	Environmental Management System
EPA	Queensland Environmental Protection Agency
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FQ	Fisheries Queensland
GAP	Global Action on Peatlands
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
HAT	Highest Astronomical Tide
IBRA	Interim Biogeographic Regionalisation of Australia

IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IUCN	International Union for Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
KMC	Knowledge Management Committee
LAC	Limit(s) of Acceptable Change
NCA	Queensland *Nature Conservation Act 1992*
NES	National Environmental Significance
NRM	Natural Resource Management
ORV	Off road vehicles
QPWS	Queensland Parks and Wildlife Service
QWQG	Queensland Water Quality Guidelines
RE	Regional Ecosystem
REDD	Regional Ecosystem Description Database
RIS	Ramsar Information Sheet
ROKAMBA	Republic of Korea- Australia Migratory Bird Agreement
RRC	Rockhampton Regional Council
SDR	Seagrass Depth Range
sp.	Species (singular)
spp.	Species (plural)
SWBTA	Shoalwater Bay Training Area
USL	Unallocated State Land
VMA	Queensland *Vegetation Management Act 1999*

EXECUTIVE SUMMARY

The Shoalwater and Corio Bays Area Ramsar site is one of 65 Australian wetlands that are listed as Wetlands of International Importance under the *Convention on Wetlands of International Importance especially as Waterfowl Habitat* or, as it is more commonly referred to, the Ramsar Convention (the Convention). The site was listed under the Convention in 1996 and is widely recognised for its outstanding coastal wetlands and wilderness values.

This report provides the Ecological Character Description (ECD) for the Shoalwater and Corio Bays Area Ramsar site, prepared in accordance with the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (2008)("the National Framework"). The ecological character description of a wetland provides the baseline description of the wetland at a given point in time and can be used to assess changes in ecological character.

The Shoalwater and Corio Bays Area Ramsar site is located within the North East Coast Drainage Division of Australia, situated about 50 km north of Rockhampton in Central Queensland. The majority of the area falls within the boundaries of Shoalwater Bay Military Training Area (SWBTA) and includes marine waters, intertidal areas, and adjacent lands up to highest astronomical tide (HAT) mark from Broome Head in the north to the southern boundary of SWBTA near the township of Byfield. South-eastern inland parts of SWBTA (the Dismal Sector) are included within the boundaries of the Ramsar site but not the extensive inland western parts. The site also includes the tidal lands and waters of Corio Bay, a small embayment on the coast situated between SWBTA and the town of Yeppoon. The lower reaches of Water Park Creek, which flows into Corio Bay, are also included within the boundaries of the Ramsar site. A large proportion of the marine waters in the Ramsar site are included in marine parks (Commonwealth and Queensland), including the Great Barrier Reef Marine Park (Commonwealth) and Great Barrier Reef Coast Marine Park (State). Parts of Byfield National Park and Shoalwater Bay Regional Park are also included in the Ramsar site.

The site contains diverse wetland types with nine 'coastal' and nine 'inland' wetland types present (using the Ramsar typology). These habitats include open (high energy) sandy and rocky shorelines, estuarine embayments and inlets, and a number of remarkable groundwater-dependent freshwater wetlands particularly within the Dismal Sector of SWBTA.

Ecosystem processes that underpin the wetlands of the Shoalwater and Corio Bays Area Ramsar site include coastal processes and hydrodynamics (with the marine and estuarine wetlands of the site heavily influenced by the large tidal range and associated inundation patterns), surface freshwater flows (particularly at Corio Bay) and groundwater hydrology, water quality, geomorphology, climate, and a range of notable biological processes.

The wetland supports a broad range of natural values including nationally/internationally threatened wetland species, significant species diversity and large populations of waterbirds, green turtles, dugong and fish which use the site for vital life history functions such as roosting, nesting, feeding and breeding.

The Ramsar nomination criteria under which the site was listed in 1996 have been reviewed as part of the current study on the basis that revised and additional criterion have been adopted by the Convention since listing. The results of the review are that the Shoalwater and Corio Bays Area Ramsar site has been assessed as addressing criteria 1 through 8, as shown in Table E-1.

Table E-1 Ramsar Nomination Criteria met by the site

Nomination Criterion	Currently met by the site?
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.	**Yes**
Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	**Yes**
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.	**Yes**
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.	**Yes**
Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.	**Yes**
Criterion 6: A wetland should be considered internationally important if it regularly supports 1 per cent of the individuals in a population of one species or subspecies of waterbird.	**Yes**
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.	**Yes**
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.	**Yes**

While the Ramsar criteria principally relate to natural values of the site, cultural and socio-economic values associated with the site are also important, noting the predominantly undeveloped state of SWTBA and Corio Bay makes it an important reference site for scientific research as well as providing 'wilderness' values that are nationally and internationally recognised.

The size, coastal geography and relative isolation of SWBTA also make it one of the Australian Department of Defence's (DoD) prime defence training areas. The value of SWBTA to the DoD largely relates to the capacity to conduct military activities involving any of the three services (army, navy and air force) operating either singularly, jointly or combined with defence forces of other nations. The majority of defence training activities within SWBTA occur outside the boundaries of the Ramsar site and any effect to the ecological character of the wetlands within the Ramsar boundaries is minimised through access restrictions, land management activities and the management of defence training activities in the adjacent lands and waters.

Compared to SWBTA, Corio Bay is more accessible from regional centres such as Rockhampton and Yeppoon and has important local significance for recreational fishing and other forms of coastal recreation. Water Park Creek, which flows into Corio Bay, is an important source of potable water supply for the Capricorn Coast, noting that the majority of the flow that supplies this creek originates from groundwater infiltration through the freshwater wetlands and dunefields of the SWBTA Dismal Sector. While the future water supply for the region is to be secured through construction of a water

pipeline from the Fitzroy River, Water Park Creek will continue to supply potable water to these coastal communities and represents a strategic reserve for the future.

Following the methodology set out in the National Framework document, Table E-2 summarises the critical ecosystem components and processes provided by the Shoalwater and Corio Bays Area Ramsar site.

The critical wetland ecosystem services/benefits are based on attributes of the site described in the Ramsar nomination (refer Table E-1) as well as critical cultural services/benefits provided by the site in terms of human use. Critical wetland ecosystem components and processes have been selected on the basis that they underpin the critical ecosystem services/benefits, noting that these components and processes vary across the diverse range of ecosystems present within the site.

The study has sought to define natural variability and limits of acceptable change (LACs) for the critical services/benefits, components and processes identified. A summary of the LACs (as they relate to nomination criteria and critical components and processes) is shown in Table E-3. LACs have also been set within the ECD for the critical components (principally in relation to key wetland species, populations and wetland habitats) and underlying critical processes (such as water quality that affects wetland habitat condition). LACs are a tool by which ecological change can be measured. However, ECDs are not management plans and LACs do not constitute a management regime for the Ramsar site. Exceeding or not meeting LACs 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 LACs may require investigation to determine whether there has been a change in ecological character.

In the context of changes to ecological character of the site since listing in 1996, the study has examined:

- impacts or other possible adverse changes to ecological character that have been observed or documented in literature and on the basis of the expert opinions of the Steering Committee and Knowledge Management Committee
- identification of current and future threats to ecological character.

Based on literature and data reviewed as part of the study and expert opinions provided from the Committees, there has not been any observable or significant deterioration in the condition of wetlands within the site or other noteworthy changes to the ecological character of either SWBTA or Corio Bay outside the bounds of natural variability.

An assessment of the condition of the intertidal wetlands and freshwater swamps of the Shoalwater Bay section of the site by Jaensch (2008b) has indicated that overall condition of these habitats are very good, based in part on the present environmental management regime for the site. In this context, no LACs set as part of the current study were determined to have been exceeded since the date of listing.

Key threats that should be considered in future management of the site include: future infrastructure development within or adjacent to the site, pest plants and animals, uncontrolled fires (particularly in the freshwater wetlands and heavily vegetated areas of the site), and recreational usage of the site principally in terms of land-based off-road vehicles and recreational watercraft.

The implications of climate change on the site – particularly sea level rise and changes to rainfall and runoff patterns – are a relevant long term threat to the ecological character of the Shoalwater and Corio Bays Area Ramsar site. However, the predominantly natural character, minimal prior or current human disturbance of the site and on-going land and water management activities will ensure better resilience to these impacts than at many other (highly modified) coastal environments of eastern Australia.

Information gaps, monitoring needs and recommendations in relation to communication, education and public awareness messages are also identified in the ECD. Better information and understanding about the natural variability of critical components (e.g. wetland habitats and fauna populations) and the key attributes and controls on those populations (e.g. critical processes) are needed, noting that the limits of acceptable change stated in the ECD are based on best professional judgement and will need to be evaluated as better or more current information becomes available.

In general, the wetland components and processes of Corio Bay are far less studied than those of SWBTA which represents a broad information gap, noting a range of studies about the ecological condition of Corio Bay have been undertaken by Central Queensland University. In looking at specific threats to Corio Bay, the interaction between the Corio Bay and Iwasaki wetlands and the effects of the long term bunds between the wetlands is a particularly important issue. Investigation of the existing Water Park Creek weir (used to supply water to coastal urban communities outside of the Ramsar site) in terms of its potential impacts to riparian vegetation, fish passage and environmental flows are currently being progressed by Fisheries Queensland.

Monitoring needs and recommendations presented in the ECD principally relate to obtaining more robust baseline data to assess natural variability and future changes to ecological character as defined by the critical services/benefits, components and processes.

Continuing to undertake periodic assessments of wetland habitat condition and usage (similar to the approach taken in Jaensch 2008b) and research into population dynamics of key species such as turtles and dugong to establish a long term baseline for the key wetland populations within the boundaries of the Ramsar site are recommended. In this context, while all wetland habitats are important, priority should be given to the monitoring of notable freshwater wetland values of the site and critical life stage habitat areas (e.g. roosting sites in Port Clinton, breeding sites, nesting sites, etc.) that underpin the listing of the site as a Wetland of International Importance.

Finally, in terms of communication, education and awareness messages, the ECD outlines some key messages about the ecological character of the site.

Table E-2 Summary of critical services and benefits, components and processes of the Shoalwater and Corio Bays Area Ramsar site

Ecosystem services/benefits	Ecosystem components	Ecosystem processes
1: The site contains marine, estuarine and freshwater landscapes and ecosystems that are representative of the biogeographic region and are rare in the context of a large coastal system that remains in a near natural state **2:** The site has wetland types (notably the peat swamps in the Dismal Sector and the Clinton Lowlands) that are rare, unusual and noteworthy for the biogeographic region and at greater spatial scales. **3:** The site supports national and internationally threatened wetland species. **4:** The habitat diversity present within the site supports outstanding biodiversity values including several notable vegetation communities. **5:** The site supports substantial numbers of wetland species during a critical life stage (e.g. breeding, nesting, roosting, feeding, and/or refugia). **6:** The site supports substantial numbers of resident and migratory waterbirds. **7:** The site supports a high diversity of fish species reflecting the diversity of habitats of the site and a biogeographical overlap zone. **8:** The site supports nursery habitat of critical importance to regional commercial and recreational fisheries. **9:** The site supports a range of pristine/near natural wetland environments that are important for scientific research and assessing the future impacts of climate change. **10:** The site provides a significant regional asset in terms of water supply to the Capricorn Coast and will provide a strategic reserve for freshwater in the future. **11:** The site and its values are a major part of a broader 'wilderness area'. .	**Wetland habitats,** including the following Ramsar types: *Coastal/Marine* • 9 Types *Inland* • 9 Types **Populations of wetland-dependent fauna and flora species of national or international conservation significance**, including populations of: • Aquatic animals (marine): Sea turtles and dugong • Aquatic animals (freshwater): honey blue eye • Wetland-dependent terrestrial fauna species: water mouse • Wetland-dependent flora: lesser swamp orchid **Wetland vegetation communities** reliant on the site for conservation security **Populations** of migratory and resident waterbirds **Populations** of fish and invertebrates that are of recreational and commercial significance	**Physical coastal processes.** Hydrologic and hydrodynamic controls on habitats through tides, currents, waves, wind and associated erosion and accretion processes. **Surface freshwater inflows** Freshwater inflows from creeks and surface run-off most notably into Corio Bay and into Shoalwater Bay. **Groundwater.** Groundwater dynamics and interaction with freshwater wetland systems. **Water quality.** Water quality that provides aquatic ecosystem values within wetland habitats. **Geomorphology**. Key geomorphologic/ topographic features of the site. **Energy and nutrient dynamics.** Primary productivity and the natural functioning of carbon and nutrient cycling processes. **Biological processes.** Important biological processes such as growth, reproduction, recruitment, migration and dispersal. **Climate.** Patterns of temperature, rainfall, and evaporation.

Table E-3 Critical components and processes of the Shoalwater and Corio Bays Area Ramsar site - Limits of Acceptable Change

Ramsar criteria	Critical components and processes	Baseline/Supporting Evidence	Limit of acceptable change	Confidence
Criteria 1	Wetland habitats (Marine) – Seagrass (Wetland Type A, B, F)	Mapped extent in 1995-1996 (post Ramsar listing) ~13,000 ± 800-890 ha (Lee Long *et al.* 1997). For late spring (seasonal maximum) monitoring, aerial extent is likely to be relatively stable.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Mangroves (Wetland Type F, G, H, I)	While broad-scale mapping of wetland and vegetation community types exists (e.g. RE mapping), there are no data describing the range of natural temporal variability in extent of different vegetation communities and the controls on these changes.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Saltmarsh (Wetland Type G, H, I)	See Wetland habitats (Marine) - Mangroves.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Rocky reef coral communities (Wetland Type C, D)	There is very coarse mapping available for rocky reefs in the site. Broad community structure and species is available but not at a site or community scale. This needs to be updated to form a baseline for the LAC.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Sandy shores (Wetland Type E, G)	Aerial photography could be used to establish a baseline extent for beach and dune features. Literature reviewed indicates that these habitats are fairly stable in the SWTBA area. There is likely a combination and natural and anthropogenic impacts on beaches at Sandy Point in Corio Bay.	Presence of habitat	Moderate
	Wetland habitat (Freshwater) – marshes, Peat swamps (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y)	While broad-scale mapping of wetland and vegetation community types exists (e.g. RE mapping), there areno data describing the range of natural temporal variability in extent of different vegetation communities and the controls on these changes. It should be noted that a mapping layer specifically for the extent of peat swamps has not been derived.	Presence of habitats	Moderate
	Hydrology – freshwater flows (e.g. Waterpark Creek, Peat swamps, saltmarsh) (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y)	Annual volumes (ML) at Water Park Creek gauging station (1957-1996): Range = 24,278 to 429,030; Mean = 156,135.9; Median = 109,157; CoV = 73.6%. There are no available baseline data to determine ranges of natural variability under different flow conditions. Until such time as site specific flow duration curves are developed for each wetland type, no LAC is proposed. Changes in LAC for wetland habitats could be used as surrogate measures for this process.	No direct LAC has been developed and instead the critical process will be assessed indirectly through changes in wetland habitats and threatened species.	
	Hydrology – groundwater dynamics (e.g. Freshwater wetlands, Peat swamps) (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y)	There are no available baseline data to determine ranges of natural variability under different flow conditions. Until such time as site specific flow duration curves are developed for each wetland type, no LAC is proposed. Changes in LAC for wetland habitats could be used as surrogate measures for this process.	No direct LAC has been developed and instead the critical process will be assessed indirectly through changes in wetland habitats and threatened species.	
Criteria 2	Threatened species – water mouse	There is insufficient site data for this species which is typically regarded as occurring in potentially low population densities and patchy occurrence.	Presence of water mouse in the site	Low
	Threatened species – dugong	Population numbers outlined in GBRMPA (1997): 765 ± 161 S.E. in 1987; 406 ± 78 S.E. in 1994.	Information presently insufficient for proposing any LACs	

		However, there is insufficient available information on the population dynamics and genetics of dugongs to develop a definitive LAC.		
	Threatened species – flatback turtle	Wild Duck Island to the north of Shoalwater Bay is one of the two major flatback rookeries in eastern Australia, with several hundred females nesting annually. Low density or sporadic nesting occurs on many other beaches and islands in the vicinity of Shoalwater Bay (Limpus *et al.* 2005). The area encompassing SWBTA south of the Percy Islands south to Stockyard Point and the Duke Island Group between Wild Duck Island and the Marble Group remains unsurveyed. It is expected that this unsurveyed area will contain *N. depressus* and *C. mydas* rookeries.	The loss or prolonged absence (>5 successive years) of flatback nesting within the beaches of the site	Moderate
	Threatened species – green turtle	Specific feeding areas, prey types and prey densities required to support turtles are unknown. Limpus *et al.* (2005) suggests that seagrass represents ~86% of turtle volume of turtle diet, followed by red algae (~10% by volume). Presently there is no data on red algae distribution and abundance. Limpus *et al.* (2005) found over an 18 year monitoring period the following breeding rates: ♀ Mean = 0.119 ± 0.026 S.E.; ♂ Mean = 0.34 ± 0.072 S.E. There is comparatively fewer pre-listing data (n = 7-11 years): ♀ Mean = 0.118 ± 0.032 S.E.; ♂ Mean = 0.39 ± 0.010 S.E. Insufficient empirical data to derive definitive LACs. There is a need to develop baseline data describing variability in key turtle food resources within and adjacent to the site in order to develop empirical LACs. It is not possible at this stage to provide guidance on these limits as, to a large extent, these will be dependent on the adopted sampling methodology and levels of natural variability. There is also insufficient empirical data to derive empirical, threshold-based LACs that are meaningful in the context of maintaining turtle populations.	Information presently insufficient for proposing any LACs	
	Threatened species – Honey blue-eye	This species typically has low population densities hence empirical population estimated have not been determined. There is insufficient empirical data to derive definitive LAC.	Presence of Honey blue-eye	Moderate
	Threatened species – lesser swamp orchid	There are no available data on water requirements of the lesser swamp orchid, nor are there suitable baseline data describing water regimes/water levels at particular locations supporting the threatened plant species. No information is available regarding the population sizes, dynamics and viability of the threatened plant species within the site. Should an adequate baseline be established, such as watering requirements of each species, LACs could be calculated based on the range of variability at representative sites. It is not possible at this stage to provide guidance on these limits as, to a large extent, these will be dependent on the adopted sampling methodology and levels of natural variability, and will vary across locations.	Presence of lesser swamp orchid	Moderate
Criteria 3	Biodiversity	The site supports 18 Ramsar wetland types (9 coastal/marine; 9 inland). In terms of wetland dependent species, the site supports 22 frog species, 77 waterbird species and 32 shorebird species. Surveys have recorded 428 estuarine and marine fishes and 17 freshwater fishes, not including records of the Honey blue-eye.The Queensland State Government WildNet database records 909 species of native	No direct LAC has been developed and instead the critical component will be assessed indirectly through changes in wetland habitats and threatened species. See	

		plants. Changes in LAC for wetland habitats and threatened species could be used as surrogate measures for this component.	LAC above.	
Criteria 4	Habitat for critical life stages	The site provides the following critical life stage processes: • feeding and roosting habitat for 77 waterbird species • non-breeding, feeding and roost habitat for 26 migratory shorebird species including 26 and 27 species protected under the JAMBA and CAMBA agreements respectively • habitat for 22 frog species • feeding and breeding habitat for wetland-dependent raptor species • habitat for honey blue-eye freshwater fish (entire life-cycle) • nesting habitat for flatback turtles. The ecological condition assessment by Wetlands International (refer Jaensch 2008a) provides the baseline for assessment of this LAC at SWBTA. There is no analogous ecological condition assessment for Corio Bay. Changes in LAC for wetland habitats and threatened species could be used as surrogate measures for this component.	No direct LAC has been developed and instead the critical component will be assessed indirectly through changes in wetland habitats and threatened species.	
Criteria 5 and Criteria 6	Waterbirds – numbers of species	Key shorebird species include grey-tailed tattler, bar-tailed godwit, eastern curlew, whimbrel, terek sandpiper and Australian pied oystercatcher. There is insufficient time series sequence to assess natural population variability of resident shorebird breeding success (pied oystercatcher only). Interpretation of changes in abundance for migratory species need to be assessed against potential external factors (potential variability in breeding success) and in particular, anthropogenic impacts to key sites within other parts of the flyway. As a result there in insufficient empirical data to derive definitive LACs. There is a need to develop a sequence of population estimates and measures of breeding success within site in order to develop empirical LACs.	Information presently insufficient for proposing any LACs	
Criteria 7	Fish	There are currently no recent baseline data (collected using systematic sampling techniques) to determine patterns in fish assemblages at representative locations and habitats in the site. Until such time as these data become available, this LAC cannot be directly assessed. Undertaking a marine and freshwater fish survey in similar locations and using a similar methodology to Trnski *et al.* (1993) may provide an adequate baseline from which to derive a LAC for this component. Refer survey by Trnski *et al.* (1993) as the baseline for fish diversity at the time of listing in 1996 which noted 428 marine species were present and 17 freshwater species.	Information presently insufficient for proposing any LACs	

1 INTRODUCTION

This Section provides general information about the Ecological Character Description (ECD) process and the Shoalwater and Corio Bays Area Ramsar site.

1.1 Background

The Shoalwater and Corio Bays Area Ramsar site is one of 65 wetland areas in Australia that are currently listed as a wetland of international importance under the *Convention on Wetlands of International Importance especially as Waterfowl Habitat* or, as it is more commonly referred to, the Ramsar Convention (hereafter referred to as the Convention). Shoalwater and Corio Bays was listed as a Ramsar site under the Convention in 1996 in recognition of its outstanding coastal wetland values and features.

The Convention sets out the need for contracting parties to conserve and promote wise use of wetland resources. In this context, an assessment of ecological character of each listed wetland is a key concept under the Ramsar Convention. Under the Convention, appropriate management of Ramsar wetlands includes describing and maintaining the ecological character of the wetland, and implementing planning processes that promote conservation and wise use.

Ecological character is described as the combination of the ecosystems components, processes, benefits and services that characterise the wetland at a given point in time (Ramsar Convention 2005, Resolution IX.1 Annex A). The ECD provides the baseline description of the wetland at a given point in time, and sets the baseline or benchmark to assess change in the ecological character of the site. ECDs can complement other Ramsar site documents, such as the Ramsar Information Sheet (RIS). This report provides the ECD for the Shoalwater and Corio Bays Area Ramsar site, as described in 2009.

This ECD report was prepared over a period of eleven months by the consultant study team led by BMT WBM Pty Ltd under contract with the Department of the Environment, Water, Heritage and the Arts (DEWHA). This has occurred with input from a Project Steering Committee made up of officials from the Department of Defence (DoD), DEWHA, the Queensland Department of Environment and Resource Management (DERM) and Fisheries Queensland (of the Department of Employment, Economic Development and Innovation). A range of Government and non-Government individuals with expertise and/or local research experience working within the Ramsar site have also been engaged as part of a Knowledge Management Committee (KMC) for the study.

1.2 Scope and Purpose

The National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008) (hereafter referred to as the National Framework), provides a comprehensive approach to preparation of ECD studies in Australia taking into account the obligations of the Convention, domestic legislative requirements under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and best practice approaches in other jurisdictions.

Figure 1-1 shows the key steps of the ECD process from the National Framework document.

Based on the National Framework document, the key purposes of undertaking an ECD are to:

- contribute to meeting the obligations of the Convention and EPBC Act for the site
- review existing information, data and literature, supplement the description of ecological character in the RIS for the wetland
- quantify, where possible, the natural variation and/or limits of acceptable change to the ecological character of the site such that it can be measured over time
- outline the components, processes, services and benefits that should be considered in the context of assessments under the EPBC Act and other impact assessment legislation at a State and local level
- identify information and knowledge gaps that will assist in measuring changes to ecological character over time and prioritise future monitoring and management planning for the site.

As such, the key audiences for this document are:

- the DoD and the Queensland Parks and Wildlife Service (QPWS) as the principal site managers of the Shoalwater Bay Training Area (SWBTA) and Corio Bay respectively
- other Queensland Government agencies and local governments that make decisions that could affect the ecological character of the site
- the DEWHA in terms of decision-making under the EPBC Act in relation to the site, and liaison with the Ramsar Convention
- other sectors of the community with a management, scientific, cultural or general interest in the Shoalwater and Corio Bays Area Ramsar site.

This Final Report has been prepared following a two-stage review process with the organisations represented on the Steering Committee.

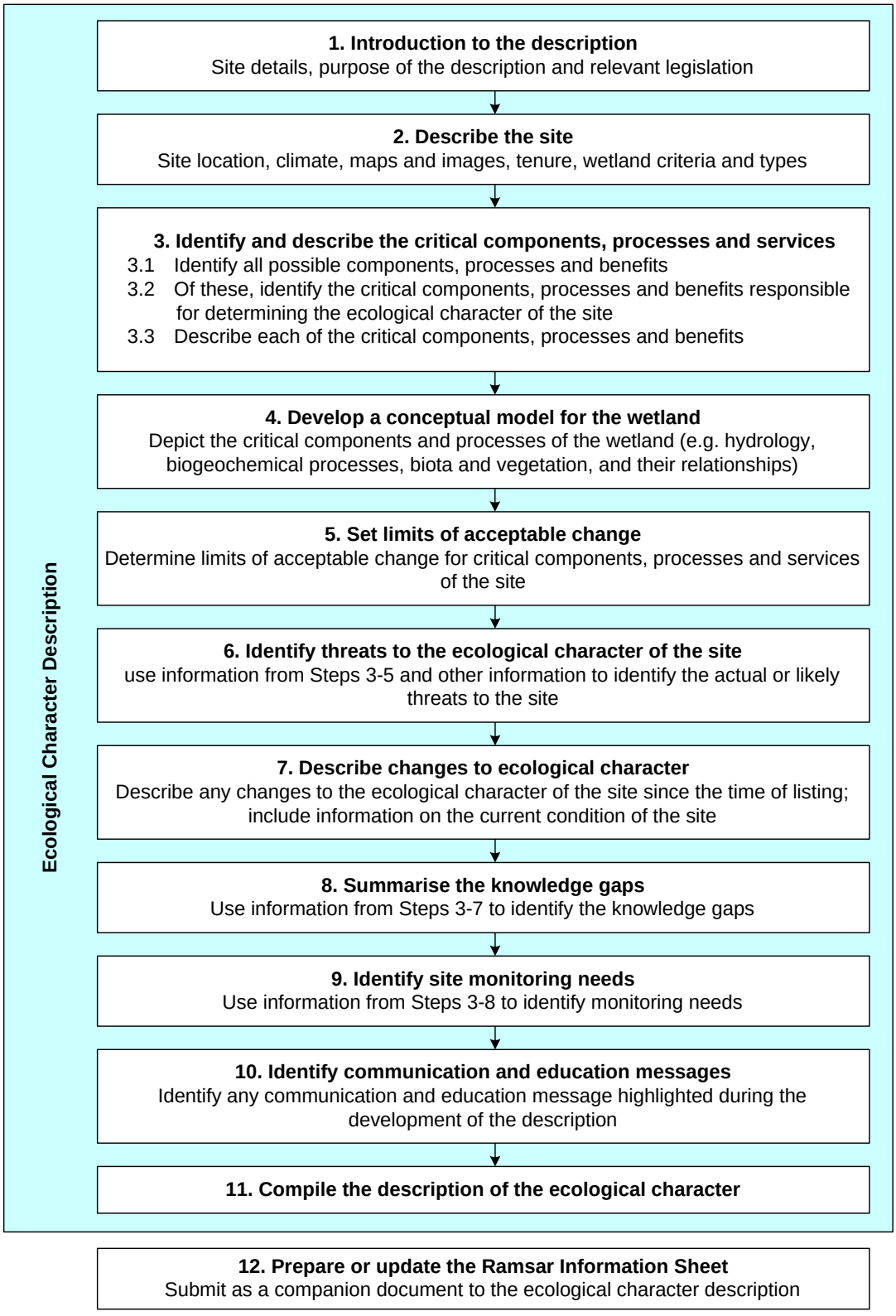


Figure 1-1 Key steps in preparing an Ecological Character Description

1.3 Relevant Treaties, Legislation and Regulations

This section provides an overview of the treaties, legislation and regulations at various levels of government relevant to the Shoalwater and Corio Bays Area Ramsar site.

1.3.1 Australian Government Legislation or Policy Instruments

Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, Iran, 1971) or as it is more commonly known, the Ramsar Convention, is an intergovernmental treaty dedicated to the conservation and sustainable use of wetlands (EA 2001). Australia was one of the first 18 countries to become a signatory to the Convention in 1971. The Ramsar Convention Secretariat maintains a List of Wetlands of International Importance that includes 65 existing Australian sites totalling 8 million hectares in area. The Shoalwater and Corio Bays site, designated as a Ramsar site in 1996, is Ramsar site number 44 on the Australian list, and Ramsar site number 792 on the global List of Wetlands of International Importance.

EPBC Act (1999)

Australia's obligations to protect and maintain the ecological character of its Ramsar sites is recognised in Commonwealth legislation through the EPBC Act. The EPBC Act sets out standards for managing Ramsar wetlands through the Australian Ramsar Management Principles (established within regulations under the Act) and through the referral and assessment of activities that may have a significant impact on the ecological character of a designated Ramsar site and other Matters of National Environmental Significance (MNES).

Several of the MNES under the Act are directly relevant to the Shoalwater and Corio Bays Area Ramsar site and are discussed in the sections below. These include:

- Wetlands of International Importance (listed under the Ramsar Convention)
- listed threatened species and ecological communities
- migratory species protected under international agreements
- World Heritage properties
- National Heritage places.

EPBC Act and Ramsar wetlands

In the context of assessing significant impacts on the ecological character of Ramsar wetlands, actions that are considered to have an effect or potential effect on wetland ecological character result in one or more of the following:

- areas of the wetland being destroyed or substantially modified
- a substantial and measurable change in the hydrological regime of the wetland - for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland
- the habitat or lifecycle of native species dependent upon the wetland being seriously affected

- a substantial and measurable change in the physico-chemical status of the wetland - for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland, or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health
- an invasive species that is harmful to the ecological character of the wetland being established in the wetland.

The Australian Government Minister for the Environment (the Minister) decides whether the action has had, will have, or is likely to have a significant impact on the ecological character of the Ramsar wetland and whether the action will require approval under the EPBC Act. If approval under the EPBC Act is required, then an environmental assessment of the action must be carried out. The Minister decides whether to approve the action, and what conditions (if any) to impose, after considering the environmental assessment.

EPBC Act and protection of species listed under international conventions

Under the EPBC Act, actions that have, or are likely to have, a significant impact on a MNES requires approval from the Minister. The Minister will decide whether assessment and approval is required under the EPBC Act.

Several species that are protected under the EPBC Act are listed under international agreements. The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention) was adopted in 1979 and aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty under the United Nations Environment Programme (UNEP), concerned with the conservation of wildlife and habitats on a global scale.

The Japan-Australia Migratory Birds Agreement (JAMBA) and China-Australia Migratory Birds Agreement (CAMBA) are bilateral agreements between the governments of Japan and Australia and China and Australia, which seek to protect migratory birds in the East Asian-Australasian Flyway. The two agreements list terrestrial, water and shorebird species that 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 from take or trade except under limited circumstances, protect and conserve habitats, exchange information, and build cooperative relationships. The JAMBA agreement also includes specific provisions for cooperation on conservation of threatened birds.

In April 2002, Australia and the Republic of Korea also agreed to develop a bilateral migratory bird agreement similar to the JAMBA and CAMBA. The Republic of Korea-Australia Migratory Birds Agreement (ROKAMBA) agreement obliges its Parties to protect bird species which regularly migrate between Australia and the Republic of Korea, and their environment. The Annex to the ROKAMBA contains the list of species or subspecies of birds for which there is reliable evidence of migration between the two countries.

EPBC Act and Heritage

The marine components of the Shoalwater and Corio Bays Area Ramsar site form part of the Great Barrier Reef World Heritage Area, inscribed onto the World Heritage List in 1981 and the National Heritage List in 2007. SWBTA was also included on the Commonwealth Heritage List in 2004

EPBC Act and Commonwealth Lands

The EPBC Act also applies generally to all actions undertaken by Commonwealth agencies on Commonwealth land. As such, many activities proposed on SWBTA require assessment under the Act through the referral and controlled action approval process or otherwise are assessed and managed through guidelines and arrangements agreed between DoD and DEWHA (DoD 2009).

Great Barrier Reef Marine Park Act (1975)

The marine waters of the Shoalwater and Corio Bays Area Ramsar site are a combination of both State and Commonwealth territorial waters. Marine areas below the mean low-water mark are part of the Commonwealth Great Barrier Reef Marine Park (GBRMP) and areas between the mean low-water mark and the mean high-water mark are generally part of the Great Barrier Reef Coast Marine Park (Queensland). Port Clinton is excluded from both marine parks. The marine park zoning plan for the Shoalwater section of the GBRMP, where the majority of the Ramsar site is situated, is shown in Figure 1-2. Commonwealth and State Marine Park zoning is complementary to provide for consistent management. Much of the area within and surrounding the Ramsar site is managed for marine conservation with designation as either Marine National Park Zone (green) or Conservation Park Zone (yellow). However, those areas within Shoalwater Bay itself under State jurisdiction (between low- and high-water marks and including the mangrove forests) have lower protection as Habitat Protection Zone (dark blue). Corio Bay is also part of the Great Barrier Reef Coast Marine Park and managed under a General Use Zone (light blue), with an adjacent Conservation Park Zone (yellow) along the coast (refer Figure 1-3).

In recognition of the Ramsar site's importance for supporting the largest habitat for dugongs (*Dugong dugon*) in the Mackay/Capricorn section of the Great Barrier Reef Marine Park, a large part of Shoalwater Bay and Port Clinton is designated a Special Management Area for Species Conservation (Dugong Protection) under the Great Barrier Reef Marine Park Regulation 1983 (Cwlth) within the GBRMP to protect the species from impacts of fishing. This Dugong Protection Area is subject to the Shoalwater Bay (Dugong) Plan of Management (GBRMPA 1997), which aims to manage activities within Shoalwater Bay that threaten dugongs and their seagrass habitats.

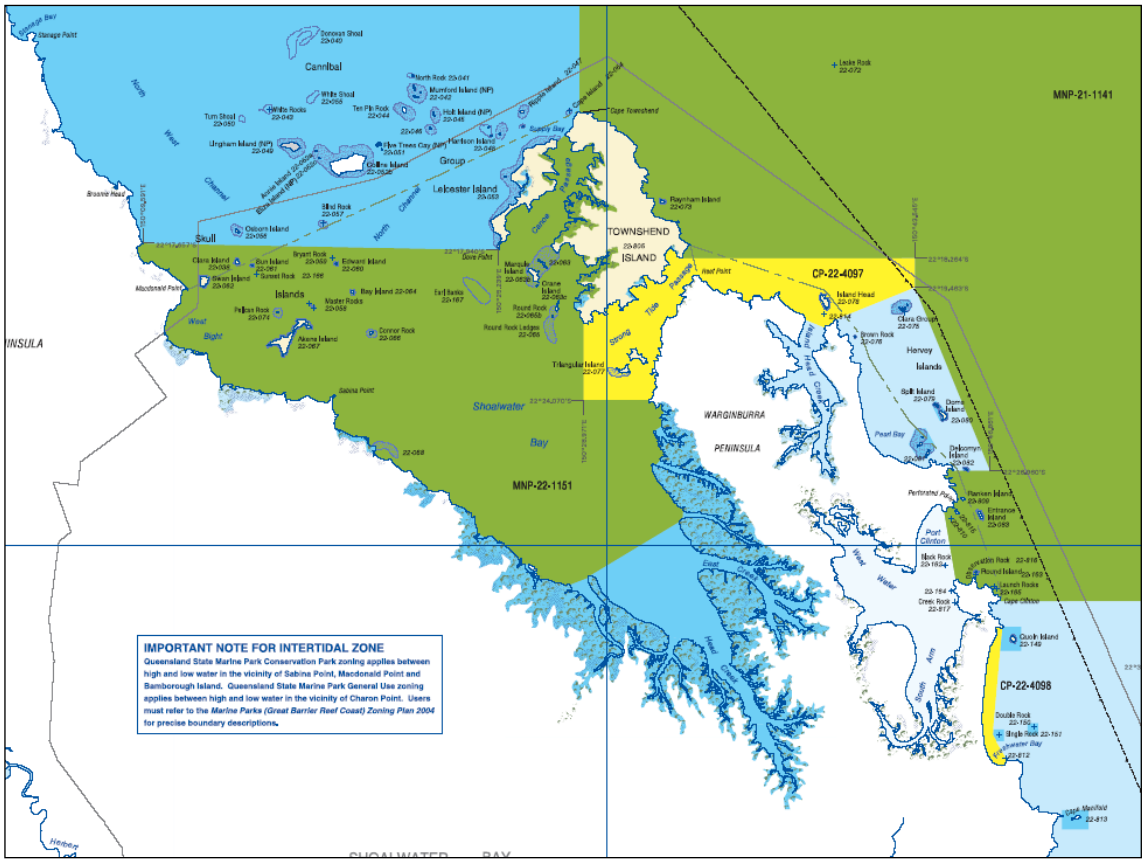


Figure 1-2 Marine park zoning in the vicinity of the Ramsar site (Shoalwater Bay section) (© Copyright, BMT WBM)

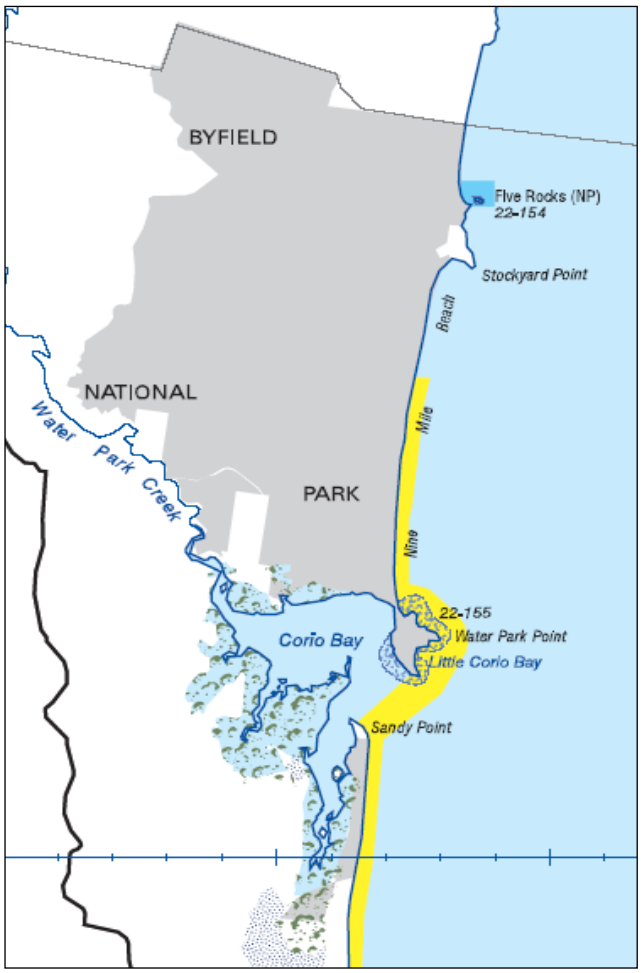


Figure 1-3 Marine park zoning in the vicinity of the Ramsar site (Corio Bay section) (© Copyright, BMT WBM)

Commonwealth Commission of Inquiry

A Commission of Inquiry into the Shoalwater Bay Area (the Area) was undertaken over a one year period in 1993-1994, principally to investigate proposals for sand exploration and mining. The Commission presented 35 recommendations and a set of detailed findings with respect to the values of the Area and the potential impacts and effects of various uses and activities.

The two major findings of the Commission were that: (1) the biodiversity and wilderness values of the Area should be conserved and managed as an area of national, State and regional significance; and (2) that the conservation use of the Area as a whole (including land and sea) be elevated and recognised as being 'a concurrent and equally significant use with defence use of the area' (DoD 2009).

Other relevant findings of the Commission, including reference to various technical reports that underpinned its findings, are discussed throughout this ECD report.

1.3.2 Queensland Government Legislation or Policy Instruments

There are many of State laws, policies, plans and strategies that apply directly and indirectly to the conservation and wise use of the Shoalwater and Corio Bays Area Ramsar site.

Applicable State legislation includes: the *Marine Parks Act 2004, Environmental Protection Act 1994*, *Fisheries Act 1994*, *Nature Conservation Act 1992* (NCA), *Land Act 1994*, *Coastal Protection and Management Act 1995*, *Sustainable Planning Act 2009*, *Vegetation Management Act 1999* (VMA), *Water Act 2000*, *Forestry Act 1957*, *Land Protection (Pest and Stock Route Management) Act 2002, Transport Operations (Marine Pollution) Act 1995, Transport Operations (Marine Safety) Act 1994*, *Queensland Heritage Act 1992*, *Aboriginal Cultural Heritage Act 2003*, and their respective regulations. While many of these laws do not apply over the Commonwealth land covered within SWBTA, they are relevant to surrounding land uses or otherwise regulate adjacent activities that could have an impact on the Ramsar site.

The principal State Government management planning regimes that guide day to day management within the marine and estuarine waters and some foreshore areas of the Ramsar site include the Great Barrier Reef Coast Marine Park (declared under the *Marine Parks Act 2004*), the Corio Bay Declared Fish Habitat Area (FHA-067, declared under the *Fisheries Act 1994*; refer Figure 1-4), and the Byfield National Park and Shoalwater Bay Regional Park (declared under the *Nature Conservation Act 1992*).

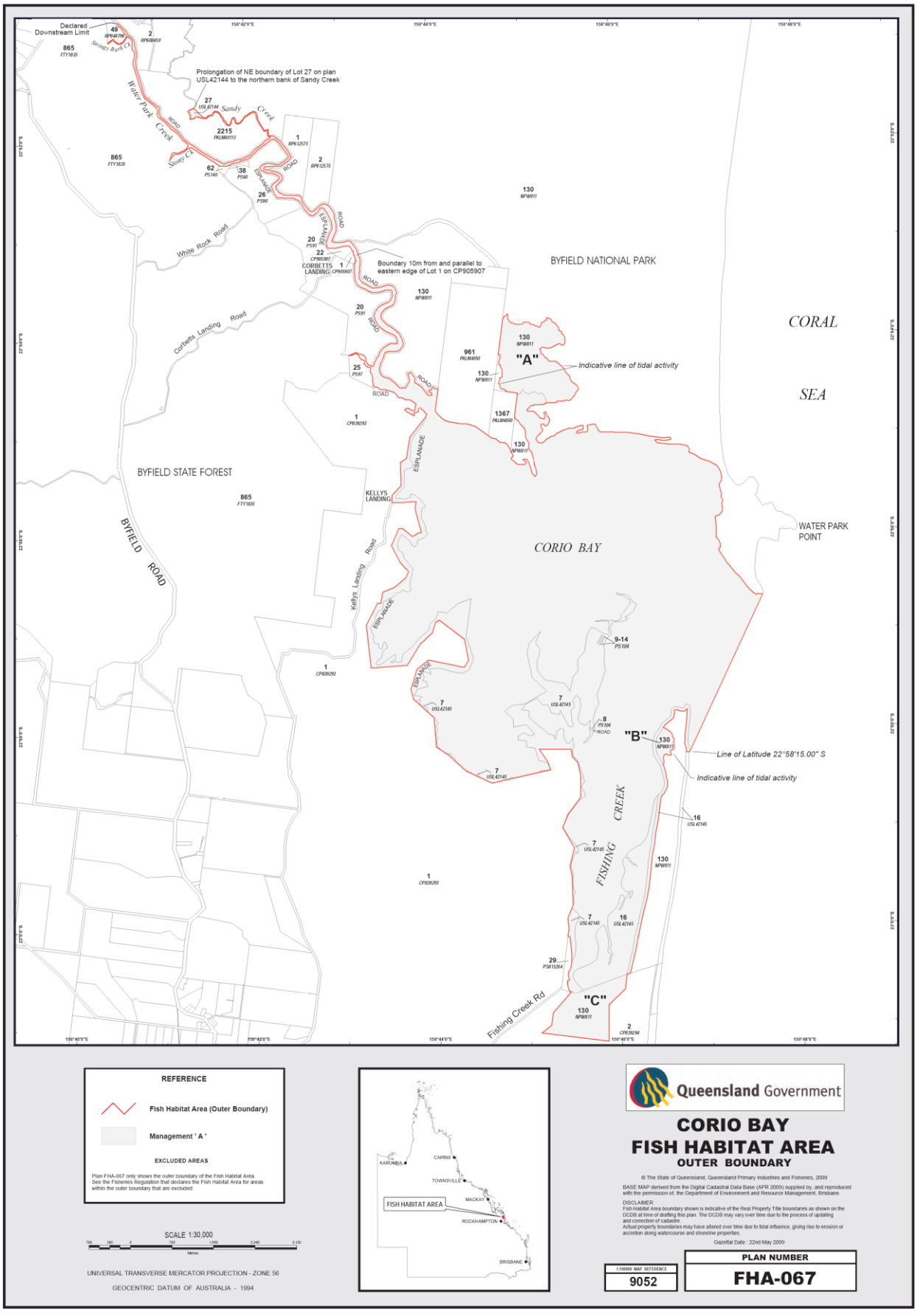


Figure 1-4 Corio Bay Fish Habitat Area (© Copyright, Fisheries Queensland)

1.4 Key Terminology and Concepts

The sections below discuss key terms and concepts from the National Framework used throughout the report. Specific definitions of these and other commonly used terms are contained in the Glossary in Section 7.

1.4.1 Wetland Processes

Wetland ecosystem processes are defined as the dynamic forces within the ecosystem between organisms, populations and the non-living environment. Interactions can be physical, chemical or biological. Examples include:

- climate – rainfall, temperature, evaporation
- hydrology – water balance, flooding and inundation regime
- geomorphology and physical processes – topography, soils, sedimentation processes, erosion
- energy and nutrient dynamics – primary production, decomposition, carbon cycle
- biological Processes such as:

  (a) biological maintenance – reproduction, migration, dispersal, pollination

  (b) species interactions – competition, predation, succession, disease, infestation.

1.4.2 Wetland Components

Wetland ecosystem components are the physical, chemical and biological parts or features of a wetland. Examples include:

- physical form – wetland type, geomorphology
- wetland soils – profiles, permeability, physico-chemical properties
- water quality – physico-chemical properties such as salinity or pH
- biota – flora, fauna and habitats.

It is noted in the National Framework that some components may be viewed as both wetland components and wetland processes (e.g. geomorphology, water quality).

1.4.3 Wetland Services/Benefits

The terms 'services' and 'benefits' are defined within the National Framework document as the 'benefits that people receive from ecosystems'.

The National Framework also notes that wetland ecosystem services and benefits are based on or underpinned by wetland components and processes, and can be both of direct benefit to humans (e.g. food for humans or livestock) or of indirect benefit (e.g. wetland provides habitat for biota which contribute to biodiversity).

The National Framework has four categories for potential wetland services/benefits. The categories and examples of services/benefits in each category are:

- provisioning services – products obtained from wetlands such as water or food
- regulating services – water quality regulation, flood regulation and other natural functions
- cultural services – relating to education, recreation, tourism, cultural heritage and similar values
- supporting services – biodiversity and other ecosystem services.

1.4.4 Interaction of Wetland Elements

Figure 1-5 from the National Framework document shows a generic conceptual model of the interaction between ecosystem processes, components and services/benefits for a wetland. In general terms, the model shows how wetland ecosystem processes interact with wetland components to generate a range of wetland services/benefits. These services/benefits can be broadly applicable to all wetlands ecosystems (such as primary productivity) or specific to a given site (e.g. breeding habitat for an important avifauna species or population).

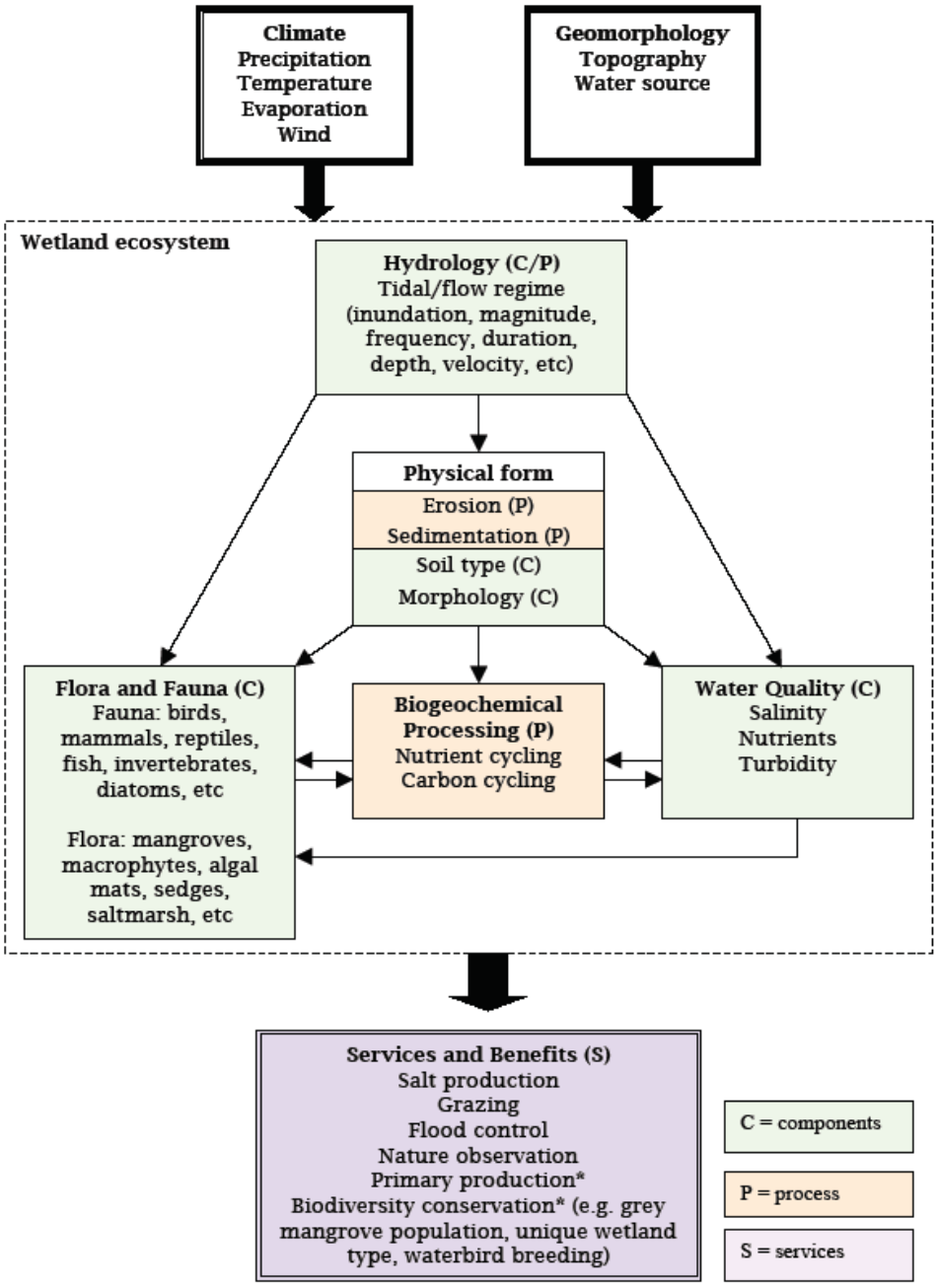


Figure 1-5 Generic conceptual model showing interactions between wetland ecosystem processes, components and services/benefits

1.4.5 Bioregionalisation Scheme

Guidelines under the Ramsar Convention (contained in the Ramsar Handbook v.3) favour the use of international or national biogeographic regions in the context of interpretation of Ramsar Nomination Criteria and other aspects of the Convention. In this context, the Australian Drainage Divisions and Interim Marine and Coastal Regionalisation for Australia (IMCRA, version 4, June 2006) have been adopted as the most relevant national bioregional scales for this ECD. Use of Australian Drainage Division and IMCRA also accords with recent policy direction from the Australian Natural Resource Management Ministerial Council.

The relevant classifications under these schemes for the Shoalwater and Corio Bays Area Ramsar site are shown in Table 1-1.

Table 1-1 Bioregional references used for this report

System	Unit	Relevant Boundaries for Shoalwater and Corio Bays
Australian Drainage Divisions and River Basins	Drainage Division	North East Coast Drainage Division
	River Basin	Shoalwater Creek Water Park Creek Fitzroy River
IMCRA v4.0	Provincial Bioregion	Tropical Waters – Northeast IMCRA Province
	Meso-scale Bioregion	SC – Shoalwater Coast

1.5 Report Structure

The report has been structured largely in accordance with the key steps outlined in the National Framework and as shown in Table 1-2.

Table 1-2 Key steps in preparing an Ecological Character Description and relevant report sections

Framework Step	Report Section
Introduction to ECD	1
General description of the site	2
Identify and describe critical components, processes and services	3
Compile the description of the ecological character	3
Develop a conceptual model for the wetland	3
Set limits of acceptable change	3
Identify threats to the ecological character of the site	4
Describe changes to ecological character	4
Summarise knowledge gaps	5
Identify site monitoring needs	5
Identify communication and education messages	5
References	6
Glossary	7

2 GENERAL DESCRIPTION OF THE SITE

2.1 Site Details – Summary

This Section of the report provides an overview and general description of the Shoalwater and Corio Bays Area Ramsar site. The wetland habitat components of the site, the natural and cultural values of the site, the uses and tenure of land and waters within and adjacent to the site, and the nomination criteria for which the site has been listed under the Ramsar Convention are reviewed and discussed.

Details of the Ramsar site are summarised in Table 2-1, with further descriptions provided below. The matters addressed in this Section are important considerations in the selection of the critical components, processes and wetland benefits/services that make up the basis of the ECD, summarised in Section 3 of the report.

Table 2-1 Details of the Shoalwater and Corio Bays Area Ramsar site

Ramsar Site Name	Shoalwater and Corio Bays Area Ramsar Site
Location in Coordinates	Latitude: 22° 16' S to 23° 3' S Longitude: 150° 9' E to 150° 47' E
General Location	The majority of the site is within Shoalwater Bay Training Area (SWBTA), which is located approximately 85 km north of Rockhampton on the Central Queensland Coast. Within SWBTA, the site extends to intertidal and subtidal areas from Broome Head in the north along the coast to Cape Manifold, excluding the terrestrial areas of the major islands. The site also includes Corio Bay, which is a small estuarine embayment at the end of the Water Park Creek catchment located about 50 km north of Rockhampton. The Corio Bay section of the site also includes part of Byfield National Park.
Area	239 100 ha (total area)
Date of Ramsar Listing	1996
Dates Used for Description	1996 (time of listing); 2009 (time of preparation of this ECD)
Original Description Date	This is the first Ecological Character Description prepared for the site.
Compiler's Name	BMT WBM Pty Ltd with expert input from Austecology Pty Ltd and Wetlands International Oceania (WIO) under contract with DEWHA
Ramsar Information Sheet	Last updated 1999 (by Department of Defence, 1999). Ramsar sites information service, Ramsar sites database: http://ramsar.org/ris/key_ris_index.htm
Management Plan	There is no single management plan that applies to the Ramsar site. A suite of plans and strategies are prepared and implemented by the various landholder and management authorities as discussed below to ensure wise use and conservation of wetland values.
Management Authority	SWBTA is managed by the Australia Government Department of Defence in accordance with a national Environmental Management System (EMS). Marine park areas are jointly managed by the GBRMPA and Queensland Parks and Wildlife Service (QPWS). Corio Bay is also managed as a declared Fish Habitat Area (FHA-067) under the provisions of the *Fisheries Act 1994* (Qld). Byfield National Park and Shoalwater Bay Regional Park are managed by QPWS.

2.2 Location and Area

The Shoalwater and Corio Bays Area Ramsar site is located on the Central Queensland Coast. The site is made up of two discontinuous areas, hereafter referred to as the Shoalwater Bay section and Corio Bay section. Figure 2-1 is a locality map showing the key geographic features of the area as well as the SWBTA administrative boundary and Ramsar site boundary.

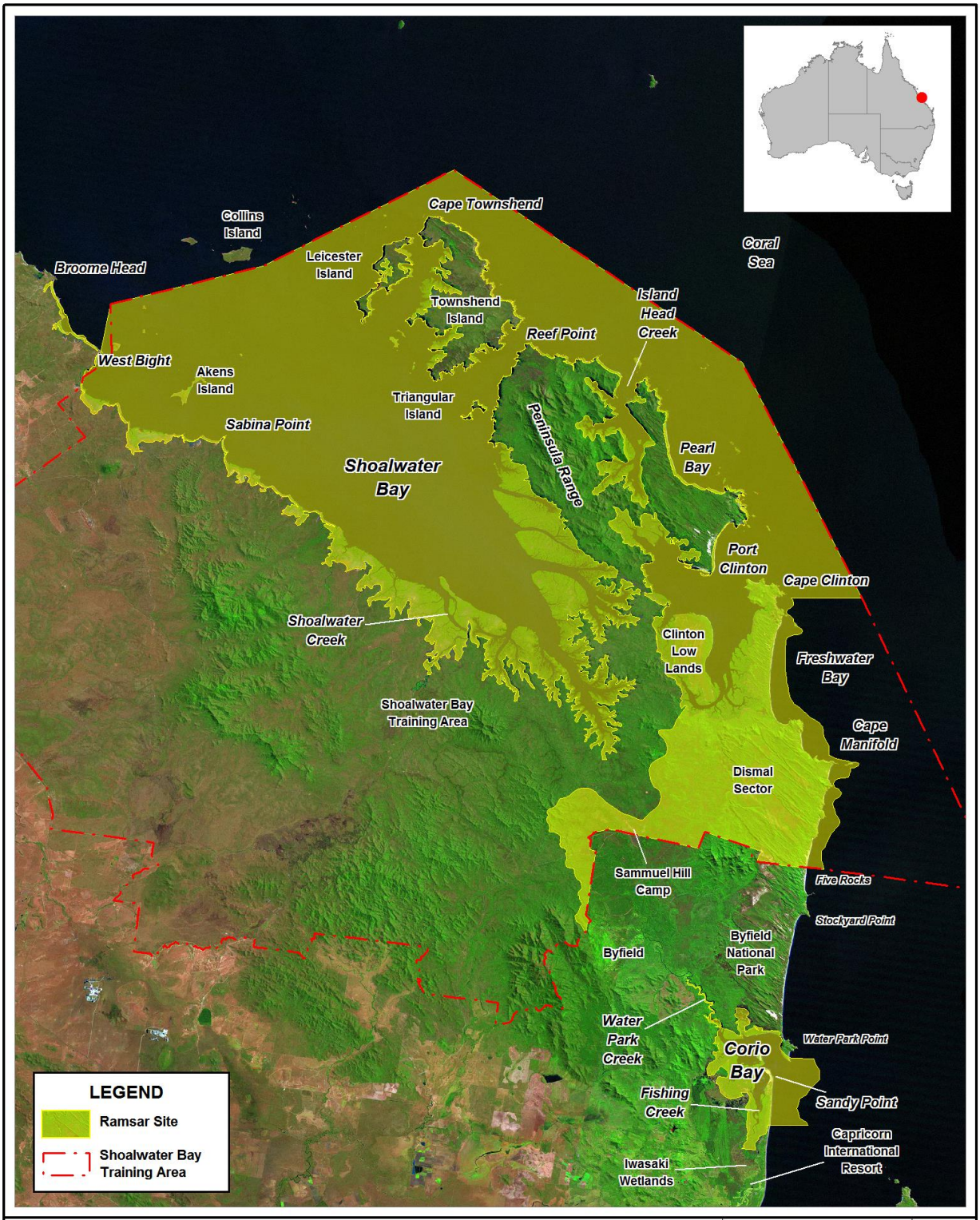
The Shoalwater Bay section of the site is located approximately 85 km north of Rockhampton. Within SWBTA, the boundary of the Ramsar site extends from Broome Head in the northwest along the coast in a south-easterly direction around Cape Manifold to the southern boundary of SWTBA at Five Rocks Beach along the eastern coastline. Generally the site encompasses the estuarine waters and associated intertidal habitats to the extent of the highest astronomical tide (HAT) within the area. A large marine area (including waters to a depth of 20 m) is also included within the site boundaries, coincident with the marine boundaries of SWBTA.

A number of islands within Shoalwater Bay are within the boundaries of the site (Akens Island, Triangular Islands, and Skull Islands) but the terrestrial areas of Townshend Island, Leicester Island and the Peninsula Range are excluded. Likewise, Collins Island and the Cannibal Group of islands that are further offshore from Shoalwater Bay are not included. Inland from the coast at Cape Manifold, the Ramsar site boundary includes most of the Dismal Sector of the SWBTA where the bulk of the site's freshwater wetland resources are located.

The Corio Bay section of the site is located approximately 50 km north of Rockhampton. This section of the Ramsar site includes the estuarine embayment of Corio Bay and the lower reaches of Water Park Creek (extending northwest about 10 km from its connection with the Bay). The various estuarine arms of Corio Bay including Fishing Creek and associated wetland areas below HAT are also included within the site.

This component of the site also includes the northern part of the Byfield National Park (most notably the Sandy Point spit) and an adjacent marine area offshore from the Bay but does not include the area around Water Park Point and the open beach areas of Little Corio Bay. The Iwasaki freshwater wetlands are located to the south of Corio Bay behind a series of bunds that pre-date Ramsar listing and do not form part of the Ramsar site.

Figure 2.1 Shoalwater and Corio Bays Area Ramsar site (© Copyright BMT WBM)



Title:
Shoalwater Bay and Corio Bay Ramsar SIte

Figure: **2-1**

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2.3 Description of Wetland Types

A high level of habitat diversity is present within the boundaries of the Shoalwater and Corio Bays Area Ramsar site. Wetland types present include subtidal beds and shallow marine waters, intertidal marshes and forests, non-forested peatlands and shrub-dominated wetlands. For this report, the Ramsar Classification System for Wetland Types (approved by Recommendation 4.7 and amended by Resolutions VI.5 and VII.11 of the Conference of the Contracting Parties) is used.

Detailed Regional Ecosystem (RE) mapping within the region has been undertaken by the Queensland Herbarium. REs are vegetation communities that are consistently associated with a particular combination of landform, soil and geology, and are unique to individual biogeographic regions.

Additionally, wetland mapping has been undertaken by the Queensland DERM as part of the State-wide Queensland Wetlands Program. The DERM mapping method uses a combination of RE mapping and water body mapping (interpreted from satellite imagery) in order to classify wetlands into the broad categories of marine, estuarine, riverine, lacustrine and palustrine types. Although there is a degree of overlap between the DERM classification and the Ramsar classification systems (lacustrine ~ lake, palustrine ~ marshes/pools, riverine ~ river channel), these systems have not been aligned in the project. The DERM wetland mapping for the site is shown in Figure 2-2. As shown in the figure, the dominant wetland systems within the boundaries of the Ramsar site include:

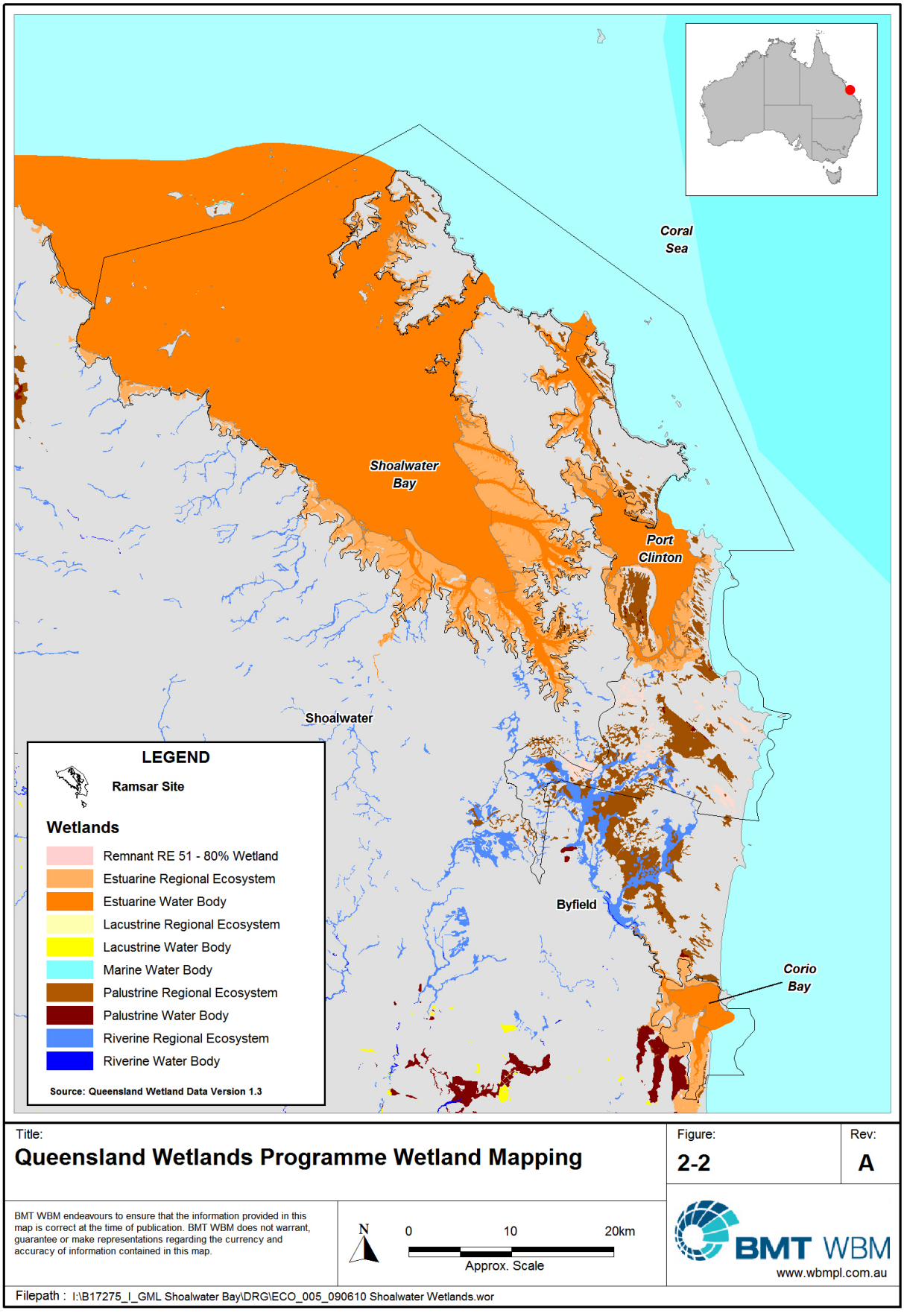
- marine Water Bodies
- estuarine Water Bodies
- estuarine REs
- palustrine REs
- riverine REs
- small areas of Remnant RE where the predominant vegetation (51 – 80%) is classified as wetland.

Using the approach of collating information obtained from RE mapping, the Regional Ecosystem Description Database (REDD, refer EPA 2007) and DERM wetland mapping, the presence of Ramsar wetland types within the Shoalwater and Corio Bays Area Ramsar site has been refined and the following habitat types are seen as being represented:

- nine marine/coastal wetland types
- nine inland wetland types
- no human-made wetland types.

Table 2-2 provides a comparison of the Ramsar wetland type classifications with the DERM wetland mapping and RE mapping that was developed for the site as part of this process. Table 2-3 provides estimates of extent of individual wetland types within the Ramsar site as derived from existing mapping (but note the above-described differences of existing mapping in terms of overlap with Ramsar wetland typology). Furthermore, note that many of the Ramsar wetland types are not mutually exclusive. For example, marine subtidal beds (Type B) are found within permanent shallow marine waters (Type A), and as such the overlapping areas are represented for both wetland types in the table.

Figure 2.2 Queensland Wetlands Programme wetland mapping (© Copyright BMT WBM)



Title:
Queensland Wetlands Programme Wetland Mapping

Figure: 2-2

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Table 2-2 Ramsar wetland types and their most likely equivalent under Queensland DERM wetland and vegetation classification regimes

Ramsar wetland type	DERM wetland systems[1]	Wetland RE
A Permanent shallow marine waters	Marine	N/A
B Marine subtidal aquatic beds	Estuarine, Marine	N/A
C Coral reefs	Marine	N/A
D Rocky marine shores	N/A	N/A
E Sand, shingle or pebble shores	N/A	N/A, or can be vegetated with: 11.2.2 - Complex of *Spinifex sericeus*, *Ipomoea pes-caprae* and *Casuarina equisetifolia* grassland and herbland on foredunes
F Estuarine waters	Estuarine	N/A
G Intertidal mud, sand or salt flats	Marine	N/A
H Intertidal marshes	Estuarine	8.1.2 - Samphire open forbland to isolated clumps of forbs on saltpans and plains 8.1.3 - *Sporobolus virginicus* grassland on marine sediments 11.1.2 - Samphire forbland on marine clay plains
I Intertidal forested wetlands	Marine	8.1.1 - Mangrove vegetation of marine clay plains and estuaries 11.1.4 - Mangrove forest/woodland on marine clay plains
M Permanent rivers, streams or creeks	Riverine	N/A, or: 8.3.1 - Semi-deciduous notophyll/mesophyll vine forest fringing watercourses 8.3.3 - *Melaleuca leucadendra* or *M. fluviatilis* ± *Casuarina cunninghamiana* open forest to woodland 8.3.8 - *Syncarpia glomulifera, Eucalyptus portuensis, Corymbia intermedia* open forest on sandy creek flats 11.3.25 - *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines
N Seasonal rivers, streams or creeks	Riverine	N/A
Tp Permanent freshwater marshes and pools	Palustrine	8.2.4 - Wet heath complex on coastal sand plains and depressions
Ts Seasonal freshwater marshes and pools	Palustrine	8.2.4 - Wet heath complex on coastal sand plains and depressions
U Non-forested peatlands	Palustrine	N/A

Ramsar Wetland Type	DERM Wetland Type[2]	Wetland RE
W Shrub-dominated wetlands	Palustrine	8.2.4 - Wet heath complex on coastal sand plains and depressions
Xf Freshwater tree-dominated wetlands	Palustrine	8.2.4 - Wet heath complex on coastal sand plains and depressions 8.2.7 - *Melaleuca* spp. and/or *Lophostemon suaveolens* and/or *Eucalyptus robusta* open woodland to open forest in wetlands 8.2.11 - *Melaleuca* spp. woodland in parallel dune swales 8.3.13 - *Eucalyptus tereticornis* and/or *Corymbia tessellaris* and/or *Melaleuca* spp. open woodland to open forest on alluvial and old marine plains
Xp Forested peatlands	Palustrine	N/A
Y Freshwater springs	N/A	8.2.5* - Notophyll feather palm vine forest dominated by *Archontophoenix cunninghamiana*

*Not classified as a wetland RE, but relevant under Ramsar wetland typology

Note: A number of wetland types were not originally listed as being present at the site when it was designated as a Ramsar wetland in 1996, but they are now considered present and include wetland types C, M, N, Tp, Ts, U, W, Xf, Xp, Y. Wetland type J (Coastal brackish/saline lagoons) was thought to be present at the site, but this has now been removed.

[1] Note there are finer wetland types in the DERM mapping which are not described here.
[2] Note there are finer wetland types in the DERM mapping which are not described here.

Table 2-3 Estimated areas of wetland types within the Ramsar site

Wetland type	Area (ha)	Source
A Permanent shallow marine waters	46,400	DERM wetland mapping
B Marine subtidal aquatic beds	13,000	Lee Long *et al*. 1997
C Coral reefs[3]	3,799	Coastal Habitat Resources Information System (CHRIS)
D Rocky marine shores	No data	
E Sand, shingle or pebble shores	No data	
F Estuarine waters	100,237	DERM wetland mapping
G Intertidal mud, sand or salt flats	No data	
H Intertidal marshes	2,742	RE mapping
I Intertidal forested wetlands	20,057	RE mapping
M Permanent rivers, streams or creeks	No data	
N Seasonal rivers, streams or creeks	No data	
Tp Permanent freshwater marshes and pools	7,949	RE mapping
Ts Seasonal freshwater marshes and pools		
U Non-forested peatlands		
W Shrub-dominated wetlands		
Xf Freshwater tree-dominated wetlands		
Xp Forested peatlands		
Y Freshwater springs	184	RE mapping

[3] Numerous rocky reefs with coral communities occur within the Ramsar site (typically on the headlands in the Shoalwater Bay section of the site). On this basis, Type C is deemed to apply.

2.3.1 Coastal Wetlands

Type A: Permanent shallow marine waters

This wetland type incorporates marine waters that are less than six metres deep at low tide, including sea bays and straits. Within the Ramsar site, shallow marine waters include deeper portions of Shoalwater Bay, Island Head Creek, Port Clinton, Corio Bay, Canoe Passage, Strong Tide Passage and the coastal waters east of Townshend Island, Gibraltar Sector, Freshwater Sector, Dismal Sector and Corio Bay.

Type B: Marine subtidal aquatic beds

Within the Ramsar site, marine aquatic beds are represented by seagrass meadows, however, these occur predominantly on the large intertidal mud and sand flats (see Type G below). Small areas of subtidal seagrass also occur in clear, shallow sheltered waters (refer Figure 2-3). The Ramsar site contains over 13,000 hectares of seagrass beds (Lee Long *et al.* 1997), considered to be some of the most extensive seagrass meadows on the east coast of Australia (DoD 2009). A relatively high diversity of seagrass species comprises the meadows, with a total of eight species present of the twelve species present in the GBR region (Lee Long *et al.* 1997). Seagrass meadows are primarily located surrounding Leicester Island, along the western and southern shores of Townshend Island, along the shores of the Clinton Lowlands and along the mainland shore within Shoalwater Bay. Seagrass beds within the Ramsar site provide important habitat for prawns and fish, and are important feeding grounds for dugongs and green turtles.

Figure 2-3 Seagrass at Sabina Point (© Copyright, R. Jaensch, Wetlands International)

Type C: Coral reefs

Although not listed in the 1999 RIS, many of the islets within the Ramsar site have fringing rocky reefs that comprise coral communities. Surveys have revealed that coral cover is highly variable and reefs are generally composed of a moderately low diversity of species (Ayling *et al.* 1998). Examples of rocky reefs within the Ramsar site include Leicester Island Reef, Marquis Reef, Triangular Reef, Pelican Rock Reef and Connor Rock Reef.

Type D: Rocky marine shores

Rocky foreshores are present within the Ramsar site, with representative examples located along the shores of Akens Island and Townshend Island and at Sabina Point (refer Figure 2-4).

Figure 2-4 Rocky shores along Townshend island (© Copyright, DoD)

Type E: Sand, shingle or pebble shores

This wetland type is composed of sand, shingle or pebble shores, including sand bars, spits, sandy islets, dune systems and humid dune slacks. Sandy foredunes along the open shores within the site may either be unvegetated (refer Figure 2-5), or may be vegetated with *Spinifex sericeus* (beach spinifex) grasslands, herblands dominated by *Ipomoea pes-caprae* subsp. b*rasiliensis* (dune morning glory or goats foot) and scattered shrubs and trees including *Casuarina equisetifolia* subsp. *incana* (coast she-oak). Vine scrubs occur immediately on the landward parts of some beach ridges, and are notable due to their national conservation status of critically endangered (but are not considered to be wetland habitats). Pebble shores are also present within the Ramsar site.

Figure 2-5 Sandy shore (© Copyright, R. Jaensch, Wetlands International)

Type F: Estuarine waters

Representation of this wetland type is extensive within the Ramsar site as all coastal waters within the embayment's of Shoalwater Bay, Island Head Creek, Port Clinton and Corio Bay are classified as estuarine by the DERM wetland mapping (and refer Figure 2-6).

Figure 2-6 Estuarine waters (and mangroves) within Shoalwater Bay (© Copyright, R. Jaensch, Wetlands International)

Type G: Intertidal mud, sand or salt flats

This wetland type encompasses intertidal mud, sand and salt flats. Saltpans and intertidal flats are widespread within the Ramsar site, particularly along unexposed shorelines on the seaward side of mangroves or saltmarsh communities (refer Figure 2-7). At low tide, intertidal mudflats are an important feeding ground for shorebirds.

Figure 2-7 Intertidal mud flats at Port Clinton (© Copyright, R. Jaensch, Wetlands International)

Type H: Intertidal marshes

Intertidal saltmarshes within the Ramsar site are represented by samphire forblands on marine clay plains (refer Figure 2-8). Characteristic species present include *Tecticornia* spp. (glasswort), *Sesuvium portulacastrum* (sea purslane), *Suaeda* spp. (seablite), *Sarcocornia* spp. (bead weed) and *Sporobolus virginicus* (marine couch). Saltmarsh communities typically occur in the upper-intertidal zone along the landward edge of mangroves, above the level of most tides.

Figure 2-8 Saltmarsh community at Shoalwater Bay (© Copyright, R. Jaensch, Wetlands International)

Type I: Intertidal forested wetlands

This wetland type is represented within the Ramsar site by mangrove low open shrublands to closed forests on marine clay plains and estuaries (refer Figure 2-9). Extensive mangrove communities occur along the sheltered sections of coastline in Shoalwater Bay and Port Clinton as well as Corio Bay and its tributaries, occupying approximately 21,000 hectares (Byron and Hall 1998 and RE mapping). Almost half the mangrove species present in Australia occurs within the Ramsar site (DoD 2009), with *Rhizophora stylosa* (stilted mangrove), *Avicennia marina* (grey mangrove), *Aegiceras corniculatum* (river mangrove) and *Ceriops tagal* (yellow mangrove) the most commonly encountered species within the site (Byron and Hall 1998). Mangroves provide habitat for a variety of organisms, including roosting and sheltering sites for a variety of shorebirds, as well as nursery habitat for important fish species.

Figure 2-9 Mangroves at Port Clinton (© Copyright, R. Jaensch, Wetlands International).

Type J: Coastal brackish/saline lagoons

This wetland type incorporates brackish to saline lagoons with at least one relatively narrow connection to the sea. While listed in the 1999 RIS, it is the opinion of the authors of this ECD that this wetland habitat type is not represented in the Shoalwater and Corio Bays Area Ramsar site.

2.3.2 Inland Wetlands

Type M: Permanent rivers, streams or creeks

This wetland type incorporates permanent rivers, streams and creeks. Although not listed in the 1999 RIS, permanent creeks are present within the Ramsar site (refer Figure 2-10). Representative examples include Sandy Creek and Sandy (Cowan) Creek in the Shoalwater Bay section, and Water Park Creek in the Corio Bay section. Fringing riverine wetland communities are also present, composed of tree species such as *Eucalyptus* spp., *Melaleuca* spp., *Lophostemon* spp. and *Casuarina cunninghamiana* and in some places riparian rainforest with or without emergent palms.

Figure 2-10 Sandy Creek (© Copyright, DoD)

Type N: Seasonal rivers, streams or creeks

This wetland type incorporates seasonal, intermittent or irregular rivers, streams and creeks, as present in the eastern sand mass of the Shoalwater Bay section of the Ramsar site (noting that many of the rivers, streams and creeks within the Ramsar site are permanent as they are likely to be sustained by spring flow).

Type Tp and Ts: Permanent freshwater marshes and pools and Seasonal freshwater marshes and pools

This wetland type incorporates marshes and swamps on inorganic soil, with emergent vegetation that is water-logged for at least most of the growing season. Although not listed in the 1999 RIS, palustrine wetlands are found within the Ramsar site at localities including Clinton Low Lands, Freshwater Swamp and Dismal Swamp. However, it is noted that a large proportion of the freshwater marshes within the Ramsar site are on peat, and are therefore classified as Type U.

Type U: Non-forested peatlands

This wetland type incorporates non-forested peatlands, including shrub or open bogs, swamps and fens. Although not listed in the 1999 RIS, larger wetlands within the Ramsar site contain well-developed peat deposits (Jaensch 2008b, refer Figure 2-11). Dismal Swamp, Freshwater Swamp, most of the swamps of the Clinton Lowlands and several other sedge-dominated swamps are mostly if not wholly on peat substrate. As outlined in the Ramsar Guidelines for Global Action on Peatlands (GAP), peatlands are increasingly being recognised as a highly important wetland type at the global level through their role in contributing to global biodiversity, as an important carbon sink and through the retention of paleo-environmental information about previous landscapes and climate states.

Figure 2-11 Peat swamp sedgeland on the Clinton Lowlands (© Copyright, R. Jaensch, Wetlands International)

Type W: Shrub-dominated wetlands

This wetland type includes shrub-dominated swamps and marshes on inorganic soils. Although not listed in the 1999 RIS, shrublands are represented within the Ramsar site by wet heath complexes on coastal sand plains. Characteristic species include *Banksia robur* (swamp banksia), *Baeckea frutescens* (weeping baeckea), *Epacris microphylla* (coral heath) and *Sprengelia sprengelioides* (white swamp heath). Although shrub-dominated wetlands are shown in the RE mapping, the extent of this wetland type on inorganic soils is currently not known, as most of the shrubland within the site is thought to occur on peat (R. Jaensch, pers. comm. 2009).

Type Xf: Freshwater tree-dominated wetlands

This wetland type incorporates freshwater swamp forests, seasonally flooded forests and wooded swamps on inorganic soils. Although not listed in the 1999 RIS, it is represented within the Ramsar site by palustrine open woodlands to open forests, often in association with parabolic dunes (refer Figure 2-12). Patches of freshwater tree-dominated wetlands are primarily found within the Dismal and Freshwater Sectors, as well as at Corio Bay. Characteristic species of these palustrine wetlands include *Melaleuca* spp. (paperbarks), *Lophostemon suaveolens* (swamp mahogany) and *Eucalyptus robusta* (swamp mahogany). Additionally, freshwater tree-dominated wetlands within the Ramsar site include fringing riverine or floodplain open forest wetlands, often dominated by *Eucalyptus* and/or *Corymbia* species.

Figure 2-12 Melaleuca swamp within Dismal Sector (© Copyright, DoD)

Type Xp: Forested peatlands

This wetland type incorporates peat swamp forests, and is not listed in the 1999 RIS. However, while the majority of the area of peat swamp within the Ramsar site is non-forested, a narrow fringe of tree swamp is present in the margins of Dismal Swamp, which is peat-dominated (R. Jaensch, pers. comm. 2009). Also, there is a narrow zone of swamp forest in the ecotone between steeply sloped upland and the gently sloped intertidal zone on the north side of Port Clinton and the south-east side of Island Head Creek, also, a wider block of swamp forest between Freshwater Swamp and Port Clinton; preliminary investigations suggest these also are at least partly on peat substrate. These rare features require closer investigation.

Figure 2-13 Peat swamp with forested periphery in Dismal Swamp (© Copyright, R. Jaensch, Wetlands International)

Type Y: Freshwater Springs

Although not listed in the 1999 RIS, freshwater springs are present within the eastern sand dunes of the Ramsar site. These occur in the form of large 'sinkholes' that have permanent freshwater springs emanating from their floors (Commonwealth of Australia 1993, DoD 2009) (refer Figure 2-14). These sinkholes are conical topographic depressions, measuring up to 30 metres in depth and 100 metres in maximum width, that usually form through the development of voids that collapse as soluble minerals are removed from the underlying rock by rainwater and groundwater (DoD 2009). Rainforest communities are supported by the sinkholes, typically notophyll feather palm vine forest dominated by *Archontophoenix cunninghamiana* (piccabeen palm), with other species present including *Elaeocarpus grandis* (blue quandong), *Cryptocarya vulgaris* (northern laurel), *Calophyllum australianum* (alligator bark) and *Elaeocarpus eumundi* (Eumundi quandong) (Melzer *et al.* 1993, Queensland Herbarium 2009).

Figure 2-14 Sinkhole within the Dismal Sector (© Copyright, DoD)

2.4 Description of Natural, Cultural and Socio-Economic Values

The sections below provide a brief overview of the most notable values of the site (relevant to Ramsar listing and wetland ecosystem values) which forms the basis for the selection of critical services/benefits, components and processes for the site in Section 3 of this document. Section 2.4.1 discusses natural ecosystem values while section 2.4.2 provides an overview of cultural and socio-economic values of the site.

2.4.1 Natural Values

The natural values of the Ramsar site have been described in a number of documents, notably the *State of Environment Report for Shoalwater Bay Training Area* (DoD, 2009), the *Commonwealth Commission of Inquiry Shoalwater Bay, Capricornia Coast, Queensland: Summary* (Commonwealth of Australia, 1994) and the existing Ramsar Information Sheet (1999). Brief summaries of the key natural values of the Ramsar site are provided below.

Natural Heritage

The marine component of the Ramsar site is part of the Great Barrier Reef World Heritage Area (GBRWHA). The GBRWHA, listed in 1981, is one of the largest World Heritage Areas on an international scale and is one of only a few areas that meet all four of the natural World Heritage listing criteria. Furthermore, SWBTA was included on the Commonwealth Heritage List in 2004 in recognition of the site's natural values, and the marine component of the Ramsar site was included on the National Heritage List in 2007.

Some marine sections of both the Shoalwater Bay and Corio Bay sections of the Ramsar site are within the Great Barrier Reef Coast Marine Park (State), while the Bay itself as well as adjoining wetlands to the extent of HAT are also within the Corio Bay Fish Habitat Area (FHA-067) declared under the *Fisheries Act 1994*. The Corio Bay section of the Ramsar site includes part of Byfield National Park.

Habitat Diversity

As described above, the Ramsar site contains a diversity of habitats, with a total of 18 estuarine, marine and freshwater wetland types present. These habitats comprise a significant representation of a number of pristine vegetation types that were previously widespread in southern Queensland (Department of Environment 1996). Several of the notable wetland habitats and their values include:

- seagrass beds which assist ecosystem functioning through primary production by seagrass, grazing of seagrass by marine megafauna and provision of habitat for fisheries
- mangroves and saltmarshes which provide habitat for juvenile fish and other marine organisms, as well as roosting and feeding sites for birds, and function in protecting the shoreline from erosion
- freshwater tree-dominated swamps, shrub-dominated swamps and marshes which provide habitat for a variety of wetland flora and fauna, including species of conservation significance
- peat swamps which are notable due to their carbon sink properties and possible fossil pollen records.

Species Diversity and Threatened Species

A remarkably high biodiversity is supported by the Ramsar site and surrounding lands and waters, reflecting the geomorphic diversity, the location that overlaps tropical and temperature regions, and the marked rainfall gradient from east to west. A total of approximately 400 vertebrate animal species have been recorded within or adjacent to the site, while approximately 900 plant species have been recorded. The biodiversity of the Ramsar site also includes a number of species of conservation significance, listed as threatened on a national or international scale:

- freshwater fish - honey blue-eye, *Pseudomugil mellis*
- marine aquatic fauna - green turtle, *Chelonia mydas*; loggerhead turtle, *Caretta caretta*; hawksbill turtle, *Eretmochelys imbricata;* dugong, *Dugong dugon*
- terrestrial wetland fauna - water mouse, *Xeromys myoides*
- terrestrial wetland flora - lesser swamp orchid, *Phaius australis.*

Notably, the Ramsar site supports an abundance of waterbirds, providing important feeding, resting and breeding habitat for approximately 77 waterbird species.

2.4.2 Cultural and Socio-Economic Values

The cultural and socio-economic values of the site have been described in various documents, notably including *State of Environment Report for Shoalwater Bay Training Area* (DoD 2009) and *Commonwealth Commission of Inquiry Shoalwater Bay, Capricornia Coast, Queensland: Summary* (Commonwealth of Australia 1994). Brief summaries of the key cultural and socio-economic values of the Ramsar site are provided below:

Defence Use

SWBTA was purchased for defence training purposes in 1965. The area is located strategically on the central Queensland coast and is underpinned by the fact that it addresses a broad range of criteria for military training use as outlined as part of the Commonwealth Commission of Inquiry Report (refer Commonwealth of Australia 1994) including:

- geographic location (in terms of its coastal location to facilitate amphibious operations; its ability to be fully utilised without encroachment from or disamenity to civilian populations)
- size (in terms of being large enough to allow freedom of tactical manoeuvre at the level exercised or trained; allows relocation of exercises during drought or heavy rain so as to prevent unacceptable environmental impacts and allow exercises to proceed; allows for live firing when required without risk to civilians, civilian infrastructure or other exercising military elements)
- diversity (in terms of providing a variety of climate and terrain, including littoral, plains, mountains, swamps, dunes and forests to create realism, challenge, diversity and flexibility in training)
- suitability for joint air, land and sea exercises with allies.

A key finding of the Commission of Inquiry was that while defence use should remain the primary use of SWBTA, conservation should be a concurrent use and be of equal significance. It was also determined by the Commission, that defence training use was generally complementary to conservation use of the area where natural resources and defence training activities were appropriately managed.

Accordingly the site's natural resources are managed under a Defence Environmental Management System (EMS) and Environmental Clearance Certificate (ECC) process (DoD 2009) which includes extensive monitoring of water quality, vegetation, sediment quality and other parameters (refer GHD 2007). For larger defence training exercises, an Environmental Risk Workshop with key regulating agencies is carried out and such activities are subject to referral and approval processes under the EPBC Act (for copies of referrals and approvals granted since the commencement of the Act refer: www.environment.gov.au).

Notably, the large majority of defence training activities that occur within SWBTA are undertaken outside the boundaries of the Ramsar site in the inland western portion of the site and in the more remote areas of Peninsula Ranges and in the Gibraltar Sector which are used for bombing and gunnery ranges (M. Drewe pers. comm., DoD 2009).

For the most part, defence occupation and use of SWBTA contributes to avoiding or otherwise controlling threats to the values of the Ramsar site and maintaining the ecological character of the wetlands within the Ramsar boundaries. This is achieved through a combination of:

- broad access restrictions that are in place for SWBTA which prevent human occupation (e.g. urban development) and associated threatening activities such as ORV usage, introduction of feral animals, etc.
- investment by DoD in land management activities as the principal land manager for the site such as fire management regimes, feral animal control and weed management
- management of defence training activities in the adjacent lands and waters.

The site continues to have an important role in the preparation of Australian Defence Force personnel, and is currently the only economically viable location in Australia that allows large-scale combined exercises where most weapon systems can be employed (DoD 2009).

Indigenous Cultural Heritage

An understanding of the original Shoalwater Bay Aboriginal people is poor, and knowledge of archaeological sites within the Ramsar site is limited. It has been noted that the main focus for archaeological surveys has been the eastern dune fields and the coastal zone (Commonwealth of Australia 1994). Accounts of early European contact with Aboriginal people have been documented by several authors (notably Cosgrove 1996). The site is culturally and spiritually very significant to the descendants of the original Aboriginal inhabitants of the area, and in the present day the site provides an important venue for cultural renewal amongst the Darumbal people (DoD 2009).

European Cultural Heritage

Significant forays ashore were first made by Matthew Flinders in 1802 and documented in his journal. Panoramas painted by William Westall during this voyage portray landscapes of the Ramsar site that today are unchanged. Pastoralist dwellings were established within SWBTA by the early 1900s, but few of these are still in existence. The role of the site in preparation of troops for the Vietnam conflict is considered to be a special part of the defence heritage (DoD 2009).

Scenic

The Ramsar site has considerable scenic value afforded by the diverse, pristine landscapes. Of particular aesthetic importance is the contrast between marine and terrestrial components of the site, and the spectacular coastal ranges.

Tourism and Recreation

The Ramsar site does not attract as much tourism and recreation as other areas of coastal Queensland because community entry into SWBTA (other than coastal waters) is restricted (noting that all areas can have restrictions placed on access during major training activities). Corio Bay is also relatively undeveloped but has frequent recreational use due to its proximity to Yeppoon and suitability for the launching of boats. Recreational activities undertaken within the Ramsar site primarily include recreational fishing and boating, with kayaking and camping also undertaken within the Corio Bay section of the site. Uncontrolled off-road vehicle use is a threat to coastal ecosystems in this area including Sandy Point for shorebird roosting and as a breeding location for little tern *Sterna albifrons*.

Commercial Fishing

Some commercial net fishing and crab potting is undertaken within waters included in the Ramsar site (trawling is prohibited). Commercially harvested species include barramundi, threadfin salmon, mackerel and mud crabs. The relatively small-scale of commercial fishing within the Ramsar site is largely a reflection of restricted access to SWBTA.

The mud crab fishery in the mangrove areas of Port Clinton and Shoalwater Bay, and to a lesser extent in Corio Bay, is a significant industry for the region. Around 8% of the annual Queensland crab production is harvested in the Shoalwater Bay region.

Education and Interpretation

Similarly to tourism and recreation, education and interpretation is currently not prevalent within the Ramsar site. However, the Corio Bay section provides opportunities for the establishment of education and visitor engagement such as interpretive signage featuring the values of the Ramsar site.

Scientific

The Ramsar site provides a variety of opportunities for scientific research due to the diversity of habitat types and the rich biodiversity. Additionally, the natural or near-natural condition of wetlands within the Ramsar site makes it an ideal 'reference' location for scientific research. As such, numerous scientific investigations have been conducted within the Ramsar site, many of which have been reviewed in the context of this study. A number of knowledge gaps requiring further scientific research have also been highlighted in the current study.

Water Supply

Water Park Creek is the water supply for coastal communities of the Capricorn Coast. The upper catchment of Water Park Creek is located within the Shoalwater Bay section of the Ramsar site, and the downstream reaches and mouth are located within the Corio Bay section. Additionally, a relatively small volume of water is extracted from Sandy Creek for Defence use at Samuel Hill camp.

2.5 Land Use and Tenure

The land use and tenure within and adjacent to the site are described in this section.

2.5.1 Tenure and Land Use within the Site

Land in the Shoalwater Bay section of the site is mostly Commonwealth freehold tenure and there are two smaller areas of protected area under the Queensland *Nature Conservation Act 1992*. The small area at Broome Head is part of Shoalwater Regional Park and a small area of Byfield State Forest falls within the Ramsar site. The small area of Byfield State Forest is part of a plantation licence area, subject to a 99 year lease (from 2010), that is managed by HQ Plantations. As already discussed, the marine areas are a mix of both State and Commonwealth waters largely managed as Marine Park. The principal land use within SWBTA is military training, and it remains one of Australia's premier military training areas managed by the Department of Defence. Marine areas are subject to zoning provisions of the Great Barrier Reef Marine Park and the Great Barrier Reef Coast Marine Park, already discussed in Section 1. Enforcement of permitting and other regulatory provisions in these waters is carried out jointly by the Great Barrier Reef Marine Park Authority, Queensland Department of Environment and Heritage Protection, Queensland Department of National Parks, Sport and Racing (through Queensland Parks and Wildlife Service), and the Queensland Police Service Water Police.

The Ramsar site in the vicinity of Corio Bay is predominantly Queensland State waters but includes some small areas of unallocated State land (USL), and generally follows the boundaries of the Corio Bay Fish Habitat Area. The area is mostly part of the Great Barrier Reef Coast Marine Park and includes a small portion of the Byfield National Park (east of Fishing Creek) that is a protected area under the Queensland *Nature Conservation Act 1992*.

2.5.2 Tenure and Land Use Adjacent to the Site

Both components of the Ramsar site are situated in predominantly undeveloped or otherwise slightly modified catchments.

The complete catchment for the Shoalwater Bay section of the site is contained within SWBTA, except for a small portion at the north-west extremity where the catchment is part of leasehold land used for grazing. Surrounding land uses of SWBTA include national park, State forest and leasehold land all of which are the responsibility of the State of Queensland. Some freehold and unallocated State land also occurs. The predominant human use of the leasehold and freehold land is for grazing and pastoral use but much of this land is located far away from the Ramsar boundary to the southwest of the Training Area boundary (near Broad Sound).

Surrounding land uses for the Corio Bay section of the site include Byfield National Park to the north, Byfield State Forest to the west and north-west, the township of Byfield and small rural allotments to the north-west, and freehold land to the south that contains the Rydges Capricorn International Tourist Resort (and associated Iwasaki wetlands). As noted above, Byfield State Forest is currently under the management of HQ Plantations as part of their plantation licece area.

2.6 Nomination Criteria Met by the Site

Each site nominated under the Ramsar Convention must satisfy at least one of the Ramsar Nomination Criteria established by the Convention. At the time of listing in 1996, the Shoalwater and Corio Bays Area Ramsar site was identified as meeting a number of these criteria related to the site's usage by waterbirds, overall biodiversity and natural functioning as a coastal wetland complex.

Since the time of listing Shoalwater and Corio Bays as a Ramsar site, the Ramsar Nomination Criteria under the Convention have been modified. As such, there was a need to re-assess the status of the site against the existing criteria as well as the 'new' criteria for the site as part of the current study.

Table 2-4 presents a comparison between the pre-1999 and the post-1999 Ramsar Nomination Criteria (noting those criteria that are currently supported by the site as documented in the 1999 RIS). Based on findings of the current study (refer Sections 3 – 6 of this document), the site is now considered to address Ramsar Nomination Criteria 1-8 at the time of preparation of this ECD.

The assessment and justification of the criteria has been undertaken using the guidance for interpretation of the Nomination Criteria provided within the Ramsar Handbook 14, 'Designating Ramsar sites' within the Ramsar Handbooks for the Wise Use of Wetlands 3rd Edition (published by the Ramsar Secretariat).

Criterion 1 – **Met** *(at time of listing in 1996 and continues to be met based on current assessment)*

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

The Ramsar site contains a mosaic of 18 marine, estuarine and freshwater wetland types that are representative of Australia's North East Coast Drainage Division (east-draining catchments from near Brisbane to Cape York). It displays many of these types in complex assemblages and patterns and to a large spatial extent.

Many of these wetland types are unusually good examples of these habitats in the Drainage Division because of their near-natural state and the relatively undisturbed nature of the catchments flowing into

the Ramsar site. The Ramsar site is widely regarded to have 'wilderness' quality; the Drainage Division otherwise includes much coast that is urbanised or otherwise modified.

Furthermore, the site contains a wetland type that is rare and unusual in the Drainage Division (and at broader spatial scales) – namely, freshwater peat swamps; major examples of these occur in Dismal Swamp, near Freshwater Beach and in parts of the Clinton Lowlands. Peat-based wetlands are extremely rare in the mostly arid continent of Australia and in the North East Coast Drainage Division they mainly occur in relatively small areas of coastal sand mass.

Criterion 2 - **Met** *(at time of listing in 1996 and continues to be met based on current assessment)*

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

In terms of marine megafauna, the Ramsar site supports green turtle *Chelonia mydas* and dugong *Dugong dugon* in very substantial numbers: green turtle is nationally vulnerable and internationally endangered and dugong is internationally vulnerable. Loggerhead turtle *Caretta caretta*, hawksbill turtle *Eretmochelys imbricata* and flatback turtle *Natator depressus* also occur within the site, but in much smaller numbers: Loggerhead turtle is nationally vulnerable and internationally endangered, flatback turtle is nationally vulnerable and hawksbill turtle is nationally vulnerable and internationally critically endangered.

One nationally vulnerable freshwater fish species is supported by the site, the honey blue-eye *Pseudomugil mellis*. One nationally vulnerable wetland-dependent terrestrial mammal species is supported by the site, the water mouse *Xeromys myoides*. A specimen of the water mouse was recorded in March 2008 in mangrove habitat on the western shore of Shoalwater Bay, between Shoalwater and Georges Creeks on the SWBTA. Though only known from a few localities, surveys have been far from comprehensive and it is possible that these species occur more widely in the extensive suitable habitat (permanent freshwater wetlands and mangrove-saltmarsh communities respectively).

One nationally endangered wetland-dependent plant species exist within the site: the lesser swamp orchid *Phaius australis* (Orchidaceae), which is a large terrestrial orchid that primarily inhabits swamp forests.

Furthermore, the site supports potential habitat for other threatened species, although there are no records to date for these species. These species, all of which principally frequent freshwater wetlands, include the nationally endangered Oxleyan pygmy perch *Nannoperca oxleyana* freshwater fish (high chance of occurrence), the internationally endangered Australasian bittern *Botaurus poiciloptilus* (low chance) and the nationally vulnerable Australian painted snipe *Rostratula australis* (low chance, cryptic species).

Criterion 3 – **Met** *(at time of listing in 1996 and continues to be met based on current assessment)*

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

The biodiversity of the Ramsar site is extremely rich, across its range of broad wetland habitats. Particular examples of wetland biological diversity representation within the Ramsar site include:

- wetland-dependent plants in freshwater wetlands of the site are likely to be numerous: Melzer *et al*. (1993) recorded very high flora species diversity within SWBTA, but of the 791 species found to-date, there are no specific data to determine what proportion of these are within the Ramsar site boundaries or what proportion of these are wetland-dependent

- eight seagrass species are known within the site out of a total of 15 species known to occur within Queensland (Lee Long *et al.* 1997; Coles *et al.* 2004)

- at least 13 species of mangrove are known within the site, out of a total of 35 species known to occur within Queensland (DoD 2009; Lovelock 1999)

- twenty two frog species (Nix 1972, Habitat 1974, Schodde *et al.* 1992, Catling *et al.* 1994, DoD 2009)

- seventy seven waterbird species (Walker *et al.* 1993, O'Neill 1995, Driscoll 1996, Houston and Mitchell 1997, Habitat 1974, Jaensch 2008a, DoD 2009, EPA 2009)

- thirty two shorebird species (O'Neill 1995, Driscoll 1996, Houston and Mitchell 1997, Habitat 1974, Jaensch 2008a, DoD 2009)

- seventeen species of freshwater fish were recorded within SWBTA, with an additional 8 species recorded in adjoining streams that are also likely to occur in the area (Trnski *et al*. 1993). Pusey *et al.* (2004) suggests that up to 37 freshwater fish species occur in the catchments of Shoalwater and Water Park Creek which does not include the record of honey blue-eye found in the survey undertaken by Trnski *et al.* (1993). Overall this number of freshwater fish species within the site represents ~35% of the total North East Coast Drainage Division fish fauna (Pusey *et al.* 2004)

- four hundred and twenty eight marine and estuarine fish species (Trnski *et al*. 1993). This represents ~22% of the north-east tropics marine fish fauna.

This richness can be attributed to an uncommon if not unique combination of factors, including:

- the large area of the site

- the complexity and diversity of habitats present

- the natural or near-natural condition of the wetlands

- the site location that overlaps tropical and subtropical climates.

Few data are available that specify precise numbers of wetland flora and/or fauna species within the Ramsar site, as well as within the wider North East Coast Drainage Division. However, the examples of biodiversity given above are sufficient indicators that the Ramsar site is important for maintaining the biodiversity of the Drainage Division.

The Ramsar site is also important in maintaining the biodiversity of the bioregion in terms of the presence of a wetland vegetation community that is dependent on the site for its conservation security due to a substantial proportion of their remaining extent being located within the site. This vegetation community is described as *Melaleuca* spp. and/or *Lophostemon suaveolens* and/or *Eucalyptus robusta* open woodland to open forest in wetlands associated with parabolic dunes (Ramsar wetland type Xf).

Criterion 4 – **Met** *(at time of listing in 1996 and continues to be met based on current assessment)*

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

The Ramsar site supports habitats and other ecological components and processes that are important at critical stages in the life cycles of numerous wetland-dependent species. Examples of these stages are:

- feeding and roosting by 77 waterbird species, in particular, substantial numbers of migratory shorebirds (26 species) use the site annually and predictably for feeding and roosting. Monthly variations in numbers and data from other sites suggest that for some species this may be the end of their southward migration path and the place where pre-migration fattening occurs, but for others it serves as a staging area for migration farther south
- breeding by waterbirds, notably the resident Australian pied oystercatcher and beach stone-curlew, both of which occur in substantial numbers, and wetland-dependent raptors such as the eastern osprey
- some breeding by flatback turtles at Akens Island and other shorelines (noting that a formal survey of nesting has not been carried out to date)
- the entire life cycles of (most of) 22 frog species
- the entire life cycle of numerous freshwater fish, included the threatened honey blue-eye.

Criterion 5 – **Met** *(at time of listing in 1996 and continues to be met based on current assessment)*

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

The site regularly supports at least 20,000 waterbirds, with nearly all of these being migratory shorebirds (Driscoll 1996, Jaensch 2008b). Over 23,000 migratory shorebirds and small numbers of other waterbirds were counted at SWBTA in December 1995 and by extrapolation the total numbers were estimated to be 20,000 to 25,000 in each of three surveys in 2007 (Table 6 in Jaensch 2008a). These data refer only to the SWBTA; shorebirds also occur, in smaller numbers, in Corio Bay but simultaneous counts of both areas have not been conducted.

Systematic comprehensive surveys of SWBTA have been performed only in December 1995 (at about 100 roost sites, single counts at ground level: Driscoll 1996) and in January, March-April and September of 2007 (at a sample of the 100 roosts, mean numbers from paired counts, mostly aerial, some ground-level: Jaensch 2008a). In the absence of additional surveys, and aware of the high site fidelity of these species, the good condition of the habitat and the large gap between threshold and maximum count, it can be assumed for now that the 20,000 threshold is met regularly.

Criterion 6 – **Met** *(at time of listing in 1996 and continues to be met based on current assessment)*

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

The Ramsar site supports six species (five migratory and one resident shorebird species) which occur in excess of the 1% of population threshold (O'Neill 1995, Driscoll 1996, Jaensch 2008a, Bamford *et al*. 2008, Wetlands International 2006):

- grey-tailed tattler *Tringa brevipes* (1% = 500; counts up to 3014 birds)
- bar-tailed godwit *Limosa lapponica* (1% = 3250*; counts up to 3831 birds)
- eastern curlew *Numenius madagascariensis* (1% = 380; counts up to 2844 birds)
- whimbrel *Numenius phaeopus* (1% = 1000; counts up to 7089 birds)
- terek sandpiper *Xenus cinereus* (1% = 600; counts up to 3410 birds)
- Australian pied oystercatcher *Haematopus longirostris* (1% = 110; counts up to 376 birds).

(Note: * if bar-tailed godwits at the Ramsar site prove to be all or mostly the subspecies *baueri* then the 1% threshold would be around 1550 birds.). These data refer only to SWBTA; most of these species also occur, in smaller numbers, in Corio Bay but simultaneous counts of both areas have not been conducted.

Systematic comprehensive surveys of SWBTA were performed in December 1995 (at about 100 roost sites, single counts at ground level: Driscoll 1996) and in January, March-April and September of 2007 (at a sample of the 100 roosts, mean numbers from paired counts, mostly aerial, some ground-level: Jaensch 2008a). However, in each of these four surveys with only one exception, the 1% thresholds were exceeded for each of the six species. In the absence of additional surveys, and aware of the high site fidelity of these species, the good condition of the habitat and the large gap between threshold and maximum count, it can be assumed for now that these thresholds are met regularly.

The 1999 RIS identified the great knot *Calidris tenuirostris* as exceeding 1% (3800) of their population at the Ramsar site. However, this was based on numbers reported in Lane and Davies (1987) that included extensive intertidal areas associated with the Broad Sound area and therefore does not apply to the Ramsar site alone. Surveys conducted within the Ramsar site during 1995 (see Driscoll 1996) and 2007 (see Jaensch 2008b) recorded numbers of this species well below the 1% threshold and recent surveys in Broad Sound have confirmed presence therein of high numbers (thousands: see Jaensch 2009).

Additionally, the beach stone-curlew *Esacus magnirostris* has been recorded in numbers of up to 90 birds (DoD 2009). This abundance would exceed the 1% threshold for the Australian population (i.e. 50 birds; Garnett and Crowley 2000), though less than the 1% threshold for whole flyway population (i.e. 250 birds; Wetlands International 2006).

Criterion 7 – **Met** *(criterion did not exist at time of listing; proposed to be met based on current assessment)*

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.

Ramsar Handbook 14 published by the Ramsar Convention Secretariat (2007) suggests that a wetland meets this criterion if it demonstrated that:

1. a large proportion of species within the bioregion are represented in the site
2. the term diversity can encompasses number of life-history stages, species interactions and complexity of fish-environmental interactions
3. endemism as an important element of biodiversity.

In terms of marine fish species richness:

- Waters of SWBTA are known to support 428 marine and estuarine fish species (Trnski *et al*. 1993). This represents 12% of Australia's marine fish fauna, and ~22% of the marine fish fauna of the north-east tropics (closely equating to the Tropical Waters Northeast IMCRA Province). This is remarkable given:
    - the limited sampling effort compared to better studied areas elsewhere
    - that the total number of fish in the bioregion includes deep water habitats (absent from the site) and reefs (scarce within the site), which contain a distinct fish fauna not found in other habitat types.
- The high diversity of fish species is due to an overlap of faunal regions, as well as the diversity of marine and estuarine habitats available – see Criterion 8. Studies of Corio Bay by Habitat (1974) and Melzer *et al*. (2007) recorded a lower overall diversity, with 50 and 70 fish species within the Bay and its major tributaries of Water Park Creek and Fishing Creek.
- Fish assemblages of the site comprise species with different life-history characteristics, including potadromous (entirely freshwater) species, to catadromous (requiring marine and freshwaters to complete life-cycle) and fully marine species. The site also supports a wide variety of life-history stages for many species (i.e. eggs, larvae, recruitment sites, spawning sites). This component of the criterion is therefore met.
- The third part of the criterion relates to endemism. Three fish species surveyed by Trnski *et al.* (1993) in Shoalwater Bay were identified as being unusual in the context of the site and more characteristic of temperate waters. These included the pipefish (*Lissocampus runa*); *Springeratus* sp. (an undescribed species of weedfish from the family Clinidae); and the clingfish *Pherallodichthys* sp. *Lissocampus runa* is a wide ranging species in temperate areas, whereas the other two species are presently undescribed. However, the extent to which these two undescribed species are endemic only to the Shoalwater Bay area cannot be conclusively determined and forms an information gap. Therefore, this part of the criterion is not met.

In terms of freshwater fish species richness:

- a total of 17 species of freshwater fish were recorded within the boundaries of SWBTA with an additional eight species recorded in adjoining streams that are also likely to occur in the area as part of fish surveys by Trnski *et al.* (1993)

- Pusey *et al*. (2004) suggests that up to 37 freshwater fish species occur in the catchments of Shoalwater and Water Park Creek which does not include the record of honey blue-eye found in the survey undertaken by Trnski *et al.* (1993)

- overall this number of freshwater fish species within the site represents ~35% of the total Northeast Coast Drainage Division fish fauna (Pusey *et al.* 2004).

The marine and estuarine macro-invertebrate assemblages of the Shoalwater and Corio Bays Area Ramsar site are generally poorly known. Notwithstanding, Melzer *et al.* (2007) found a rich macrobenthic assemblage (112 species) of bivalves, gastropods, annelids, crustaceans and other macroinvertebrates in Corio Bay. Local-scale studies of benthic assemblages around Triangular Island in Shoalwater Bay identified over 153 marine macro-invertebrate species (Lewis *et al.* 1981) dominated by annelid polychaetes. There is insufficient information to determine whether this part of the criterion is met.

Criterion 8 – **Met** *(criterion did not exist at time of listing; proposed to be met based on current assessment)*

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 seagrass resources of the Ramsar site (in Shoalwater Bay, Island Head Creek and Port Clinton) are critical nursery and feeding habitats for species that contribute to locally and regionally important fish stocks and fisheries. These include commercial prawn trawl and fin-fish gill-net fisheries, commercial crab fisheries as well as fin-fish fisheries of recreational and tourism value. Seagrass-associated bait fish also contribute to the health of target-species fish stocks in these commercial and recreational fisheries (Lee Long *et al.* 1997).

Extensive mangroves and saltmarsh are present in both the Corio Bay and Shoalwater Bay sections of the Ramsar site. These areas are utilised by juvenile stages of a variety of fish, prawns and crab species. Corio Bay is particularly important as nursery areas for recreational fisheries (Walker 1997).

Rocky reefs present in the Ramsar site also support fish diversity and provide nursery habitat. The headlands and rocky reefs present in the site are the most extensive of this habitat type north of New South Wales and are a relatively rare habitat type in the tropics (Trnski *et al.* 1993).

The nursery habitats provided by the site are also seen as being important to commercial fishery species at broader spatial scales because of their undisturbed and intact nature relative to degraded fish nursery habitat elsewhere on the Queensland coast (Commonwealth of Australia 1994).

Criterion 9 – **Not Met** *(criterion did not exist at time of listing; not met based on current assessment)*

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

Some of the key non-avian wetland species within Shoalwater and Corio Bays that are appropriate to consider in the context of Criterion 9 would include:

- water mouse
- dugong
- green turtle
- honey blue-eye.

In interpreting the application of Criterion 9 to these species, Ramsar Handbook 14 indicates that reliable population size limits from published sources must be included in the justification for the application of the Criterion. A further complication for highly migratory species is the determination of the appropriate geographic area of the population.

The current study has noted that survey data for these species is largely incomplete and forms an information gap. On this basis, there is no definitive data from which to determine the applicability of the Criterion. However, it is acknowledged that expert opinion provided by various researchers to the study team and literature reviewed supports the view that the criterion is met by several of the species listed above.

In particular, it is likely that dugong - based on estimates that the site supports about one quarter of the 'East Coast' population - would meet the 1% threshold for Criterion 9. Honey blue-eye may also meet the Criterion on the basis that the extent of suitable wallum habitat types elsewhere in the drainage division is limited and these species are likely to exist as discrete populations within a local area. However, as noted above the lack of definitive data precludes inclusion of these species under this criterion at this time.

Table 2-4 Nomination Criteria currently addressed by the Ramsar site

*Note: **Bold italics** in column 2 of the table indicates Ramsar Nomination Criteria at the time of listing*

Met	'New' Criteria	Pre-1999 Criteria
Yes	**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.	***1(a) it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region*** 1(b) it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region ***1(c) it is a particularly good representative example of a wetland which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position*** 1(d) it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.
Yes	**Criterion 2**: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	***2(a) it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species.***
Yes	**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	***2(b) it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna*** ***2(d) it is of special value for one or more endemic plant or animal species or communities*** ***3(b) it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity.***
Yes	**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.	***2(c) it is of special value as the habitat of plants or animals at a critical stage of their biological cycle.***
Yes	**Criterion 5**: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.	***3(a) it regularly supports 20,000 waterfowl.***
Yes	**Criterion 6**: A wetland should be considered internationally important if it regularly supports 1 per cent of the individuals in a population of one species or subspecies of waterbird.	***3(c) where data on populations are available, it regularly supports 1 per cent of the individuals in a population of one species or subspecies of waterfowl.***
Yes	**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.	4(a) 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.
Yes	**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.	4(b) 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.
No	**Criterion 9**: A wetland should be considered internationally important if it regularly supports 1 per cent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.	None.

3 SUMMARY OF CRITICAL SERVICES, COMPONENTS AND PROCESSES

This Section of the report summarises the critical services/benefits, components and processes that make up the ecological character of the Shoalwater and Corio Bays Area Ramsar site and provides the limits of acceptable change to those critical elements. Appendix A outlines the basic methodology used in the selection of the critical services/benefits, components and processes for the site.

3.1 Overview of Critical Services, Components and Processes

A summary of the critical wetland ecosystem services/benefits, components and processes for the Shoalwater and Corio Bays Area Ramsar site are shown in Table 3-1.

As outlined in Appendix A, following the methodology within the National Framework, the assignment of a given wetland process, component or service/benefit as critical was guided by the following considerations:

- the service or underlying component/process is important for supporting one or more of the Ramsar nomination criteria under which the site was listed
- the service or component/process is an important determinant of the uniqueness of the site
- the service or component/process may be subject to change in short to medium time frames (<100 years) and/or the change will cause potentially significant consequences (e.g. change the ecological character).

Eight ecosystem services/benefits have been identified principally through identification of services/benefits that relate back to the updated Ramsar Nomination Criteria for the Shoalwater and Corio Bays Area Ramsar site, as well as three cultural services that are seen as particularly important or noteworthy in the context of the ecological character of the site.

Critical wetland ecosystem components and processes underpin the critical services/benefits, noting that these components and processes vary across the diverse range of ecosystems present within the site.

The broad interaction of wetland services/benefits, processes and components at a whole-of-site level is shown in Figure 3-1. As shown in the figure, there are three broad processes identified (climate, geomorphology and regional-scale hydrodynamic and hydrological processes) that together have shaped the topography, marine and freshwater flow regime and other important aspects of the site. At the local habitat scale, there is a mix of physical and chemical processes as well as biological processes that control the wetland habitats and associated biota. The interaction of the wetland components with the wetland processes yields a range of wetland services/benefits (shown in the yellow box in Figure 3-1). These are characterised as either supporting (ecosystem services) or as cultural services (relevant to providing a social or economic benefit to humans) using the terminology in the National Framework.

In many cases there is a direct relationship between the critical services/benefit and critical components such as wetland habitat types or noteworthy fauna (e.g. vulnerable flora or fauna; waterbird populations). In this way, many of these habitats and species are effective surrogate measures for maintenance of the wetland service/benefit and broader ecological character of the wetland.

Table 3-1 Summary of critical services/benefits, components and processes of the Shoalwater and Corio Bays Area Ramsar site

Ecosystem services/benefits	Ecosystem components	Ecosystem processes
1: The site contains marine, estuarine and freshwater landscapes and ecosystems that are representative of the biogeographic region and are rare in the context of a large coastal system that remains in a near natural state **2:** The site has wetland types (notably the peat swamps in the Dismal Sector and the Clinton Lowlands) that are rare, unusual and noteworthy for the biogeographic region and at greater spatial scales. **3:** The site supports national and internationally threatened wetland species. **4:** The habitat diversity present within the site supports outstanding biodiversity values including several notable vegetation communities. **5:** The site supports substantial numbers of wetland species during a critical life stage (e.g. breeding, nesting, roosting, feeding, and/or refugia). **6:** The site supports substantial numbers of resident and migratory waterbirds. **7:** The site supports a high diversity of fish species reflecting the diversity of habitats of the site and a biogeographical overlap zone. **8:** The site supports nursery habitat of critical importance to regional commercial and recreational fisheries. **9:** The site supports a range of pristine/near natural wetland environments that are important for scientific research and assessing the future impacts of climate change. **10:** The site provides a significant regional asset in terms of water supply to the Capricorn Coast and will provide a strategic reserve for freshwater in the future. **11:** The site and its values are a major part of a broader 'wilderness area'. There is a strong, regional, State and national community attitude supporting conservation of the wilderness values of the site.	**Wetland habitats,** including the following Ramsar types: *Coastal/Marine* • nine Types *Inland* • nine Types. **Populations of wetland-dependent fauna and flora species of national or international conservation significance**, including populations of: • aquatic animals (marine): Sea turtles and dugong • aquatic animals (freshwater): honey blue eye • wetland-dependent terrestrial fauna species: water mouse • wetland-dependent flora: lesser swamp orchid. **Wetland vegetation communities** reliant on the site for conservation security **Populations** of migratory and resident waterbirds **Populations** of fish and invertebrates that are of recreational and commercial significance	**Physical coastal processes.** Hydrologic and hydrodynamic controls on habitats through tides, currents, waves, wind and associated erosion and accretion processes. **Surface freshwater inflows** Freshwater inflows from creeks and surface run-off most notably into Corio Bay and into Shoalwater Bay. **Groundwater.** Groundwater dynamics and interaction with freshwater wetland systems. **Water quality.** Water quality that provides aquatic ecosystem values within wetland habitats. **Geomorphology**. Key geomorphologic/ topographic features of the site. **Energy and nutrient dynamics.** Primary productivity and the natural functioning of carbon and nutrient cycling processes. **Biological processes.** Important biological processes such as growth, reproduction, recruitment, migration and dispersal. **Climate.** Patterns of temperature, rainfall, and evaporation.

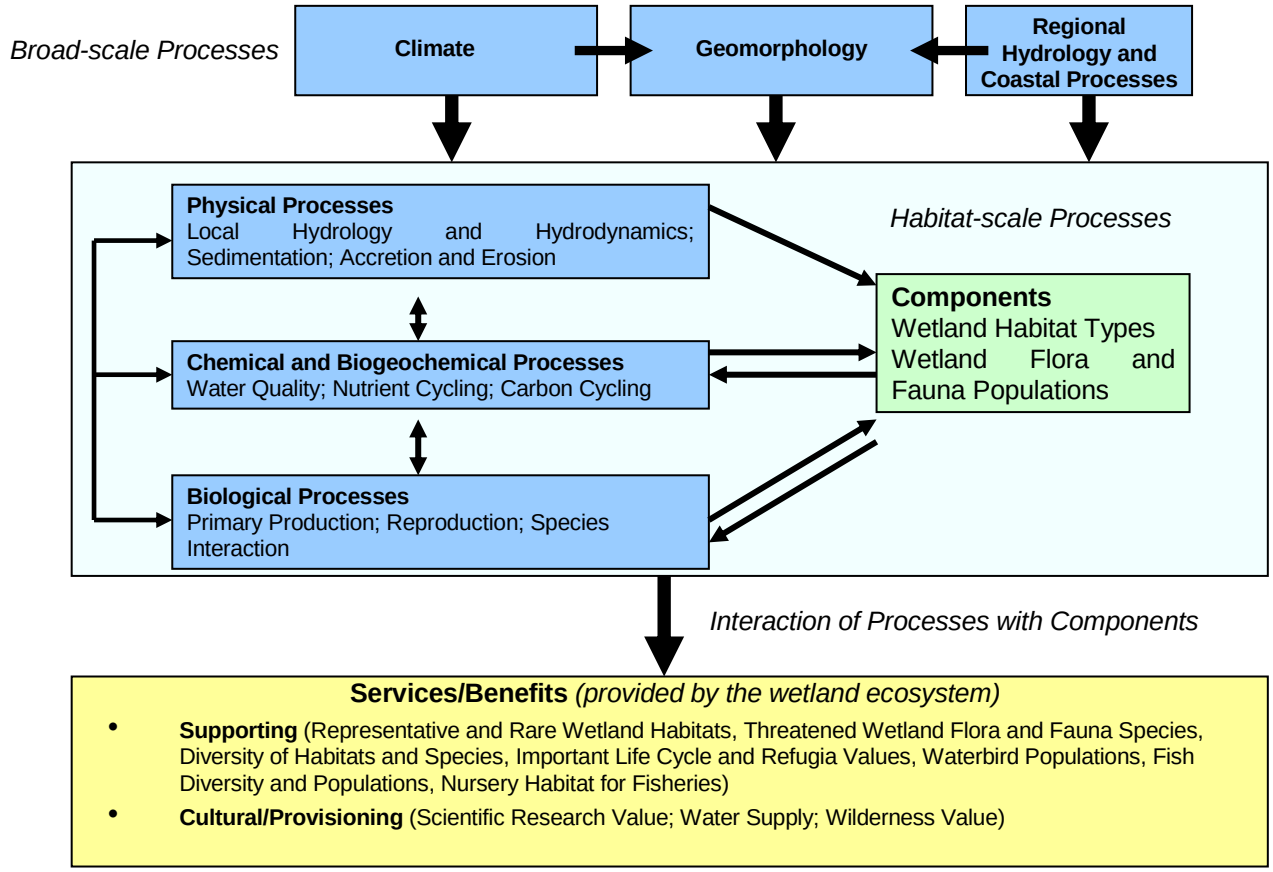


Figure 3-1 Conceptual model showing interaction of critical elements (© Copyright, BMT WBM)

3.2 Description of Critical Services/Benefits, Components and Processes

As outlined above, the eight ecosystem services/benefits selected as part of this ECD reflect a number of the Ramsar Nomination Criteria deemed to be met by the site and include three notable cultural or provisioning services/benefits derived from the site by humans. It should be recognised that a number of other candidate services/benefits were identified and discussed with the Steering Committee and KMC as part of the ECD preparation process. These included for example, commercial fishing, recreational activities on the site, and the Indigenous significance of the site, but it was decided that the three services selected best reflect linkages back to ecological character.

A short summary of each ecosystem service/benefit, component and process is provided in the sections below. In addition, Appendix B contains summary tables which underpin the text presented in this section. These summary tables provide more detailed justification for listing as a critical services/benefit, the relationship between the services and underlying critical components and processes, and more detailed information about changes to ecological character, threats, information gaps and monitoring needs that form the basis of Sections 4 and 5 of this ECD.

3.2.1 Representative Ecosystems

Photos: Shoalwater Bay (© Copyright, DoD, BMT WBM).

1: The Ramsar site contains marine, estuarine and freshwater landscapes and ecosystems that are representative of the biogeographic region and show a high degree of connectivity.

The wetland types of the Shoalwater and Corio Bays Area Ramsar Site are extremely diverse, ranging from freshwater marshes and peat swamps, to intertidal mudflats and mangroves and estuarine and open coastal marine habitats. An overview of the Ramsar wetland types present within the boundaries of the site (including reference to the DERM wetland mapping) is provided in Section 2 of this report.

As outlined in GHD (2007), the 'approximately 600 square kilometres of SWBTA have a mosaic of high integrity habitats…the diversity of SWBTA is not only represented by the variety of fauna and flora present, but also the diversity of the habitats'.

While there are notable wetland types within the site that are rare in the relevant IMCRA biogeographic region and Australian Drainage Division (refer Service 2), many of the more common subtidal and intertidal wetland habitat types such as seagrass, mangroves and saltmarsh within Shoalwater and Corio Bays are unusually good examples of these habitats in their respective bioregions because of their pristine/near natural condition.

The excellent ecological condition of these areas is provided by the relatively undisturbed nature of the site's catchments, generally excellent water quality and the presence of marine protected zones (in the forms of marine national park zones, Dugong Protection Areas and a declared Fish Habitat Area) within and adjacent to the site. In considering the Ramsar site as a subset of a larger coastal assemblage, the site's size and scale make it the largest undeveloped, intact coastal system along the Queensland coast, south of Cooktown (Commonwealth of Australia 1994).

With a diversity of habitat types supported within a discrete area, there is a high degree of connectivity between the terrestrial, intertidal and subtidal habitat types at a local scale. For example, within Shoalwater Bay, Island Head Creek and Port Clinton there are complex mosaics of saltmarsh, mangroves, seagrass, unvegetated shoals and deeper waters in close proximity to each other. This combination and diversity of habitat types may represent potentially important nursery habitat for many fish and prawn species of commercial significance (see Laegdsgaard and Johnson 1995; Tibbetts and Connolly 1998) which is reflected in the context of Service 8 (see below). In addition, there is an emerging view that fish and nektobenthic crustacean community structure in mangroves and unvegetated habitats is influenced by their proximity to seagrass beds (e.g. Jelbart 2004, Olds 2002).

Some documented examples of the beneficial interaction between wetland habitats illustrating connectivity include:

- Melville and Connolly (2003) demonstrated that organic matter, particularly from seagrasses, was important as the base of food webs for fish species of commercial significance on adjacent unvegetated mudflats in Moreton Bay
- studies by Olds (2002) in Moreton Bay and Jelbart (2004) in central NSW both found that seagrass beds (particularly dense beds – Olds 2002) in close proximity to mangroves tend to contain more abundant nekton assemblages than seagrass remote from mangroves. Both studies also found that the suite of species inhabiting seagrass varied with distance from mangroves
- many marine fauna species utilise different habitat types on a day to day basis and at different life history stages (such as feeding by juvenile green turtles on both seagrass and mangrove seeds and fruits).

The close proximity of freshwater wetland habitats with estuarine, beach and marine habitats also underpins the importance of the site in providing suitable habitat for waterbirds (particularly migratory shorebirds) that use different parts of the site for different life functions such as feeding, roosting and nesting. This is further discussed in the context of Critical Service 5.

The near-natural and representative wetland environments that occur in the site and the minimal anthropogenic threats to these habitat values are indicative that there is natural stability in the system that will retain these habitats in the long term. Notwithstanding, wetland environments can show significant seasonal/local variation depending on key drivers such as rainfall, hydrological inputs, nutrients, and sedimentation. For example recent drought in the area has seen dieback of some mangroves and coastal melaleuca forests (R. Jaensch pers. comm. 2009).

Particular habitats will be more susceptible to temporary disturbance (be it natural or of anthropogenic origin) than others. For example, seagrass, coral reefs, freshwater swamps and similar environments are highly dependent on stable water quality conditions whereas mangroves and saltmarsh will be more resilient to intense and even persistent impacts.

3.2.2 Rare Wetlands

Photos: Patterned fens in Dismal Swamp (© Copyright, DoD) and peatland in Dismal Swamp (© Copyright, R. Jaensch, Wetlands International).

2: The Ramsar site has wetland types (notably the peat swamps in the Dismal Sector and the Clinton Lowlands) that are rare, unusual and noteworthy for the biogeographic region and greater spatial scales.

The Ramsar site supports a suite of peat-based sedge/heath wetlands (fens) that are a rare wetland type in the drainage division (similar habitats can only be found on the barrier islands in the Great Sandy and Moreton regions and a few other localities) and are of national/global significance. Peat swamps are predominantly located in Dismal Swamp, Freshwater Beach swamps and parts of the Clinton Lowlands, with minor elements elsewhere.[4] In addition to rarity, the significance of this wetland type is attributed to the carbon sink properties, possible fossil pollen records and possibly distinctive acid-tolerant invertebrate, frog and fish communities, similar to the situation in the Great Sandy Straits Ramsar site (Jaensch 2008b).

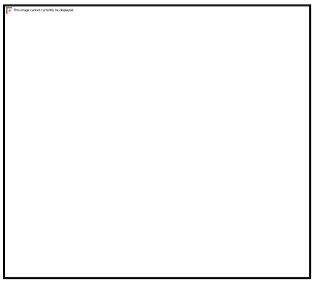
A number of critical ecosystem processes underlie the ecological functioning of these systems. These include freshwater wetland geomorphology (i.e. topography, as peat swamps form in depressions in sand masses), freshwater wetland hydrology (i.e. groundwater, as peat swamps are sustained by groundwater flows in sand masses), climate (i.e. precipitation, as peat swamps require relatively high rainfall with a mild dry season); freshwater wetland energy and nutrient cycling (i.e. decomposition, as vegetation decay is the peat forming process) and freshwater wetland physico-chemical processes (i.e. pH, as a specific chemical regime is associated with peat and the supported plant communities).

Natural variation in these systems is considered to be minimal. Due to a lack of hydrological (water depth and saturation) data over time, natural variation cannot be quantified for this Ramsar site but it is expected that peat swamps probably become dry at a multi-decadal time-scale (i.e. one in 50 years), and are vulnerable to burning during dry episodes (such as the past decade).

In addition to the peat based swamps, recent surveys of freshwater creeks flowing north on SWBTA from the Samuel Hill area to Shoalwater Bay through tall open forest showed sections lined with palm-broadleaf rainforest and other intact riparian habitats with tannin stained waters. These habitats may also be of special value for their rarity at a bioregional scale given the extent of lowland clearing throughout the North East Coast Drainage Division. However, little is known about these areas which represent an information gap in terms of associated flora and fauna significance (R. Jaensch pers. com. 2009).

3.2.3 Threatened Wetland Species





Photos: Oxleyan pygmy perch (© Copyright, BMT WBM), green turtle (© Copyright, DoD) and lesser swamp orchid (© Copyright, Shane Ruming).

3: Supports vulnerable/endangered wetland species and communities

[4] Peat swamps are also located on Townshend Island but these areas are outside of the boundaries of the Ramsar site

As discussed in Section 2.7 (in the context of Criterion 2), the site is known (or almost certain) to support the following nationally or internationally endangered and vulnerable wetland-dependent fauna and flora species:

3a Wetland-dependent Terrestrial Fauna

The water mouse *Xeromys myoides* is the only nationally threatened terrestrial fauna species that has been recorded within the site and is considered to be wetland-dependent. The water mouse is listed as vulnerable under the NCA and EPBC Act (where it is listed as false water rat). An individual animal was observed in mangroves near Shoalwater Creek in March 2008 and this represents the only record within the site (A. McDougall pers. comm. 2009; DoD 2009).

In Queensland, this species has been recorded in various coastal saltmarsh, mangrove and adjacent freshwater wetland habitats including sedgeland (composed of mainly *Juncus* spp. and *Baumea* spp.), chenopod shrubland, *Sporobolus virginicus* grassland and mangrove communities (Van Dyck and Gynther 2003, EPA 2008). The water mouse is likely to require relatively large areas of intertidal flats where it forages by following tidal waters to the low water mark, and forages until advancing waters inundate the mangrove community (Van Dyck 1997). The diet of the water mouse largely comprises marine intertidal crustaceans, pulmonate snails, marine gastropods and other invertebrates (Van Dyck 1997, Gynther and Janetzki 2008). Shoalwater Bay contains an abundance of saltmarsh, mangrove and freshwater habitat that are suitable for water mouse that is largely undisturbed and in good ecological condition.

In the context of this service, consideration was also given to the following threatened fauna species for which there is potentially suitable habitat within the site, although no site records exist.

The Australian painted snipe *Rostratula australis* is listed as vulnerable under the EPBC Act. There are no records for this species within the site, although there are breeding records from Torilla Plain (Broad Sound basin), nearby and to the west of the site (Jaensch *et al.* 2004; R. Jaensch pers. comm. 2009). This secretive, crepuscular species occurs on well vegetated shallow, permanent or seasonal wetlands (usually freshwater but occasionally brackish) (Geering *et al.* 2007). Occurrence is regarded as erratic and unpredictable (often in response to local rainfall), seldom remaining long in any locality and being absent from areas in some years and common in others (Marchant and Higgins 1993; Geering *et al.* 2007). Although freshwater swamps are present within the site (e.g. Dismal Swamp), these may be too densely vegetated for the Australian painted snipe in comparison to habitats where this species breeds on the eastern and western sides of the Broadsound basin (R. Jaensch pers. comm. 2009).

The Australasian bittern *Botaurus poiciloptilus* is listed as endangered under the IUCN Red List (IUCN 2009). There are no records for this species within the site, although there are regional records. This shy and cryptic bird roosts, feeds and breeds within dense vegetation cover of mainly freshwater wetlands, most commonly found in permanent freshwater wetlands which support a combination of tall, dense vegetation (e.g. bullrushes *Typha* spp. and spikerushes *Eleocharis* spp.) and short dense vegetation including sedges, rushes and/or reeds (Marchant and Higgins 1990, Garnett and Crowley 2000). Potentially suitable sedge-dominated wetlands occur within the site at Dismal Swamp, which has the large extent of habitat that the species seems to require (given territoriality during breeding season) (R. Jaensch, pers. comm. 2009). Garnett and Crowley (2000) consider that due to their comparatively specialised habitat requirements, this species may be more sensitive to overall habitat loss than are many wetland species.

No suitable data about the natural variability of populations of water mouse or the two bird species of conservation significance exist for the site. The combination of unpredictable occurrence and cryptic habits of these species create significant constraints to the assessment of presence, abundance and natural variability.

3b Aquatic/marine Fauna

A range of nationally and internationally threatened marine megafauna inhabit the waters of the Ramsar site of which the dugong and several species of marine turtle are noteworthy and considered to meet the requirements of Nomination Criterion 2. Several other marine megafauna of conservation significance are likely to inhabit the waters of the site from time to time including whales (humpback whales, dwarf minke whales) but have not been included here on the basis of the Ramsar site does not form core habitat for these species. Snubfin dolphins and Indo-Pacific humpback dolphins may use the coastal waters of the Ramsar site as core habitat but are not nationally or internationally listed threatened species and as such have also not been included in consideration under this service. Saltwater crocodiles are another notable species of conservation significance on the site but are not present in large numbers and the habitat is not considered as an important breeding area (DoD 2009).

There have been several detailed on-going studies of marine turtles by the Australian and Queensland Governments as well as aerial surveys of dugong populations in Shoalwater Bay. While prevalent in the Shoalwater Bay sections of the site, it is likely that dugong and green turtles are only occasional visitors to Corio Bay due to a lack of extensive seagrass which is the main feed item for these species, noting mangrove seeds and fruit in Corio Bay may provide an alternative food source for green turtles.

From these studies (as summarised in DoD 2009, GBRMPA 1997, Limpus *et al.* 2005) the following points are relevant:

- Shoalwater Bay is considered the most important dugong sanctuary on the Queensland coast south of Cooktown because it supports more than one quarter of the dugong in the region and impacts are tightly controlled. In this context, it is stated that SWBTA supports the most important dugong habitat in the southern region of the Great Barrier Reef Marine Park (GBRMP); noting dugong populations are estimated to be 12,000 in the GBRMP of which about 1,700 are found in the Southern Region of the park (GBRMPA 1997). The dugong population of SWBTA is likely to become increasingly important as threats to other east coast dugong populations increase

- Shoalwater Bay supports at least four EPBC-listed species of turtles including the green, loggerhead, flatback and hawksbill turtles. Of these, the green turtle is most abundant with the other three species in much smaller numbers. Accordingly, Shoalwater Bay is recognised as containing one of the largest and least impacted foraging populations of green turtles in eastern Australia and is a key reference site for monitoring green turtle populations

- although no accurate population estimate of green turtles in Shoalwater Bay is available, it has been estimated that about 500 turtles per km may be present over at least 30 km of mainland coastline during winter months. Based on long term surveys, many of the captured green turtles display strong site fidelity (e.g. residency) to the Area across decades.

The freshwater habitats of the Shoalwater Bay section of the site also support nationally and internationally threatened aquatic freshwater fish species, notably the honey blue-eye (*P. mellis*) which

has been observed as part of previous fish surveys (refer Trnski *et al.* 1993). Based on similar habitat and occurrence elsewhere (Great Sandy Strait Ramsar site; Moreton Bay Ramsar site), the Ramsar site may also provide suitable habitat for the Oxleyan pygmy perch (*N. oxleyana*) though this species has not been observed on the site to date.

The presence of honey blue-eye is also significant on the basis that the population present is likely at or near its northern extent in the bioregion/drainage division. Suitable habitat for honey blue-eye and Oxleyan pygmy perch include Dismal Swamp, the upper reaches of Sandy Creek (adjacent to Dismal Swamp), perched lakes and swamps between Dismal Swamp and Manifold Hills, the wetlands behind Freshwater Beach and the Clinton Lowlands.

3c Freshwater wetland-dependent flora species

One nationally threatened freshwater wetland-dependent flora species exist within the site, namely *Phaius australis* (lesser swamp orchid) listed as endangered under the EPBC Act. *Phaius australis* (Orchidaceae) is a large terrestrial orchid that primarily inhabits swamp forests.

Population sizes and dynamics are largely unknown for both of these species within the site. As such, it is difficult to assess the levels of natural variability displayed by these species without the required long-term and/or detailed data. Additionally, an understanding of the ecology and biology of these species is highly limited and represents a major knowledge gap.

3.2.4 Biodiversity

Photos: Weeping baeckia, fawn footed melomys and coral heath (© Copyright, DoD).

4: Supports significant biological diversity in terms of wetland flora and fauna species and their habitats including several notable vegetation communities.

As has been previously described in Section 2, the wetland types of the Shoalwater and Corio Bays Area Ramsar site are extremely diverse. Indeed, half of the wetland types found in Queensland occur in the Shoalwater and Corio Bays area (Department of Environment, 1996). Using the Ramsar typology, all but two of the coastal/marine wetland types are represented as well as a range of inland types within the interior of the Shoalwater Bay section of the site. The biodiversity supported by these wetlands is extremely rich, largely attributed to the location on Queensland's central coast straddling two bioregions, such that tropical and subtropical species overlap.

As discussed in the context of the other services, the habitats of the site support notable biodiversity as evidenced through:

- several species of internationally/nationally threatened flora and fauna (refer Service 2)

- support of critical life stage processes (breeding, roosting, feeding, drought refugia) of avifauna and other wetland dependent species (refer Service 5)
- a high fish and marine macroinvertebrate species diversity (refer Service 7).

Terrestrial Fauna Species

A total of approximately 400 vertebrate fauna species have been recorded within the site, or within adjacent habitat types that also occur within the site (Nix 1972, Schodde *et al.* 1992, Walker *et al.* 1993, Catling *et al.* 1994, O'Neill 1995, Driscoll 1996, Houston and Mitchell 1997, HLA 2006a-c, HLA 2007, Jaensch 2008a, DoD 2009, EPA 2009). This assemblage includes 48 mammal, 63 reptile, 22 frog, and 267 bird species. While information about species diversity is not available for the Northeast Coast Drainage Division, this species richness represents approximately 66% of the vertebrate fauna known for the Central Queensland Coast (IBRA) bioregion (CQC bioregion: 609 species; data sources include Barnard 1913, Longmore 1978, Ingram and Raven 1991, Low 1993, Crawford 1993, Houston and McCabe 1996, Driscoll 1995 and 1997, Arthington 2001, BAAM 2001 and 2002, Cooper 2003, Harding and Milton 2003, Jaensch 2004, Ecoserve and LAMR 2006, EPA 2009, L. Agnew pers. obs. 2009).

Whilst there are a relatively small number of wetland-dependent mammals and reptiles, the following wetland-dependent fauna groups are considered to be notable:

- Twenty two frog species – representing approximately 79% of frog species known for the Central Queensland Coast bioregion (CQC bioregion: 28 species)
- Seventy seven waterbird species – representing approximately 73% of the waterbird fauna known for the Central Queensland Coast bioregion (CQC bioregion: 105 species)
- Thirty two shorebird species – representing approximately 71% of the shorebird species known for the Central Queensland Coast bioregion (CQC bioregion: 45 species).

Wetland Flora Species and Communities

The precise number of wetland flora species within the Ramsar site is not known. Melzer *et al.* (1993) recorded 791 flora species within SWBTA, Brushe (2002) recorded 1341 flora species and subspecies within SWBTA, and EPA (2009) shows records for over 1500 flora species from within the Ramsar site and the surrounding area. Taking into account the extent of wetland habitats within the site, a sizeable proportion of these flora species are expected to be wetland-dependent.

Furthermore, the Ramsar site is important in maintaining the biodiversity of the bioregion in terms of the presence of two wetland vegetation communities that are dependent on the site for their conservation security due to a substantial proportion of their remaining extent being located within the site (DoD 2009). Descriptions of these vegetation communities are as follows:

- *Melaleuca* spp. and/or *Lophostemon suaveolens* and/or *Eucalyptus robusta* open woodland to open forest in wetlands associated with parabolic dunes (RE 8.2.7, Ramsar wetland type Xf)
- sand blows with bare sand and areas of sparse herbland/shrubland (RE 8.2.10, Ramsar wetland type E).

Additionally, the importance of the site in maintaining bioregional diversity is highlighted through the presence of a number of wetland vegetation communities that have a conservation status of 'Of Concern' under the Queensland VMA. This conservation status indicates that these vegetation

communities have previously undergone significant clearance at the bioregional scale. Descriptions of these vegetation communities are presented in Table 3-2.

Table 3-2 Of Concern wetland Regional Ecosystems within the Ramsar site

RE	Ramsar Wetland Type	DERM Wetland Type	Description (from REDD)	VMA status	Biodiversity status
8.1.5	Xf	Palustrine	*Melaleuca* spp. and/or *Eucalyptus tereticornis* and/or *Corymbia tessellaris* woodland to open forest (estuarine wetland) with a ground stratum of salt tolerant grasses and sedges, usually in a narrow zone adjoining tidal ecosystems	OC	E
8.2.7	Xf	Contains palustrine	*Melaleuca* spp. and/or *Lophostemon suaveolens* and/or *Eucalyptus robusta* open woodland to open forest in wetlands associated with parabolic dunes	OC	E
8.2.11	Xf	Palustrine	*Melaleuca* spp. woodland in parallel dune swales (wetlands)	OC	OC
8.3.1	Xf	Riverine	Semi-deciduous notophyll/mesophyll vine forest fringing watercourses on alluvial plains	OC	OC
8.3.8	Xf	Riverine	*Syncarpia glomulifera*, *Eucalyptus portuensis*, *Corymbia intermedia* open forest on sandy creek flats and granite outwash	OC	OC
8.3.13	Xf	Palustrine	*Eucalyptus tereticornis* and/or *Corymbia tessellaris* and/or *Melaleuca* spp. open woodland to open forest on alluvial and old marine plains, often adjacent to estuarine areas	OC	E
11.2.2	E	N/A	Complex of *Spinifex sericeus*, *Ipomoea pes-caprae* and *Casuarina equisetifolia* grassland and herbland on foredunes.	OC	OC

Notes to Table:

VMA	*Vegetation Management Act 1999* (Qld)
Biodiversity Status	As scheduled in the Vegetation Management Regulation 2000 (Qld)
OC	Of Concern
E	Endangered
REDD	Regional Ecosystem Description Database (see EPA 2007)

3.2.5 Critical Life Stages

5: The site supports several important wetland species during a critical life stage (e.g. breeding, nesting, roosting, feeding and/or refugia).

The site supports habitat and conditions that are important at critical stages in their life cycles (e.g. breeding, feeding, nesting, overwintering, moulting) for a variety of wetland-dependent fauna species such that if interrupted or prevented from occurring, the long-term conservation of those species may be threatened. These values include:

- feeding and roosting habitat for 77 waterbird species (Walker *et al.* 1993, O'Neill 1995, Driscoll 1996, Houston and Mitchell 1997, Habitat 1974, Jaensch 2008a, DoD 2009, EPA 2009) and a total site abundance of more than 20,000 birds (Driscoll 1996, Jaensch 2008a). This includes waterbirds listed as threatened at the State level and/or occurring in significant numbers such as beach stone-curlew *Esacus magnirostris* (vulnerable - NCA), little tern *Sterna albifrons* (endangered - NCA) and terns in notable roost aggregations (e.g. one record of more than 1000 birds at beach west of West Point, Port Clinton) (Houston and Mitchell 1997, Jaensch 2008a, DoD 2009). Recent surveys of roost sites indicate four roosts within the Shoalwater Bay section of the site that hold >1000 waterbirds roosting at high tide (Jaensch 2008a)
- non-breeding feeding and roost habitats for 26 migratory shorebird species (O'Neill 1995, Driscoll 1996, Houston and Mitchell 1997, Habitat 1974, Jaensch 2008a, DoD 2009). By way of these values (and other attributes which support Ramsar criteria 5 and 6), the site also demonstrates an importance for shorebird migration (Jaensch 2008a)
- breeding habitat for a variety of waterbirds, including several species listed as threatened at the State level and/or occurring in significant numbers (Walker *et al.* 1993, Houston and Mitchell 1997, DoD 2009). Site values with respect to waterbird breeding habitat are highlighted by the following:
    - Australian pelicans *Pelecanus conspicillatus* that nest on Akens Island and Pelican Rock represent the most substantial breeding colonies on the Great Barrier Reef south of the tip of Cape York Peninsula (Walker *et al.* 1993). Previously known colony sizes exceed 1000 breeding pairs, but more often comprises about 300–400 pairs. Given the susceptibility to disturbance when breeding, the remote nature of these sites increases the significance of the site as a breeding location (O'Neill and Limpus in prep. in DoD 2009).
    - little tern *Sterna albifrons* (endangered; NCA) – Commonly recorded throughout shallow waters of the site. Not observed nesting within Shoalwater Bay, though small breeding colonies possibly form at times on exposed sand spits in locations such as Port Clinton and Island Head Creek (O'Neill 1995, DoD 2009). A small colony breeds at Sandy Point in Corio Bay (Houston and Mitchell 1997), though breeding success is impacted due to continued disturbance from visitors in vehicles (DoD 2009). Within Corio Bay, a count of approximately 1300 birds has been recorded and comparison with data from other sites indicates that this is probably equal to the highest count elsewhere in this Central Queensland region (O'Neill 1995, Houston and Mitchell 1997).
- freshwater wetland habitats for 22 frog species (Nix 1972, Habitat 1974, Schodde *et al.* 1992, Catling *et al.* 1994, DoD 2009)

- feeding and breeding habitat for wetland-dependent raptors, i.e. osprey *Pandion haliaetus*, white-bellied sea-eagle *Haliaeetus leucogaster*, and Brahminy kite *Haliastur indus* (Houston and Mitchell 1997, Jaensch 2008a, DoD 2009)
- some nesting usage by flatback turtles (*Natator depressus*) on Akens Island and other shorelines of the site (though low density and not formally surveyed to date)
- feeding habitat for green turtles (*Chelonia mydas*), particularly prior to the breeding season.

It should be noted that important life cycle habitats and functions for fish species are not addressed as part of this service but are instead addressed as part of Service 8 (recognising the distinction between nomination criterion 4 and criteria 7 and 8 in the Convention).

Patterns in abundances of all fauna species are thought to vary across a range of spatial and temporal scales, though suitable site-specific data is either absent or is not sufficiently robust to assess natural variability (though noting that there is comparatively more data for shorebirds and terns than any other species or fauna group subject to this service; see also comments below in regards to shorebirds and off-site influences on shorebird populations for Service 6).

3.2.6 Waterbird Populations

6: Supports significant resident and migratory waterbird populations

A total of 77 waterbird species have been recorded within the site (Walker *et al.* 1993, O'Neill 1995; Driscoll 1996, Houston and Mitchell 1997, Jaensch 2008a, DoD 2009, EPA 2009). The site's waterbird assemblage includes 32 shorebirds, comprising 26 migratory and six resident shorebird species (Driscoll 1996, Houston and Mitchell 1997, Jaensch 2008a, DoD 2009, EPA 2009).

The following component of this assessment relates to the Shoalwater Bay section of the site. Currently, there is no comparable, substantive dataset for shorebirds within the Corio Bay section of the site. Although not a complete inventory of the whole site, the Queensland Wader Study Group has monthly records of shorebirds recorded at the major high tide roost site at Sandy Point, for a period of approximately one decade.

Data review by Jaensch (2008a) reveals that migratory shorebirds contribute a disproportionately high contribution to the abundance of waterbirds on the site. The review shows that the survey in December 1995 yielded only 1370 waterbirds other than shorebirds and 500 non-migratory shorebirds (Driscoll 1996), with similarly low numbers being recorded in 2007 (approximately 2,700 non-migratory shorebirds).

In view of those findings, Jaensch (2008a) assessed compliance with Ramsar Criteria 5 and 6 by comparing the results of migratory shorebird counts from December 1995 (as a benchmark) with those derived from the three surveys undertaken in 2007. The analysis revealed the following:

- the site continues to meet Ramsar Criterion 5, in that the site continues to support at least 20,000 waterbirds, with nearly all of them being migratory shorebirds. Specifically, over 23,000 migratory shorebirds and small numbers of other waterbirds were counted at SWBTA in December 1995 and by extrapolation the total numbers were estimated to be 20,000 to 25,000 in each of three surveys in 2007 (Table 6 in Jaensch 2008a)
- the site continues to meet Ramsar Criterion 6, in that the site continues to support at least 1% of the population size of at least one waterbird species (see below)
- the site continues to meet Ramsar Criterion 4, in that the site continues to support shorebird migration
- shorebird abundance remained generally highest in western parts of the site and the Port Clinton area
- major roost sites used in 1995 were still used in 2007 and no significant loss of high-tide roost sites was detected
- count data for the five most abundant species was largely unchanged between the 1995 survey and 2007 surveys (i.e. for grey-tailed tattler *Heteroscelus brevipes*, bar-tailed godwit *Limosa lapponica*, eastern curlew *Numenius madagascariensis*, whimbrel *Numenius phaeopus*, and terek sandpiper *Xenus cinereus*).

The most current data (Jaensch 2008a) demonstrates that six shorebird species (five migratory and one resident species) continue to be recorded in numbers which exceed 1% of the estimated population

size in the East Asian – Australasian Flyway and as such are key indicator species for shorebird usage of the site.

These species, with relevant count highlights, are as follows:

- grey-tailed tattler *Tringa brevipes* –The current flyway 1% threshold is 500 (Bamford *et al.* 2008). The threshold was exceeded in 1995 (3,014 birds; Driscoll 1996) and in all three surveys in 2007, with the highest count being 3,831 birds (Jaensch 2008a). For the three surveys undertaken in 2007 (i.e. January, March and September), the highest and lowest mean number of birds counted was 2,768 and 1,931 respectively (Jaensch 2008a)
- bar-tailed godwit *Limosa lapponica* – The current flyway 1% threshold is 3,250 (Bamford *et al.* 2008). The threshold was exceeded in 1995 (5,077 birds; Driscoll 1996) and in all three surveys in 2007, with the highest count being 4,242 birds (Jaensch 2008a). For the three surveys undertaken in 2007 (i.e. January, March and September), the highest and lowest mean counts were 3,336 and 1,860 respectively (Jaensch 2008a). From this count, it is likely that most of these godwits are of the subspecies *baueri* which has a lower 1% threshold (1600) than for the species as a whole (Wetlands International 2008; Bamford *et al.* 2008)
- eastern curlew *Numenius madagascariensis* –The current flyway 1% threshold is 380 (Bamford *et al.* 2008). The threshold was exceeded in 1995 (2844 birds; Driscoll 1996) and in two of the three surveys in 2007, with the highest count being 1,365 birds (Jaensch 2008a). For the three surveys undertaken in 2007 (i.e. January, March and September), the highest and lowest mean counts were 1,020 and 346 respectively (Jaensch 2008a)
- whimbrel *Numenius phaeopus* –The current flyway 1% threshold is 1,000 (Bamford *et al.* 2008). The threshold was exceeded in 1995 (7,089 birds; Driscoll 1996) and in all three surveys in 2007, with the highest count being 2,891 birds (Jaensch 2008a). For the three surveys undertaken in 2007 (i.e. January, March and September), the highest and lowest mean counts were 2,097 and 999 respectively (Jaensch 2008a)
- terek sandpiper *Xenus cinereus* – The current flyway 1% threshold is 600 (Bamford *et al.* 2008). The threshold was exceeded in 1995 (3,410 birds; Driscoll 1996) and in all three surveys in 2007, with the highest count being 1,953 birds (Jaensch 2008a). For the three surveys undertaken in 2007 (i.e. January, March and September), the highest and lowest mean counts were 1,275 and 539 respectively (Jaensch 2008a)
- Australian pied oystercatcher *Haematopus longirostris* – The current flyway 1% threshold is 110 (WIO 2006). The threshold was exceeded in 1995 (376 birds; Driscoll 1996) and in all three surveys in 2007, with the highest count being 307 birds (Jaensch 2008a). The threshold was also met twice at one high tide roost surveyed (i.e. beach and salt flat near Shoalwater Creek estuary (SB02); Jaensch 2008a).

Notably, the beach stone-curlew *Esacus magnirostris* has been recorded in numbers of up to 90 birds (DoD 2009). This abundance would exceed the 1% threshold for the Australian population (i.e. 50 birds; Garnett and Crowley 2000), though less than the 1% threshold for whole flyway population (i.e. 250 birds; Wetlands International 2006). It is thought that Shoalwater is an especially important habitat for beach stone-curlew given increasing levels of disturbance of available habitat on Queensland islands in the region and the mainland (DoD 2009).

The 1999 RIS noted that “six species of migratory shorebirds have been recorded at numbers exceeding 1% of their population in the East Asian Australasian Flyway, including eastern curlew *Numenius madascariensis*, whimbrel *Numenius phaeopus* and great knot *Calidris tenuirostris*”. The identity of the remaining migratory species is not clear, though the 1999 RIS does note that the resident beach stone-curlew also occurs in “significant” numbers within the site.

The current report includes the eastern curlew, whimbrel, and beach stone-curlew as part of a suite of shorebird species whose presence on the site continues to exceed the 1% population threshold. This group does not include the great knot for the following reasons. Previously this species was reported in Lane and Davies (1987) in numbers (4160 birds - based on unidentified medium-sized waders assumed to be mainly great knot seen in aerial surveys) exceeding the 1% threshold for that species (3,800) for the “Broadsound and Shoalwater Bay” area. This area includes the site, though also other large intertidal habitat areas associated with the “Broad Sound” area, thus does not apply to the site alone. Over 2000 birds have been observed in Broad Sound (Jaensch 2009). The claim in the 1999 RIS for the site is not supported by suitable evidence from either the 1995 survey (820 birds; Driscoll 1996), or the 2007 surveys (between 600 to 900 birds depending on count approach (i.e. aerial versus ground counts); Jaensch 2008a). The most recent estimate of the 1% population threshold for the flyway is 3,500 birds, with 938 birds being the threshold to identify “staging” sites of international importance during migration (Bamford *et al.* 2008).

Patterns in abundances of both resident and migratory shorebirds are known to vary across a range of spatial and temporal scales, though suitable site-specific data is either absent or is not sufficiently robust to use. In regards to migratory shorebirds, populations are known to fluctuate between seasons and are likely to change between years (though in regards to the latter, current data does not indicate any significant change in abundance or species richness between 1995 and 2007 surveys). The causes for potential change in abundance may be influenced by local factors and/or by external factors (e.g. declines linked to the loss of habitat at external critical stopover locations on migration routes; Gosbell and Clemens 2006). Such losses may eventually reduce the numbers of migratory shorebirds using Shoalwater Bay and monitoring of migratory shorebirds within the site will need to take account impacts external to the site though liaison with researchers in the flyway.

3.2.7 Fish Diversity


Photos: Shoalwater Bay (© Copyright, DoD) and rainbowfish (© Copyright, BMT WBM).

7: Supports a high diversity of fish species reflecting the diversity of habitats and biogeographical factors that affect the site (i.e. located within overlap zone).

As discussed in Section 2, the site has a high diversity of fish species in terms of:

1. numbers of species (~428 species)
2. a high proportion (a fifth) of the total number of marine fish species known to occur in the bioregion, despite not containing other habitats that are known to contain a high level of biodiversity and greatly contribute to the high numbers of species in the bioregion
3. a high degree of complexity in terms of the life-history characteristics of fish species (i.e. freshwater, estuarine and marine species)
4. a wide range of life-history stages for many species are supported (eggs, larvae, juvenile, breeding adults)
5. a high degree of complexity in terms of species interactions with the environment.

With the possible exception of small intermittently closed and open lagoon systems within the broader bioregion, it is acknowledged that most coastal lagoons and estuary systems would automatically support points 3, 4 and possibly 5 listed above. What makes this a critical service is the large number of species found in the site, which itself is a reflection of the wide variety of habitats types within relatively close proximity to each other, together with the large waterway area. Given the number and complexity of habitats and associated richness of the fish fauna, the other attributes describing fish 'diversity' are also met.

The high diversity of fish assemblages reflects in part the wide diversity and interconnectivity of habitats present (fresh to marine-estuarine waters) and the large size of the site. Furthermore, the key processes that ultimately control the diversity of habitats (as outlined in Section 3.4) are also likely to maintain fish biodiversity values. Maintenance of other underpinning processes/controls, such as 'good' water quality, 'natural' river flow regimes into estuarine and freshwater environments, and reproductive/recruitment cycles, are also considered critical.

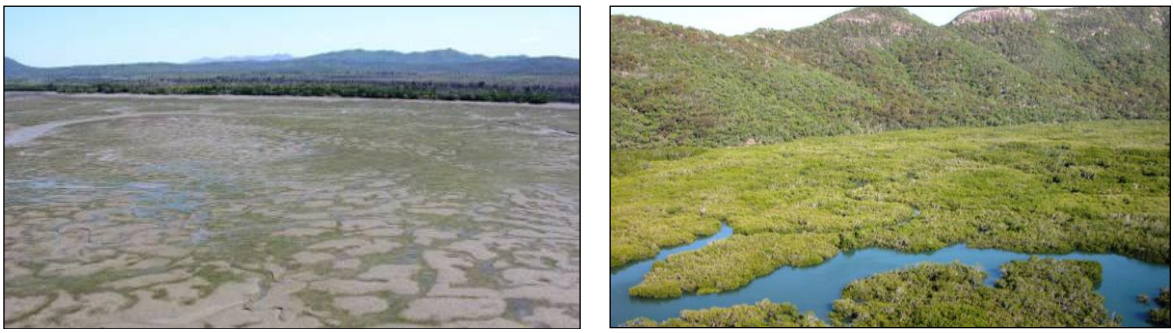
It should be noted that the total number of fish species recorded in the site has been derived from a range of data-sets collected over many years. It cannot be inferred that the site has this number of fish

species at any given time as many fish species are only transient visitors to the site. At a whole of site scale, it is likely that fish species richness is likely to vary greatly over a range of time scales, subject to prevailing (e.g. salinity, chance recruitment events etc.) and historical (e.g. recent flow regimes, changes in habitat distribution/extent) conditions.

There are limited available data describing natural variability in fish species richness at smaller spatial scales, e.g. within and among habitat types; stations within habitat types. The only long-term data describing fish assemblages within the site are commercial fish catch data (i.e. catch per unit effort for selected species). These data are not suitable for assessing patterns in species richness. Systematic monitoring would be required to assess patterns in natural variability.

Furthermore, Lee Long *et al*. (1997) provide fish count data collected from seagrass beds during two survey events: September 1995 and April 1996. Great variability in catches among sites over time were noted, however these data are insufficient to develop an appropriate baseline for LAC development.

3.2.8 Fisheries Nursery Values



Photos: Seagrass in western Shoalwater Bay (© Copyright, DoD) and mangroves at Island Head Creek (© Copyright, R. Jaensch, Wetlands International).

8: Supports critical nursery habitat of importance to regional commercial and recreational fisheries.

The site provides important habitats, feeding areas, recruitment areas, dispersal and migratory pathways, and spawning sites for numerous fish and crustacean species of direct and indirect fisheries significance. These fish have important fisheries resource values both within and external to the site. The commercial fishery within and adjacent to the site is based mostly on mud crabs, prawns, sharks and a range of finfish.

Estuarine/marine habitats present within the site are well known nursery habitats for fisheries of commercial and recreational significance. As discussed in Section 2, the site provides the following habitat values:

- high fisheries value as nursery habitats, most notably seagrass, mangroves, saltmarsh (Walker 1997). The nursery habitats provided by the site are also seen as being important to commercial fishery species at broader regional scales because of their undisturbed and intact nature relative to degraded fish nursery habitat elsewhere on the Queensland coast (Commonwealth of Australia 1994)
- Including habitat for bait fish, most notably seagrass (Lee Long *et al.* 1997) and open waters

- reef areas which provide nursery habitat, as well as feeding habitat for adult fish. Rocky reefs with associated coral communities also occur in the deeper channels of Port Clinton and Shoalwater Bay which is uncommon for tropical zones (J. Platten pers. comm. 2009)
- key habitat for mud crabs and prawns.

What is especially critical from a fisheries habitat perspective is that the site contains a wide range of habitats within relatively close proximity to each other, essentially forming a mosaic of habitat patches. Almost all important fisheries species commonly found within the Ramsar site are not found exclusively in any one habitat type during any part of their life-cycle. Rather, these species have relatively plastic habitat requirements, and are typically found in a variety of habitat types. In general terms, most of the species listed in the table below spend their juvenile stages in shallow nearshore waters, particularly around seagrass and mangroves, whereas most species tend to spawn in inshore waters. Adults of most species tend to utilise a variety of habitats. In the context of this service, it is considered critical that spatial patterns in habitat patch configuration, distribution and extent are maintained in order to preserve fisheries habitat values.

From an economic perspective, mud crab is considered to represent a particularly notable species within the site. Shoalwater produces ~8% of the state's total mud crab catch. Between 1998-2005, this species had an annual gross value of production (GVP) of $360,000 within the three commercial grids covering the site (FQ unpublished data). Figure 3-2 shows that total crab catches markedly increased between 2000-2005, despite relatively similar levels of fishing effort.

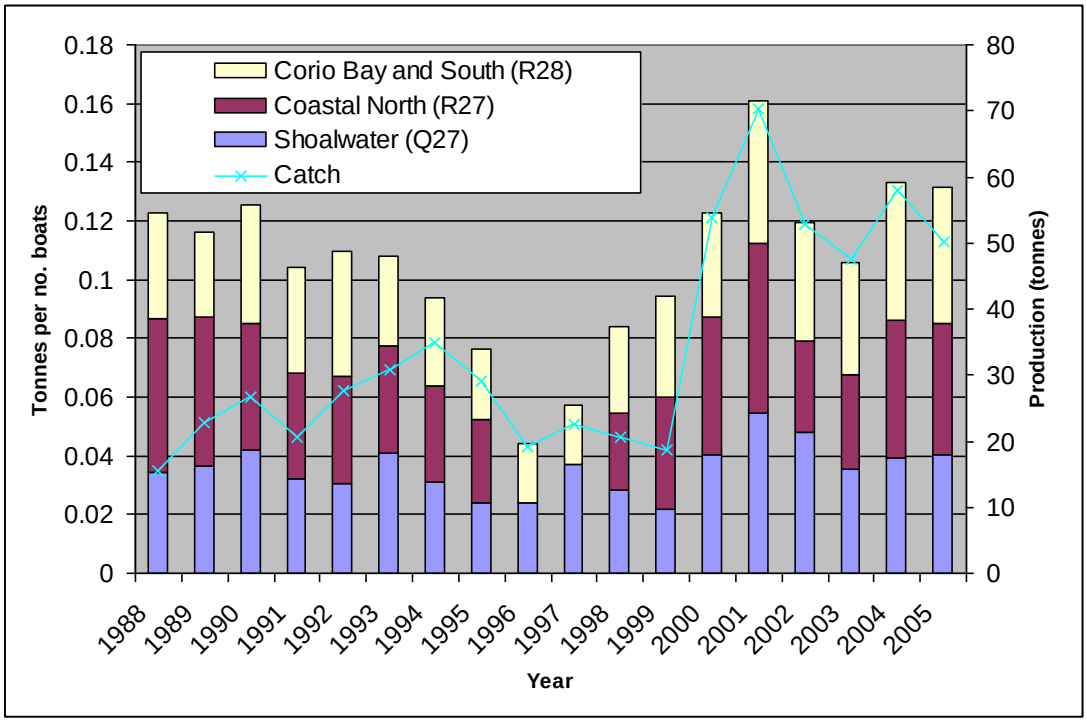


Figure 3-2 Commercial mud crab catches from grids R28, R27 and Q27 expressed as catch per unit effort (tonnes/days fished) and total production for all grids (© Copyright, BMT WBM)

Finfish and prawn production is comparatively lower within the site, most likely due to the remoteness of the site and access restrictions (Fitzsimmons 1996). Despite the low production, as discussed above the site does maintain high fish habitat values for these species, and likely contributes to commercial production elsewhere.

The natural variability of key nursery habitats is not generally known, but is unlikely to have been influenced by anthropogenic impacts. The extent of seagrass communities did not change markedly between the 1997 and 2007 surveys reported in DoD (2009) but some species distribution changes were detected. Local dieback or stress is likely the result of natural hydrodynamic and sediment transport processes or coastal storm events.

Seasonal and inter-annual variability in seagrass percent cover is only available for western Shoalwater Bay. Percent cover of *Zostera* dominated meadows monitored in Ross Creek and at Wheelan's Hut may range inter-annually between 15% and 40% (Source: www.SeagrassWatch.org).

DoD (2009) reports that the mangrove communities of the Shoalwater Bay section of the site have not been grossly modified and remain in excellent condition - as do the saltmarsh communities apart from localised damage caused by feral pigs.

3.2.9 Scientific Research

Photos: Water quality sampling (© Copyright, DoD and GHD).

9: Supports a range of pristine/near natural wetland environments that are important for scientific research and assessing the future impacts of climate change.

As demonstrated by this ECD, the Ramsar site provides a wide range of situations and habitats that present opportunities for research activities. In particular, the pristine/near-natural nature of wetlands within the Ramsar site makes it an ideal 'reference' or 'benchmark' location for scientific research. Furthermore, the coastal location of the Ramsar site renders it vulnerable to the future impacts of climate change (e.g. sea level rise, increases in storm intensity and frequency), thereby providing a stable system to assess climate change impacts.

A range of scientific research has been conducted within the Shoalwater Bay section of the Ramsar site. Many of these studies have been prepared for the DoD and have been reviewed in the context of the State of Environment report (DoD 2009). Major studies that have been undertaken include:

- condition assessments of wetlands and waterbirds (e.g. see WIO 2008)
- landscape monitoring overall several years (e.g. see GHD 2007)

- water quality monitoring over many years
- shorebird surveys (e.g. see O'Neill 1995, O'Neill and Holmes 2000)
- fauna assessments (e.g. see HLA-Envirosciences 2006d, 2007).

Scientific research within the Shoalwater Bay section of the site has also been conducted by/for the GBRMPA, with notable studies including a reef assessment (see Ayling *et al.* 1998), seagrass survey (see Lee Long *et al.* 1997) and previously mentioned work on green turtles (Limpus *et al.* 2005). The Commonwealth Science and Industrial Research Organisation (CSIRO) has had a long-standing interest in the site (e.g. Gunn *et al.* 1972, Grant *et al.* 1979), as have several Universities and Queensland Government departments.

Research and data is also being collected about fisheries by the CapReef community based monitoring programme, for which a number of technical reports have been produced about the fish tag and release program operating in Shoalwater Bay (refer Sawynok and Platten 2009).

Conversely to Shoalwater Bay, limited scientific research has been conducted within Corio Bay. Notable studies include:

- an ecological study of Corio Bay (Habitat, 1974)
- a survey of waders and terns (Houston and Mitchell, 1997)
- a survey of macrofauna and fish (Melzer *et al.* 2007).

However, it is understood that further research assessing the condition of Corio Bay has recently been undertaken by Central Queensland University (currently unpublished). This research will provide an understanding of aquatic fauna, sediments and water chemistry of Corio Bay, forming a baseline for future research and will contribute to development of an ecosystem health monitoring program.

Based on the literature reviewed as part of this study, the Ramsar site is seen as a critically important site for expanding scientific knowledge. In particular, a number of knowledge gaps that require scientific research have been identified for each of the critical services above. Furthermore, baseline monitoring studies are an important component of future scientific research in order to ensure that the values of the Ramsar site do not become degraded over time.

3.2.10 Water Supply

10: The Ramsar site provides a significant regional asset in terms of water supply to the Capricorn Coast and will provide a strategic reserve for freshwater in the future.

Water Park Creek is a source of water supply for Yeppoon and other coastal communities of the Capricorn Coast. The upper catchment of Water Park Creek is located within the Shoalwater Bay section of the Ramsar site, and the downstream reaches and mouth are located within the Corio Bay section.

As a source of supply, the catchment of Water Park Creek has met the needs of the Capricorn Coast for some 35 years. An existing weir is situated on Water Park Creek (outside of the boundaries of the

Ramsar site) to supply the Capricorn region. During dry periods, water extraction continues even if no base flow passes over the weir.

The water supply values of the Capricorn coast which originate from the catchment and dune fields contained within the Ramsar site were recognised as a critical regional asset in the Commonwealth Commission of Inquiry and a key justification for the decision that sand mining of the site should not be a permissible future use of the area. In particular, the Commission noted that any land use within the catchment which reduced the quantity of water supply would place a strategic and financial burden on the local Council and the ratepayers therein; including the financial implications and uncertainty of finding an alternative source to augment existing supply infrastructure (Commonwealth of Australia 1994).

Water for defence use is only extracted from surface waterbodies within SWBTA. Water extraction is currently limited by treatment plant capacity at Samuel Hill and Camp Growl which is around 90,000 L per day. This is suspended in the event that low flow is evident and levels are dropping, in which case all water is imported (this has happened on a number of occasions at Camp Growl) (C. Bell pers. com. 2009). Specifically within the Ramsar site, water is extracted from Sandy Creek for use at Samuel Hill Camp, including provision of cooking and ablution facilities. Specific environmental guidelines apply to water extraction that occurs during special use periods such as large scale training activities (DoD 2009).

In response to concerns about domestic water security in the region, plans for an additional weir in Sandy Creek (which flows into Water Park Creek) were proposed by the then Livingstone Shire Council and referred to the Department of Environment and Heritage in 2004 under the EPBC Act. The proposal was deemed not to be a controlled action by the Department on the basis that it would not have a significant impact on the Corio Bay Ramsar site (Cardno 2005 and referral documents sourced from www.environment.gov.au). As part of this process, the DEH determined that the construction of the weir and a minimum passing flow of 50 L/s will not have a significant impact upon any downstream matters of national environmental significance (i.e. Ramsar wetlands of Corio Bay).

3.2.11 Wilderness



Photos: Townshend Island, Dismal Swamp and Raynham Island (© Copyright, DoD).

11: The Ramsar site and its values are part of a broader 'wilderness area'. There is a strong regional, State and national community attitude supporting conservation of the wilderness values of the site.

As outlined in DoD (2009), wilderness can be defined as 'a large area, free from human interference, remaining in a natural state, remote from impacts of development and landscape modification'. In this context, the Ramsar site is part of a broader, unmodified landscape that comprises a wilderness area.

Such wilderness areas are unique along the eastern coast of Australia, predominantly due to development pressures in coastal locations.

This service primarily relates to the 'vicarious use' or existence value of the site, i.e. the reassurance gained from simply knowing that a large and diverse natural tract of land exists, within which ecosystem processes are allowed to occur naturally and a safe haven for flora and fauna is provided.

The Commission of Inquiry (Commonwealth of Australia 1994) highlighted the benefits to society provided by the site. The site has highly significant conservation values due to it's large size, remoteness from settlements and access points, the absence of permanent structures from significant parts, and the generally very low levels of disturbance except for highly use areas by Defence (Commonwealth of Australia 1994).

The strong regional, State and national community attitude towards supporting conservation of the wilderness value of the area is demonstrated by the long-standing public interest in the fate of SWBTA. For example, there was public outcry in 1992 in response to a proposal to undertake sand mining within the site (e.g. see Foal and Mason 1992). Community attitude is also evidenced by individuals who responded to a survey on recreational usage of Shoalwater Bay and adjacent waters who expressed concern with regards to the need to protect the area's wilderness quality (see Jennings 1998).

In 2008, the Minister for the Environment, the Honourable Peter Garrett MP, rejected a proposal by Waratah Coal Incorporated to establish a rail line and coal port in SWBTA under the EPBC Act. A key reason stated for the decision was the values of the Ramsar site and the 'high wilderness value' of Shoalwater as acknowledged in its Commonwealth Heritage listing (Peter Garrett, Media Release 2008).

While less prominent at a state or national scale, Corio Bay holds similar wilderness attributes, due to its location, environmental quality and access limitations. While the presence of the Capricorn Tourist Resort to the south of Corio Bay introduces a level of urban development not present in Shoalwater, the waters and foreshores of the Bay and its tributaries remain undeveloped and are exposed to generally low use recreational activities such as boating and recreational fishing which present a wilderness experience that is highly valued by local communities. Note however that areas of Corio Bay are under tremendous pressure from inappropriate vehicle use (refer Section 4.3).

Into the future, it is also noteworthy that the vicarious use value of the Ramsar site is likely to increase greatly in value over time as natural coastal areas elsewhere continue to become fragmented and scarce.

3.3 Description of Critical Ecosystem Components

As outlined in Section 2, a range of wetland habitat types are known to be present within the site boundaries including those designated within the coastal/marine and inland wetland categories under the Ramsar classification scheme. Within these systems, a rich diversity of wildlife exists from all the major groups of organisms (from planktonic organisms to vertebrates) which make up the ecosystem components of the wetland.

'Critical' ecosystem components of the site have been selected on the basis of those habitats, key species and wildlife populations that underpin the critical services/benefits. Thus, they include broadly,

the 18 natural wetland habitat types contained within the site, the populations of wetland species of national/international conservation significance, wetland-dependent vegetation communities within these habitat types that support the high biodiversity values of the site and populations of those wildlife groups that underpin Ramsar listing namely, waterbirds and fisheries (including both finfish and crustaceans). A short description of each of these critical components is provided below, noting information about these components has already been discussed in the context of the wetland types (section 2) and critical services (section 3.2) and the intent below is to reduce duplication where possible.

Wetland Habitats

While all wetland habitat types represented in the site are considered critical components, the following are of specific relevance in the context of the critical services/benefits:

- **seagrass meadows** – a near-natural, representative habitat type in the drainage division (Service 1); primary feeding habitat for abundant populations of dugong and turtles (Service 3); part of a mosaic of habitats that support site biodiversity values (Service 4); and support a diversity of fish species and outstanding nursery habitat for fish of recreational and commercial significance (Services 7, 8).

  Approximately 13,000 ha of seagrass were mapped in September 1995 and again in April 1996 (Lee Long *et al*. 1996), in the site within 13 months after date of Ramsar listing. Eight species (from 3 families) and 12 major community types were identified. This is a high number of species and community types for a single section of the Shoalwater Coast bioregion and southern Great Barrier Reef region.

  Seagrasses are abundant in Shoalwater Bay, Canoe Passage, Strong Tide Passage, Island Head Creek, and Port Clinton within the SWBTA. They are most abundant and extensive on intertidal flats, with very limited distribution in channels and sub-tidal areas, due to the high velocity tidal currents and associated high water turbidity. Historical surveys have located a small amount of seagrass habitat in Corio Bay but in very low densities.

  Seagrass habitat extent generally varies less than biomass, however for both of these measures seasonal variability is usually much greater than inter-annual variability. Seagrass biomass in Queensland is usually highest in late spring-summer and lowest in winter (Coles *et al*. 2007).

- **mangroves, saltmarsh and intertidal flats** – a near-natural, representative habitat type in the Drainage Division (Service 1); habitat for the water mouse (Service 3); part of a mosaic of habitats that support site biodiversity values (Service 4); support abundance and important life history functions of waterbirds (Services 5, 6) and support a diversity of fish species and outstanding nursery habitat for fish of recreational and commercial significance (Services 7, 8).

- **rocky reefs with coral communities** – a near-natural, representative habitat type in the drainage division (Service 1); part of a mosaic of habitats that support site biodiversity values (Service 4); and support a diversity of fishes and outstanding nursery habitat for fish of recreational and commercial significance (Services 7, 8).

- **sandy shorelines** – a near-natural, representative habitat type in the drainage division (Service 1); part of a mosaic of habitats that support site biodiversity values (Service 4); support abundance and important life history functions of waterbirds and nesting for flatback turtles (Services 5, 6).

- **peat swamps and other freshwater wetlands** – a near-natural, representative habitat type in the drainage division (Service 1); a rare and unusual wetland type in the drainage division (Service 2); habitat for population of honey blue-eye and possibly the painted snipe, Australasian bittern, and Oxleyan pygmy perch (Service 3); part of a mosaic of habitats that support site biodiversity values (Service 4); support abundance and important life history functions of waterbirds (Services 5, 6); support the supply of freshwater to the Capricorn Coast (Service 10).

In addition to the above, it is considered that all wetland habitats types support or contribute to Service 1 (representative habitat types), Service 9 (scientific research) and Service 11 (wilderness values).

Populations of wetland-dependent fauna and flora species of national or international conservation significance

As discussed in the critical services section above, a number of plant and animal species that inhabit the site form critical components on the basis of their national/international conservation significance. These species have already been discussed in the context of Critical Service 2.

Wetland vegetation communities reliant on the site for conservation security

A remarkably high biodiversity is supported by the Ramsar site, afforded by the geomorphic diversity, the location that overlaps tropical and temperature regions and two bioregions, and the marked rainfall gradient from east to west. The vegetation communities within these habitats comprise a significant representation of a number of pristine vegetation types that were previously widespread in southern Queensland (Department of Environment 1996). Further discussion about these vegetation communities is contained in Service 4.

Populations of migratory and resident waterbirds

The Ramsar site supports an abundance of waterbirds, providing important feeding, roosting and breeding habitat for approximately 77 waterbird species. The critical life stages for these species supported by the site are outlined in the context of Service 5, while abundance of particular species and groups is discussed in the context of Service 6.

Populations of fish and invertebrates that are of recreational and commercial significance

As identified in Services 7 and 8, the site supports significant fish and marine invertebrate diversity and outstanding nursery habitat values. Species of recreational and commercial significance in the region include mud crabs, banana prawns, barramundi, pikey bream, yellowfin bream, goldspotted cod, barred javelin, mangrove jack, golden snapper, blue threadfin, and king threadfin (based on Captag data results and as reported in DoD 2009).

In addition to the juvenile populations of some species as expected within key nursery habitats, a large proportion of pelagic fish such as barramundi that were sampled and tagged within the waters of Shoalwater Bay by Captag were adult fish above the legal size limit, likely attracted to the area as a feeding habitat.

3.4 Description of Wetland Ecosystem Processes

Given the scope, areal extent and diversity of wetland environments present within the Shoalwater and Corio Bays Area Ramsar site, all of the generic wetland ecosystem processes listed within the National Framework were seen as occurring within the site, including a broad range of hydrological, climatic, geomorphologic, physico-chemical, biogeochemical and biological processes. It is noted that while each of these processes play a part in underpinning normal wetland functioning, many of these factors such as coastal hydrodynamics and climate operate at both regional and local scales.

The subset of critical ecosystem processes shown in Table 3-1 (and discussed below) have been selected on the basis of their importance in underpinning the critical services/benefits and in considering the wetland habitat and noteworthy flora and fauna that make up the critical components. Not all ecosystem processes will be relevant across all waterbodies/wetlands of the site, noting the diversity of habitat types and the natural variability of the site which affects key parameters such as freshwater flows, salinity and nutrient enrichment. Ecosystem processes can also be highly interlinked such as, for example, the relationship between increased rainfall, hydrological processes and the resultant runoff affecting water quality. A short discussion of each critical process is included below.

3.4.1 Climate

Key climatic processes that underpin the wetland values of the Shoalwater and Corio Bays Area Ramsar site include temperature, rainfall, and evaporation.

The Ramsar site is located in a region with a sub-tropical climate dominated by summer rainfall. Coastal influences militate against extreme temperatures which range from a mean monthly maximum of 32 Cº in January to a mean monthly minimum of 10.5 Cº in July.

Winter and early Spring are the driest periods of the year and are dominated by south-westerly and westerly winds (as opposed to the prevailing southeast and northeast winds of Summer). Mean relative humidity for the year is about 70%, being highest in the Autumn and lowest in Spring.

Annual average rainfall varies considerably from year to year largely through the influence of the El Nino Southern Oscillation effect, but has been cited by various sources as being between 1300 - 1700 mm per year. Summer rainfall is heavily dependent on cyclonic activity that typically occurs from January to March. Approximately half of the annual rainfall occurs during these first three months of the year, which has a dramatic impact on the surface water hydrology of the site and groundwater recharge.

Within SWBTA site there is generally greater rainfall in the eastern (coastal) sector of the Area compared to the western and southern inland areas as a result of orographic effects of the topography (Commonwealth of Australia 1993, DoD 2009).

Potential evaporation is highest in summer in response to higher temperatures. Summer rainfall is usually less than the potential evaporation such that soil surface layers dry rapidly after summer rains. Soils are driest in autumn and winter months noting some soils in the region can become waterlogged for long periods following heavy summer rain periods.

As climate changes, the climate of Central Queensland is expected to become warmer, water availability is expected to be reduced and extreme storm events are likely to increase in frequency (DoD 2009). In terms of water inflows and wetlands, a significant implication of climate change is that while large flow events will continue, the frequency of flooding, flows and duration of inundation are likely to be reduced (as a result of shorter wet seasons and less rainfall). Further discussion about potential threats to the Ramsar site from climate change are discussed in Section 4 of this report.

3.4.2 Geology and Geomorphology

3.4.2.1 Geomorphological Setting

The major landforms of SWBTA are mountains and hills (associated with the Normanby, Polygon, Coast and Peninsula Ranges), low hills and rises, alluvial plains and fans, mudflats and beaches and coastal sand dunes (Commonwealth of Australia 1993). Geological units (mapped in DoD 2009) show igneous (volcanic activity and migration of granites), sedimentary (sea level rise, aeolian, and fluvial processes) and metamorphic geologic processes have occurred on the site forming its unique diversity of landforms.

Accordingly, surface geological materials in SWBTA are diverse but principally relate to either weathered in-situ rock (bedrock) or material that has been transported from its original position and deposited elsewhere in the landscape through wind, wave and other coastal processes such as the mobile sand dunes.

Physical processes such as wave action, current transport and the prevailing winds have been particularly important in shaping the surficial geology of the Shoalwater Bay area. These processes are well described in DoD (2009), such that the sections below place emphasis on those coastal areas within SWBTA that is within the boundaries of the Ramsar site. Description of the geology and geomorphology of Corio Bay are taken from Habitat (1974) and other sources.

3.4.2.2 Landforms, Sediments and Soils

Beach and Terrestrial Sediment Characteristics - SWBTA

In the Shoalwater Bay section of the site, beach sediments along the eastern seaboard from Island Head southward are almost entirely influenced by coastal sediment transport processes, with rivers supplying almost no sediment to the coastline. These beaches have medium to fine sand that is subject to minor erosion and local blow outs. The beaches are typically of Holocene age, backed by a foredune formed by trapping by vegetation of sand that is being eroded by wind from the exposed beach. A notable exception to this is the Clinton Lowland area within Port Clinton which represents an older Pleistocene beach complex formed from seaward moving or prograding barrier ridges.

The transgressive dunes of Townshend Island, the Mount Gibralter-Pearl Bay region of SWBTA, the Freshwater Bay region and the sand mass located seaward of Dismal Swamp are dominated by dunes that are now largely inactive and stabilised by vegetation. These dunes contain mostly well sorted fine to medium sands but also significant quantities of other materials such as rock fragments, heavy minerals and some clay. The sand dunes of SWBTA are highly significant in a national context as excellent examples of parabolic and parallel dune formations that are in an unmodified condition (DoD 2009).

As outlined in the overview of wetland types, numerous sinkholes of various sizes occur in the Dismal Sector and associated dunal areas of SWBTA. Although their underlying geological structure is unknown, they are likely to be sand-filled depressions caused by rainwater and groundwater removing soluble minerals from the underlying rock (Commonwealth of Australia 1993, DoD 2009). Sinkholes such as those in the site are rare features in Australia, noting similar features in the Cape York region are different in that they occur in low elevation, low-relief beach ridges. The larger sinkholes in SWBTA have permanent freshwater springs and support rainforest vegetation communities often dominated by emergent piccabeen palms *Archontophoenix cunninghamiana*, noting that even the smaller sinkholes can also support denser vegetation than surrounding areas (DoD 2009).

Terrestrial soils in SWBTA are mostly infertile with low nutrients and are unstructured with clay sub-soils that are often saline and impervious to water. The large particle size and poor structure of surface soils (with high sand content) and vegetated nature of the site limits natural soil erosion processes but the subsoils are highly erodible especially due to their high salinity content.

Soils in the eastern sectors of SWBTA (e.g. within the boundaries of the Ramsar site) are wetter due to higher rainfall (see climate section) and have both sandy loams over heavy clays and podzols on the older sand dunes. Sand dune areas are an exception to this general rule, with podzols unable to form because of active re-working.

As already discussed, the sand dunes also contain the numerous freshwater wetlands of the site on soils that vary from sand with high organic matter to peat layers over one metre thick. Well-developed peat deposits are found in Dismal Swamp, Freshwater Swamp, Clinton Lowlands and Townshend Island (DoD 2009, Jaensch 2008b).

Acid sulphate soils occur in coastal parts of SWBTA similar to other coastal areas of Queensland. Testing has occurred on the site at 12 locations with natural concentrations that exceed the acid sulphate soils action criteria and would require remediation if disturbed.

Marine and Estuarine Sediment Characteristics - SWBTA

Marine sediments found offshore within SWBTA include very fine sand and poorly sorted muddy sand further out. Fine material in the offshore region is derived from the floods of the Fitzroy River which can transport such materials over massive distances.

Estuarine sediments are characteristic of areas such as Shoalwater Bay, Port Clinton and Island Head creek. In Shoalwater Bay, coastal processes form ridges of fine to medium sand that can be up to 10 m higher than the surrounding sea floor. These ridges can extend 1 km wide by 20 km in length, forming long channels oriented northwest-southeast. On the ebb tide, these channels are filled with thick, muddy waters.

A subtidal delta occupies the mouth of Port Clinton, with the seaward part an asymmetric sand bar that is prograding seawards. The delta is composed of fine to medium sand that is migrating from the southern coastal sand dune systems. The sediments within Port Clinton form extensive flat banks to the west and south, incised by deep channels which form South Arm and West Water.

Different to the embayments and inlets, the sedimentary environments within tidal influence of the site tend to be mud dominated systems that are colonised by mangrove and saltmarsh communities.

Hypersaline supratidal flats occur in small areas behind the mangrove swamps and consist of thin laminated mud deposits that are favoured by salt tolerant vegetation and cyanobacterial mats.

Corio Bay Sediment Characteristics

Corio Bay is a shallow estuarine inlet forming the efflux of the streams flowing east from the Coast Range and south from Shoalwater Bay.

The entrances of all creeks into Corio Bay are marked by a series of sand banks and the predominant estuarine sediment is sandy material with low organic context, excepting the mudflats within the well-defined wetland vegetation communities.

Most sediment in Corio Bay is comprised of fine-medium sands and can include coarse sand and gravel areas. Being predominantly sandy, the sediments contain a low organic content except for finer muds which are present in the areas with mangroves and saltmarsh (Melzer *et al.* 2007).

3.4.2.3 Bathymetry

The bathymetry of the Shoalwater Bay section of the site is characterised by naturally deep waters along the eastern coastline. The 10 m depth contour occurs in close proximity (within 1 – 2 km) to the foreshore with even deeper waters (20 m plus) immediately adjacent to Cape Manifold and Cape Clinton.

Within the more protected inlets and embayment's, the large tidal range and hydrodynamic processes define deeper channels (generally about 5 m in depth) amidst shallower shoals and bars many of which are exposed at low tide. The main subtidal channels of the site include Shoalwater Bay and its tributaries (East Creek, Head Creek and Shoalwater Creek), Island Head Creek and Port Clinton (West Water and South Arm).

Corio Bay is also relatively shallow with two or three well defined channels formed by the main watercourses of Fishing Creek, Deep Creek and Water Park Creek. Large areas of sand banks are exposed at low tide as a result of the large tidal range. Unlike Port Clinton, the deeper channels formed within Corio Bay are a product of both tidal and hydrodynamic processes as well as the persistent freshwater flow from Water Park Creek.

3.5 Hydrodynamics and Hydrology

3.5.1 Hydrodynamics and Tidal Inundation Regime

Shoalwater and Corio Bays lie in a region that experiences the highest tidal range on the eastern coastal margin with up to 5-6 metres observed in Port Clinton. The high tidal range is a result of several contributing factors including an offshore break in the Great Barrier Reef which reduces its normal sheltering effect, the convergence of regional tidal systems, and the broad continental shelf of the region that accentuates the effects of bottom interference (Commonwealth of Australia 1993). The local geomorphology also influences tidal processes and velocity as a result of inlets that constrict flow between islands, the funnel shape of bays and the shoal-channel morphology within the embayments.

The effect of the large tidal range produces alternating conditions of strong currents which are able to transport sand and slack water which enables the deposition of finer muds. The tidal processes also

repeatedly flood and expose large areas of coastline leading to the formation of an extensive intertidal zone that is characterised by a succession of ecosystems controlled by the frequency and length of tidal inundation and other related factors such as the degree of exposure and protection from wave action.

The degree of wave energy received along the coastline of the area is dependent on coastal topography, wind direction and fetch. Wave directions are persistently from the southeast during winter, but shift from southeast through northeast between September and December. Oceanic 'swell' waves can impact on the site (in part through the break in the GBR), which is one reason why the more exposed eastern shorelines do not contain mangroves and similar sheltered landforms that exist in Shoalwater Bay, Port Clinton and along the western shorelines of islands in the Ramsar site.

In addition to prevailing winds already discussed in the climate section, tropical cyclones are another source of significant wind and wave activity. Of note, while the average for the Queensland coastal region from Rockhampton to Cooktown is about one cyclone per season, the local average frequency for Shoalwater Bay is far less with an average of 1.5 cyclones per decade. This is likely due to the region being located at the southern extent of the tropical zone (Commonwealth of Australia 1993).

Based on a review of literature, there are no persistent or significant natural erosion or accretion processes occurring along the active coastline of the site.

3.5.2 Freshwater Inflows

In response to the highly variable rainfall patterns discussed in the climate section above, freshwater flows into the Shoalwater and Corio Bays are also highly variable over seasonal and inter-annual time scales.

A Digital Elevation Model (DEM) derived for the Ramsar site and surrounds (refer Figure 3-3) shows this topography; with the majority of freshwater flows derived from this catchment exiting via Shoalwater Bay or the Port Clinton estuary.

The water catchment areas that are relevant to the Ramsar site are shown in Figure 3-4. The two principal catchments are the Great Barrier Reef Marine Park Catchment, and the Water Park Creek Catchment, which drains the Dismal Sector of SWTBA and extends southward through the floodplain that is occupied by the Byfield State Forest and Byfield National Park before being channelised into Water Park Creek and Corio Bay.

In SWBTA, most freshwater creeks are ephemeral, with flows occurring during the summer wet season from December to March. Larger creeks have permanent pools scattered along their length. Creeks draining the coastal side of the ranges tend to have short catchments which flow for short periods after rainfall, whereas western creeks have larger catchments and flow is greater and of longer duration. The catchments within SWBTA are quite heavily vegetated and are not subject to more common land use impacts such as agricultural chemicals and fertilisers or effluent and stormwater discharges from urban centres.

The Corio Bay estuary is dependent on the terrestrial slopes forming its catchment and also groundwater influences which regulate the flow of water into the mangrove and saltmarsh area. Sandy Creek and Water Park Creek within the catchment maintain high levels of base flow throughout the

year due to flow from Dismal Swamp and associated sand dunes. As discussed in the context of Service 10, an existing weir is situated on Water Park Creek (outside of the boundaries of the Ramsar site) to supply the Capricorn region and the associated water supply system. It is understood that currently there is no established minimum flow at the Water Park Creek weir and during dry periods water extraction continues even if no base flow passes over the weir. The continued use of this weir may be subject to future review as it is now understood that water security for the region will be provided by a new water pipeline from the Fitzroy River that is currently under construction.

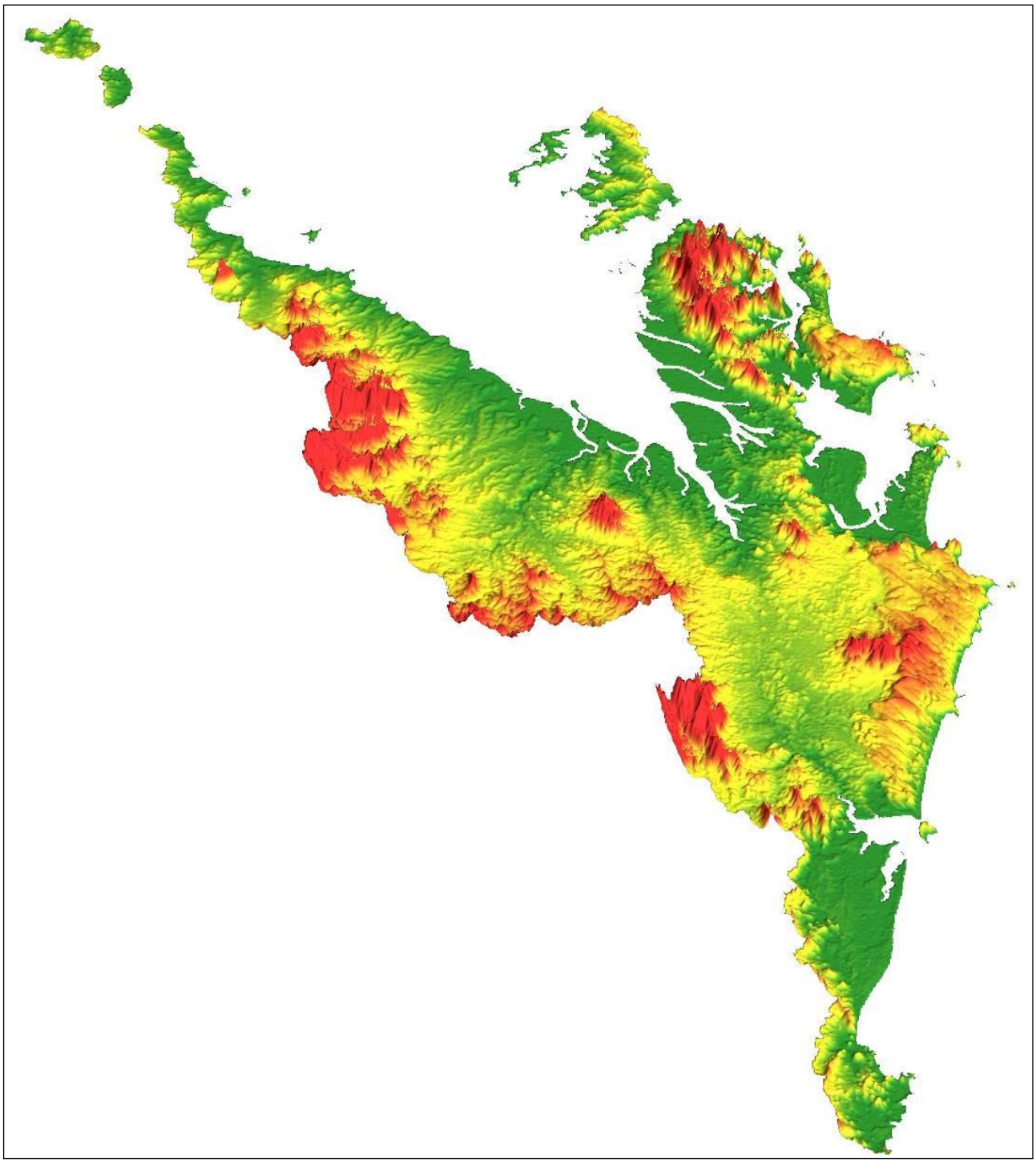


Figure 3-3 Shoalwater Bay Digital Elevation Model (© Copyright, BMT WBM)

Note that the area covered by the DEM in the above figure includes a larger area than the Ramsar site

Areas shown in green are near to MSL while areas shown in yellow and red are progressively greater elevation

Figure 3-4 Water catchments relevant to the Ramsar site (© Copyright BMT WBM)

3.5.3 Groundwater Dynamics

Groundwater dynamics (i.e. the movement of groundwater through the landscape and their possible role in ecosystem interactions) are also a critical process that underpins the wetlands of the Ramsar site.

The groundwater resources of the SWBTA and Corio Bay region are characterised by a mixture of fractured rock and primary porosity aquifers (Commonwealth of Australia, 1993). Most groundwater flow closely follows topography within the catchments shown in Figure 3-4, which are discussed below:

Water Park Creek Catchment

- The Water Park Creek Catchment is separated from the coastal Great Barrier Reef Marine Park Catchment by a distinct parabolic dune system rising to 100-200 m elevation before giving way to the estuary and coastal plain.
- In the dunal area, precipitation will typically percolate through the dune systems raising the local groundwater table.
- Water percolating through the dunes may move laterally to deflation surfaces and sinkholes between the dune ridges to a local groundwater surface creating peat springs and occasional open water in the form of lakes.
- Groundwater table elevation will also 'mound' under the dune systems and deflation surfaces creating a gradient and therefore groundwater movement.
- In the northern portion of the Water Park Creek Catchment (in the SWBTA), this movement is predominantly to the west supplying the peat swamps and other groundwater dependant-wetlands in the Dismal Sector.
- In the southern portion of the Water Park Creek Catchment (outside of the SWBTA), groundwater movement from the dune systems is also to the west and south, feeding the Sandy Creek and Water Park Creek systems.
- The lack of relief across the catchment indicates that surface runoff will largely be attenuated in shallow depressions and swamps and consequently be discharged relatively slowly from the catchment. Thus, groundwater flows both directly from the eastern parabolic dune system and indirectly from the dune-associated wetlands in the SWBTA can be a major contributor to the regularity of inflows into Corio Bay, independent of rainfall and surface runoff.

Shoalwater Bay Catchment

- Within the Shoalwater Bay catchment, short streams and creeks drain from the higher ranges across tidal flats and mangroves. Groundwater within the coastal alluvial sediments discharges into the estuarine and marginal marine areas but is generally less significant than surface flows in these areas. Groundwater flow in this catchment will be characterised by short residence times.

GBR Marine Park Catchment

- This catchment includes the narrow estuary and coastal plains associated with the Island Head Creek system, Port Clinton, and the eastern beach systems of the SWBTA from Cape Manifold to Five Rocks.

- The groundwater drainage systems within this catchment can be characterised by restricted marine drainage or sandy open-sea drainage. Restricted marine drainage is similar to that described above for the Shoalwater Bay catchment.
- The sandy open-sea drainage systems associated with the sand dunes along the eastern coastline contain groundwater aquifers similar to those discussed for the Water Park Creek Catchment section. However, in this catchment, groundwater within these systems will flow eastward to the sea, discharging according to the position of the seawater-freshwater interface within the aquifer. In some case this interface may be sited on the beachfront or at some distance offshore.

The relationship between the various types of freshwater wetlands within the Dismal Sector and Clinton Lowlands and the groundwater and surface water dynamics described above are important issues. In particular the natural percolation of groundwater through the dune system provides a year round supply of groundwater for the larger swamps that are fed by groundwater springs (such as Freshwater Swamp and the larger sinkholes) and higher elevation swamps such as Dismal Swamp which are maintained by an impervious sand layer, rainfall and local runoff.

3.5.4 Water Quality

Shoalwater Bay area

Water quality data has been collected from several sites across SWBTA since 2002 and is documented within DoD (2009). There is a general absence of ambient estuarine or marine water quality data for the site's major waterbodies such as Shoalwater Bay and Port Clinton estuaries such that the resultant water quality of these features must be inferred from adjacent sampling of freshwater/brackish streams and creeks. However, the water quality of these estuarine and marine features based on the predominantly natural catchments that flow into them, the level of usage and ecosystem condition of key indicator habitats such as seagrass are indicative of excellent water quality.

A brief analysis of water quality data supplied as part of the current study and comparison against the regional Queensland Water Quality Guidelines (QWQG) has been undertaken. A summary of this analysis is presented below:

- The 80th percentile, maximum and mean pH values are within the recommended QWQG range.
- Dissolved oxygen levels (% saturation) range from 8.6% to 98.1%. The median and 80th percentile values are less than the lower guideline value of 85% saturation.
- Mean electrical conductivity values range from <80 to 480 µS/cm. Values above the recommended guideline value of 375 µS/cm were recorded at sites which have naturally high salinity.
- Turbidity values range from 1 to 178 NTU. The median turbidity value of 9 NTU is less than the QWQG value of 50 NTU.
- Total nitrogen concentrations range from <0.1 mg/L to 2.3 mg/L. The median, 20th and 80th percentile concentrations all exceed the QWQG guideline value of 0.50 mg/L.
- The median and maximum total phosphorous concentrations exceed the QWQG guideline value of 0.05 mg/L.
- Chlorophyll-a concentrations range from 0.001 µg/L to 12 µg/L. The 80th percentile and maximum concentrations exceed the guideline value or 5 µg/L.

While some exceedances of guideline values (particularly for nutrients) have been recorded in the above, these are considered to be well within the bounds of natural variability with natural high levels of organic nitrogen and phosphorus derived from the breakdown of plant material in streams and lagoons (P. O'Neill, pers. comm. 2009).

The trends in the analysis above also conforms with water quality monitoring results shown in Table 5.2 of the State of the Environment Report (DoD 2009), noting that the analysis in the State of the Environment Report includes a much broader range of sampling sites across the site.

The lack of information regarding the water quality of the site's freshwater swamps is an information gap that will be discussed later in this ECD report. It is noteworthy however, that such wetlands (based on similar freshwater environments in Queensland such as peat swamps on North Stradbroke Island and perched lakes on Fraser Island) would likely be naturally acidic in nature (e.g. low pH), with high dissolved oxygen levels, low turbidity and relatively stable water levels characteristic of wallum habitats.

Corio Bays Area

Water quality data has also been collected by the Queensland Environmental Protection Agency (EPA) in Water Park Creek including in the downstream reaches of the creek near Corio Bay.

Water Park Creek (near its confluence with Corio Bay)

- Median dissolved oxygen levels (% saturation) are within the recommended guideline range of 85-110% saturation. The maximum recorded level is greater than the 110% saturation upper value.
- The median and maximum turbidity levels for Corio Bay are less than the guideline value of 50 NTU.
- The minimum and maximum Secchi depths recorded in Corio Bay were 0.3m and 4.2m respectively. The median Secchi depth for Corio Bay is 1.6m.
- Concentrations of total nitrogen are all less than the QWQG of 0.5 mg/L. The median total nitrogen concentration is 0.15 mg/L.
- Total phosphorous concentrations within Corio Bay range from 0.003 mg/L to 0.038 mg/L. The median concentration is 0.011 mg/L. All recorded concentrations are compliant with the QWQG value of 0.05 mg/L.
- The maximum recorded concentration of chlorophyll-a exceeds the QWQG value of 5 µg/L. The median value of 1.3µg/L is compliant with this value.

In addition to the above, Mary-Anne Jones (Central Queensland University) undertook water quality sampling in the estuarine sections of Corio Bay as part of her PhD project (information supplied as personal comments to the authors, 2009). This sampling was undertaken quarterly between August 2006 and May 2008 (inclusive), and observed the following key points:

- Corio Bay displayed features of a "typical Australian estuary", with salinity increasing seaward - a pattern arising from freshwater input and in this case from surface water flows of Water Park Creek and one which was only occasionally observed in other study estuaries of the Capricorn Coast during this time.
- Salinities of Corio Bay in the *El nino* year of 2006/07 reached up to 40 PSU towards the mouth, whereas in the *La nina* year of 2007/08 salinities down to 23 PSU were recorded – associated with

Keppel Bay waters that were affected by flooding of the adjacent Fitzroy River and also local catchment run off.

- Although tide-dominated, water clarity of Corio Bay was high near the mouth. However, no seagrasses were observed.
- Dissolved oxygen levels were above 100 % saturation and pH around 8 in depth profiles of the water column conducted in all surveys.
- Total nitrogen concentrations of samples (n = 16) increased twofold in the wet season months (Nov and Feb) of the *La nina* year compared to other times, although all samples were below 0.3 mg L^{-1}.
- Additionally, total phosphorus concentrations of samples (n = 16) showed a slight increase in February of the *La Nina* year, but again all samples were below 0.25 mg/L.
- Agricultural chemicals were examined once in the wet season of each year - both times were <LOD.
- DIN concentrations of samples (n = 16) were low in Corio Bay compared to other estuaries of the Capricorn Coast.

3.5.5 Noteworthy Biological Processes

Biological processes describe any process occurring within, or by, an organism. As such, these processes can operate at the genetic, cellular, individual, population, community or ecosystem levels. There is a vast range of biological processes that, together with physical (abiotic) processes described above, are critical to the maintenance of wetland ecosystem functioning. The following is a brief overview of some of the key biological processes operating at a whole of site scale for the Shoalwater and Corio Bays Area Ramsar site.

Energy and Nutrient Dynamics

As vegetative and animal matter begins to senesce and die, microbes invade the tissues and transform the organic material into more bio-available forms of carbon and other nutrients. While microalgae, mangroves and seagrasses are mainly responsible for primary productivity within estuarine and marine waters of the site, microbial breakdown is a key pathway for plant material entering the food-web in these ecosystems (Alongi 1990). This is especially true for marine, estuarine and freshwater macrophytes (seagrass, mangroves, saltmarshes, freshwater marshes), which with few notable exceptions (e.g. some invertebrates, fish and birds) are generally not directly grazed, but instead enter food-webs following microbial conversion of organic matter (Day *et al.* 1989). Carbon flows in freshwater wetlands are not well known and require further investigation, although freshwater marshes and peat swamps are recognised as important sinks for carbon as they actively accumulate organic matter.

In the context of energy flows through the ecosystem, some energy is lost during microbial respiration, some is leached as dissolved organic matter into the water, some is incorporated into microbial biomass, and some may be transformed to other organic compounds not incorporated in microbial cells. Of particular importance to higher trophic levels (i.e. consumers) is the conversion of detrital material into bacterial biomass, which is then in a bio-available form for animals (Day *et al.* 1989).

Microbes also affect energy flow by using dissolved organic matter, which is largely unavailable to other estuarine community components (Day 1967; Nybakken 1982; Day *et al.* 1989).

Primary Productivity and Food Webs

The main primary producers within the site include phytoplankton, benthic microalgae (microphytobenthos), seagrass, mangroves, saltmarshes, and transitional habitats such as *Melaleuca* forest. The relative contribution of each of these components to total primary productivity will vary from place to place and across a range of spatial (and possibly temporal) scales. Case studies elsewhere demonstrate that seagrass, mangroves and saltmarshes represent particularly productive communities (on a 'productivity per unit area' basis).

Grazing of phytoplankton by zooplankton is likely to represent an important link in the chain of nutrient flux and energy flow in the marine and estuarine waters of the site. Furthermore, the planktonic phase forms part of the life-cycle of most benthic and marine demersal fauna (meroplankton), including most species of direct fisheries significance. Little is known about the relationships between nutrient levels, phytoplankton dynamics and zooplankton composition, grazing and production within the wetland.

The direct consumption of macrophytes by grazers also represents a pathway for energy flow through the ecosystem. Macrophytes generally form a direct food source for only a limited number of species, including sea urchins, some amphipods, gastropod snails, some fish species (e.g. garfish, luderick and leatherjackets), together with black swan, ducks and geese. From an energy flow perspective, perhaps the most important linkage between macrophytes and higher trophic levels is through the decomposition of dead plant material by bacteria and fungi (see discussion on nutrient cycling above). This is likely to be particularly the case in detritus-based foodwebs that characterise saltmarsh and freshwater wetland systems.

On the sea floor of estuarine and marine waters, bioturbation can be critical to the structural organisation of soft sediment communities. The main bioturbators include polychaete worms, burrowing crabs (particularly in mangroves) and other crustaceans (e.g. ghost nippers), rays and fish. In particular, bioturbation results in the mixing of sediment layers. This mixing assists in the oxygenation of the sediment, increases rates of organic decomposition, and affects nutrient cycling processes (Day *et al.* 1989). Bioturbation has a strong influence on many aspects of benthic ecology including:

- physical properties of sediments
- sediment-water biogeochemical processes, including nutrient cycling
- seagrass productivity
- mangrove ecosystem functioning
- benthic fauna community interactions, including predation, competition etc.

Biological Interactions (competition, predation, biotic-habitat disturbance)

Competition, predation and disturbance all have an influence on freshwater and estuarine/marine community functioning. The influence of these processes on communities can vary across a range of spatial and temporal scales. In general terms, the following key fauna interactions are thought to be important in regulating community structure and ecosystem processes:

- Benthic macroinvertebrates - Numerous studies have examined the roles of competition, predation, larval supply, food supply and disturbance in structure in soft-sediment benthic macroinvertebrate communities. Like estuarine fish communities, it is unlikely that any single factor controls patterns in community structure, rather, the relative importance of density-dependent and density-independent controls is expected to vary across a range of temporal and spatial scales (Seitz 1998).
- Marine and estuarine fish - While there is a large body of work examining population controls and processes for reef fish (Hixon 1998; Levin 1998), with few exceptions there is comparatively little information describing the ultimate population controls for estuarine and coastal fish species. It is likely that density-dependent controls (e.g. competition for food and space) and density-independent factors (e.g. disturbance) both exert an influence of fish communities, with the relative importance of these processes varying across multiple spatial and temporal scales. These factors may operate both within and external to the Ramsar site.
- Waterbirds – The availability of food sources will affect the frequency and intensity of use of Shoalwater and Corio Bays as a feeding habitat by waterbirds, noting a broad range of feeding techniques are used by the array of waterbirds that use the site. These feeding adaptations range from shorebirds feeding on macroinvertebrates in the tidal and lake flats to pelagic fish feeders such as the little tern and raptors.

3.6 Conceptual Models

How the critical ecosystem services, components and processes identified in the preceding section interact are perhaps best shown in conceptual models for the site as shown in Figure 3-5 to Figure 3-9. Five models have been developed based on the key geographic areas of the site and include Shoalwater Bay, the Open Coast (characteristic of the open east coast of the site), Port Clinton, Dismal Swamp and other freshwater habitats, and Corio Bay.

The models include information about the Ramsar wetland types represented in each of these geographical units, identify critical components and values and show critical ecological processes underpinning these values. The models simplify many of the complex ecological attributes and processes occurring in the site, but assist the reader to understand the key attributes of Shoalwater and Corio Bays that most strongly determine their ecological character.

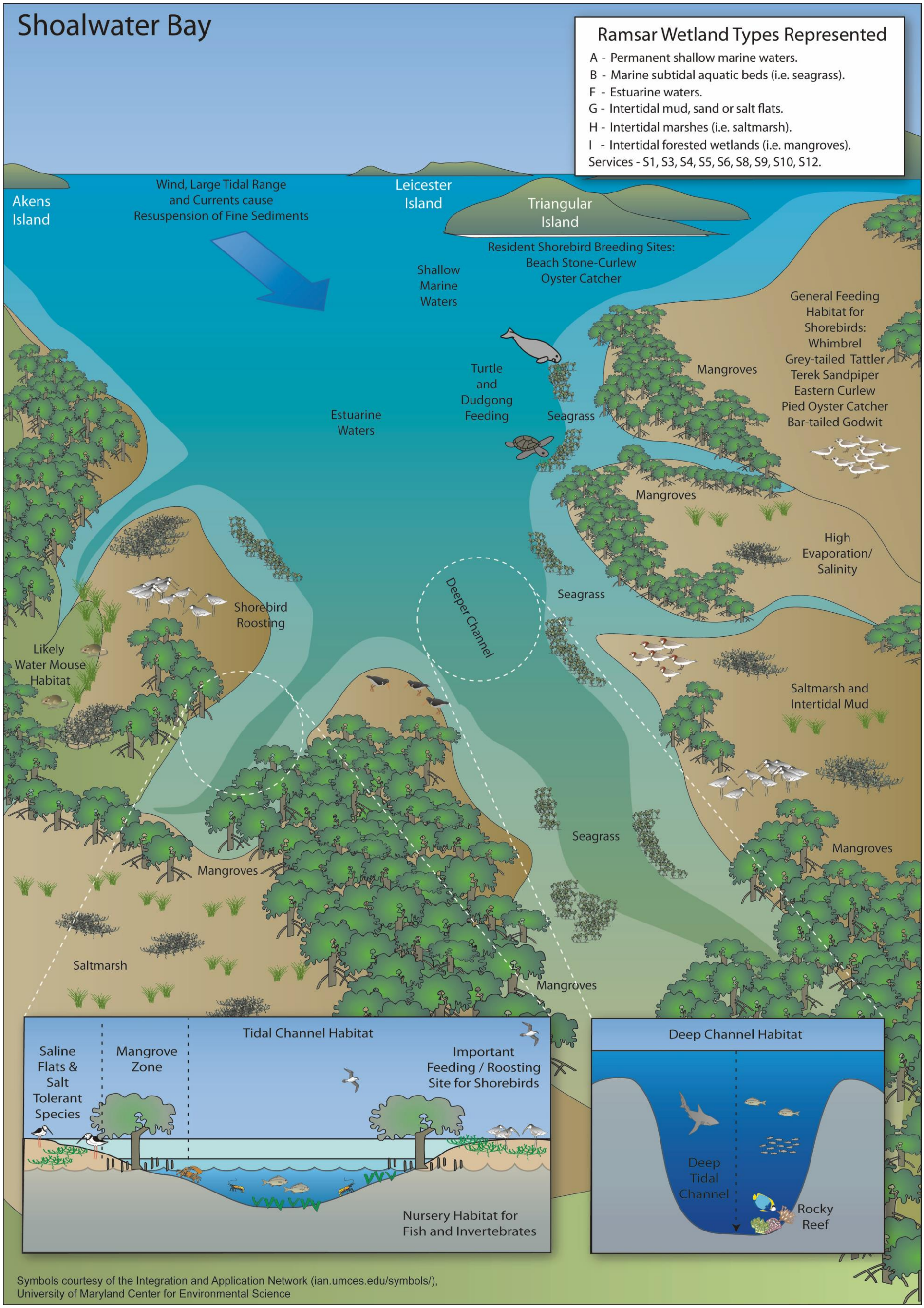


Figure 3-5 Conceptual Model: Shoalwater Bay (© Copyright, BMT WBM)

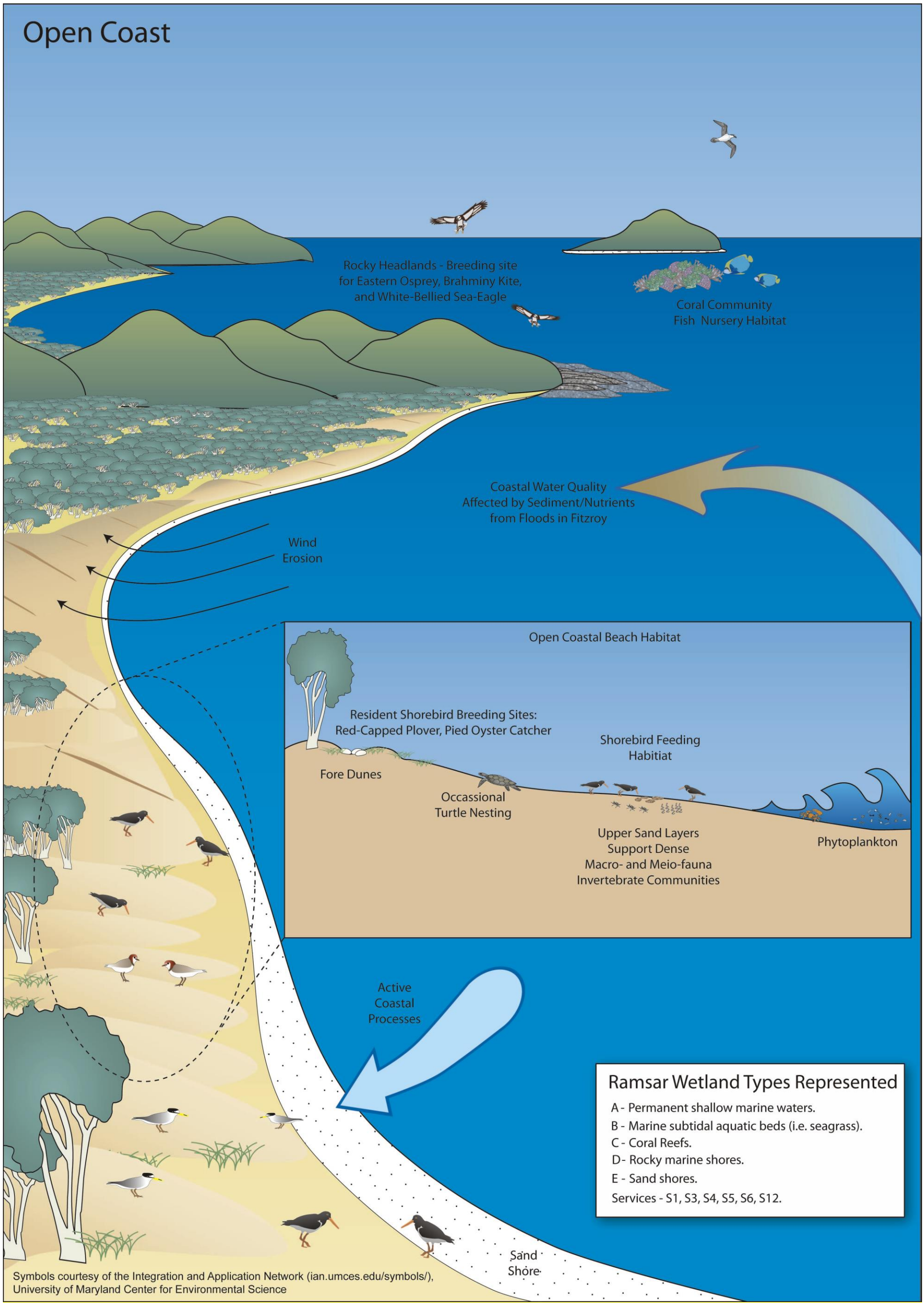


Figure 3-6 Conceptual Model: Open Coast (© Copyright, BMT WBM)

Figure 3-7 Conceptual Model: Port Clinton (© Copyright, BMT WBM)

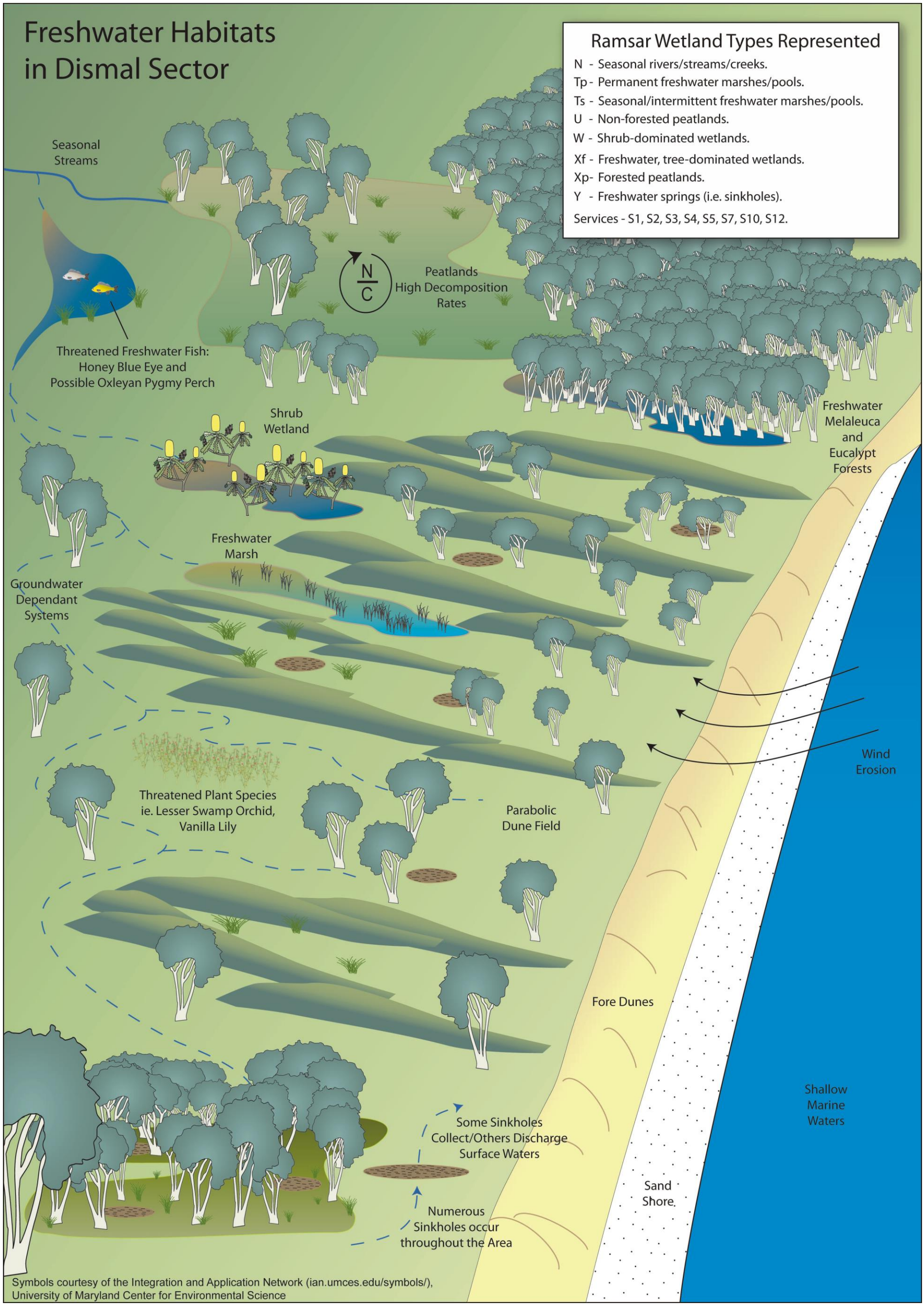


Figure 3-8 Conceptual Model: Dismal Swamp and Freshwater Wetlands (© Copyright, BMT WBM)

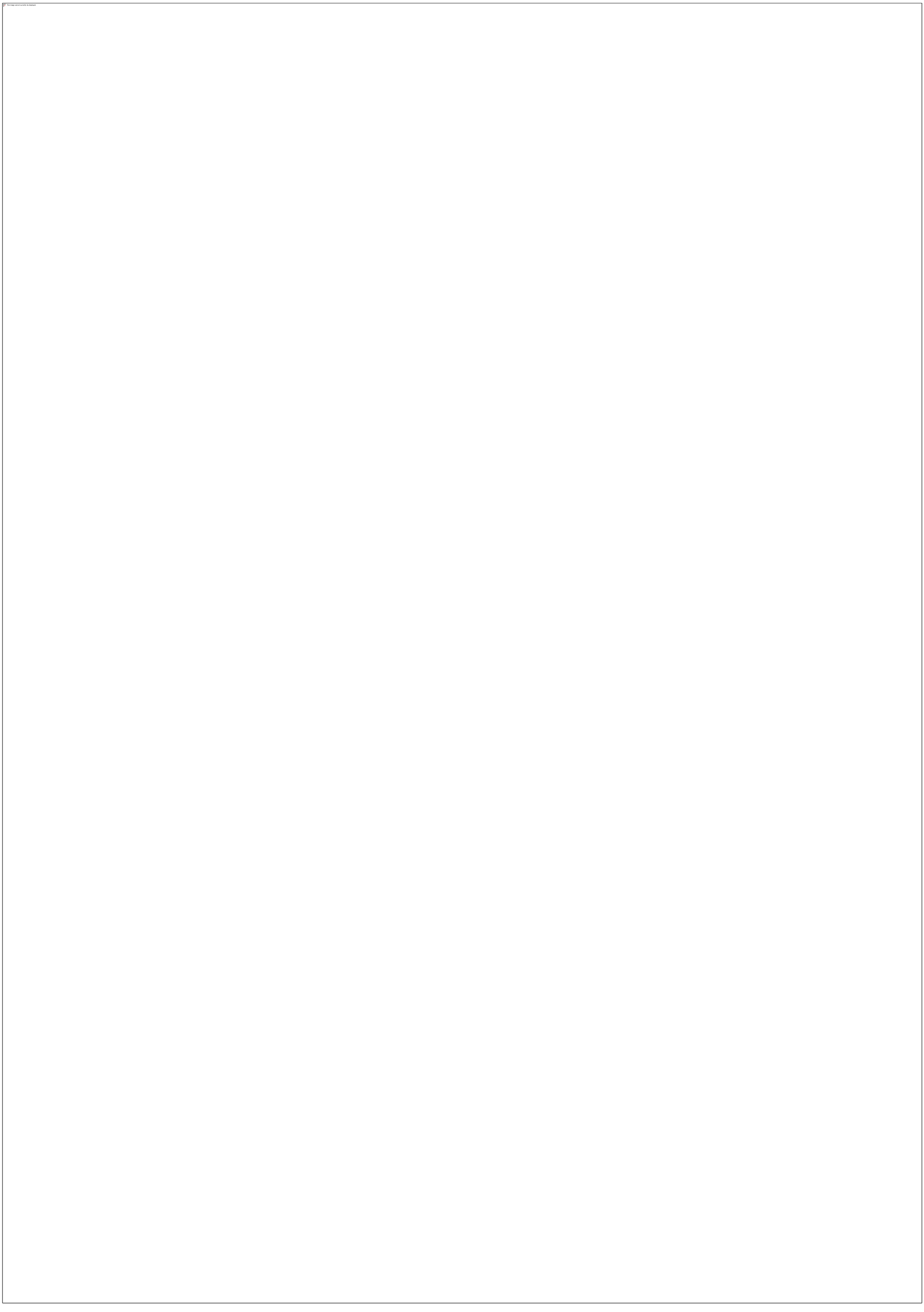


Figure 3-9 Conceptual Model: Corio Bay (© Copyright, BMT WBM)

3.7 Limits of Acceptable Change

A key requirement of the ECD is to define the limits of acceptable change (LACs) for the critical services/benefits, components and processes of the wetland. Limits of acceptable change are defined as, 'the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland' (DEWHA 2008).

LACs and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that LACs should be beyond the levels of natural variation. Setting limits in consideration with natural variability is an important, but complex concept. Wetlands are complex systems and there is both spatial and temporal variability associated with all components and processes. Defining this variability such that trends away from "natural" can be reliably detected is far from straight forward.

Hale and Butcher (2008) considered that it is not sufficient to simply define the extreme measures of a given parameter and to set LACs beyond those extremes. What is required is a method of detecting change in pattern and setting limits that indicate a distinct shift from natural variability (be that positive or negative). This may mean accounting for changes in the frequency and magnitude of extreme events, changes in the temporal or seasonal patterns and changes in spatial variability as well as changes in the mean or median conditions.

It should also be noted that LACs are not synonymous with management values or "trigger levels", and if a LAC is exceeded it does not necessarily indicate a change in ecological character. However, exceeding or not meeting a LAC 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 ECD and to consider LACs for the site, a comprehensive understanding of site character may not be possible as in many cases only limited information and data is available. The LACs 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.

Consistent with the above, the approach taken for the identification of LACs for the Shoalwater and Corio Bays Area Ramsar site has been to provide LACs for critical wetland ecosystem components and processes, where possible, specifically in the context of those wetland species (for example, species of conservation significance), populations (e.g. waterbirds and fish) and habitats (e.g. seagrass, melaleuca brackish swamps, saltmarsh) that underpin the services/benefits.

It should be noted that the LACs for the Shoalwater and Corio Bays Area Ramsar site have been simplified as there remains significant data and knowledge gaps present with respect to the site's critical services, components and processes. As a result, there are high levels of uncertainty associated with deriving the limits and the LACs should be regarded by the site manager and other users of the document as best professional judgement at the time of preparation of this ECD. LACs will be subject to further expert review over time and evaluated as further knowledge and information about the site and its ecological character improves.

It should also be noted that there may be a range of processes occurring outside of the site that could affect the exceedance of a particular LAC, such as for example, the populations of migratory species that use the site. As such, in the future evaluation of LACs it is important to determine if a potential change is attributable to anthropogenic impacts occurring near the site, or further off the site (for example, lack of available breeding habitat for migratory birds in the northern hemisphere) that is largely outside of the control of the site manager.

Users should exercise their own skill and care with respect to their use of the information in this ECD and carefully evaluate the suitability of the information for their own purposes. LACs can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of the information for their own purposes.

3.7.1 Derivation of Limits of Acceptable Change

As outlined in the National Framework, it is most preferable for LACs to be based on the known natural variability (over time) of a parameter. The LAC can then be set at appropriate levels at or exceeding the upper and lower bounds of that natural variability profile. However, in most cases such data are unavailable or incomplete.

3.7.2 Summary of Limits of Acceptable Change

Table 3-3 below lists the critical services/benefits nominated in the ECD (column 1) and the particular attribute of the service relevant to the LAC (column 2).

Table 3-4 outlines the applicable Ramsar criteria (column 1); the critical component, processes and services (column 2); information about the baseline and natural variability of the attribute (column 3); the qualitative and quantitative indicators that are LACs for ecological character (column 4); and the confidence level for that LAC (column 5).

For these tables, the baseline used for assessing the extent and condition of key habitats and populations of notable fauna species and groups are referenced to specific datasets such as previous surveys or studies undertaken in the site either recently or near the time of listing of the site in 1996. In the case of Shoalwater and Corio Bays where such information does not exist, the current (2009) extent or condition of habitats and species populations is considered to be unchanged from the time of listing in 1996 based on the low incidence of anthropogenic impacts and predominantly natural state of the site.

Table 3-3 Critical services/benefits of the Shoalwater and Corio Bays Area Ramsar site

Critical service/benefit	Aspect/attribute of the service
1: The Ramsar site contains marine, estuarine and freshwater landscapes and ecosystems that are representative of the biogeographic region and are rare in the context of a large coastal system that remains in a near natural state with relatively undisturbed catchments.	Habitat extent of representative wetland types
	Habitat condition of representative wetland types
2: The Ramsar site has wetland types (notably the peat swamps in the Dismal Sector and the Clinton Lowlands) that are rare, unusual and noteworthy for the biogeographic region and greater spatial scales.	Extent and condition of peat swamps
3: The Ramsar site supports vulnerable/ endangered wetland species.	The population viability of those threatened species relevant to Criterion 2
4: The habitat diversity contained within the Ramsar site supports outstanding biodiversity values including several notable vegetation communities.	Diversity of wetland types Habitat extent and condition Abundance and diversity of wetland dependent species and populations
5: The site supports several important wetland species during a critical life stage (e.g. breeding, nesting, roosting, feeding, migration and/or refugia).	Maintenance of critical life stage functions
6: Supports substantial numbers of resident and migratory waterbirds	Abundance of migratory waterbirds
	Maintenance of usage of the site by key migratory and resident shorebird species
7: Supports a high diversity of fish species reflecting the diversity of habitats and a biogeographical overlap zone.	Diversity of fish species
8: Supports critical nursery habitat for regional commercial and recreational fisheries.	Populations of key commercial and recreational fishery species
9: Supports a range of pristine/near natural wetland environments that are important for scientific research and assessing the future impacts of climate change.	Relies on the above.
10: The Ramsar site provides a significant regional asset in terms of water supply to the Capricorn Coast and will provide a strategic reserve for freshwater in the future.	Relies on the above.

Critical service/benefit	Aspect/attribute of the service
11: The Ramsar site and its values are part of a broader 'wilderness area'.	Relies on the above.

Table 3-4 Critical components and processes of the Shoalwater and Corio Bays Area Ramsar site - Limits of Acceptable Change

Ramsar criteria	Critical components andprocesses	Baseline/Supporting Evidence	Limit of acceptable change	Confidence
Criteria 1	Wetland habitats (Marine) – Seagrass (Wetland Type A, B, F)	Mapped extent in 1995-1996 (post Ramsar listing) ~13,000 ± 800-890 ha (Lee Long *et al.* 1997). For late spring (seasonal maximum) monitoring, aerial extent is likely to be relatively stable.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Mangroves (Wetland Type F, G, H, I)	While broad-scale mapping of wetland and vegetation community types exists (e.g. RE mapping), there are no data describing the range of natural temporal variability in extent of different vegetation communities and the controls on these changes.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Saltmarsh (Wetland Type G, H, I)	See Wetland habitats (Marine) - Mangroves.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Rocky reef coral communities (Wetland Type C, D)	There is very coarse mapping available for rocky reefs in the site. Broad community structure and species is available but not at a site or community scale. This needs to be updated to form a baseline for the LAC.	Presence of habitat	Moderate
	Wetland habitats (Marine) – Sandy shores (Wetland Type E, G)	Aerial photography could be used to establish a baseline extent for beach and dune features. Literature reviewed indicates that these habitats are fairly stable in the SWTBA area. There is likely a combination and natural and anthropogenic impacts on beaches at Sandy Point in Corio Bay.	Presence of habitat	Moderate
	Wetland habitat (Freshwater) – marshes, Peat swamps (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y)	While broad-scale mapping of wetland and vegetation community types exists (e.g. RE mapping), there are no data describing the range of natural temporal variability in extent of different vegetation communities and the controls on these changes. It should be noted that a mapping layer specifically for the extent of peat swamps has not been derived.	Presence of habitats	Moderate
	Hydrology – freshwater flows (e.g. Waterpark Creek, Peat swamps, saltmarsh) (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y)	Annual volumes (ML) at Water Park Creek gauging station (1957-1996): Range = 24,278 to 429,030; Mean = 156,135.9; Median = 109,157; CoV = 73.6%. There are no available baseline data to determine ranges of natural variability under different flow conditions. Until such time as site specific flow duration curves are developed for each wetland type, no LAC is proposed. Changes in LAC for wetland habitats could be used as surrogate measures for this process.	No direct LAC has been developed and instead the critical process will be assessed indirectly through changes in wetland habitats and threatened species.	
	Hydrology – groundwater dynamics (e.g. Freshwater wetlands, Peat swamps) (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y)	There are no available baseline data to determine ranges of natural variability under different flow conditions. Until such time as site specific flow duration curves are developed for each wetland type, no LAC is proposed. Changes in LAC for wetland habitats could be used as surrogate measures for this process.	No direct LAC has been developed and instead the critical process will be assessed indirectly through changes in wetland habitats and threatened species.	
Criteria 2	Threatened species – water mouse	There is insufficient site data for this species which is typically regarded as occurring in potentially low population densities and patchy occurrence.	Presence of water mouse in the site	Low
	Threatened species – dugong	Population numbers outlined in GBRMPA (1997): 765 ± 161 S.E. in 1987; 406 ± 78 S.E. in 1994.	Information presently insufficient for proposing any LACs	

		However, there is insufficient available information on the population dynamics and genetics of dugongs to develop a definitive LAC.		
	Threatened species – flatback turtle	Wild Duck Island to the north of Shoalwater Bay is one of the two major flatback rookeries in eastern Australia, with several hundred females nesting annually. Low density or sporadic nesting occurs on many other beaches and islands in the vicinity of Shoalwater Bay (Limpus *et al.* 2005). The area encompassing SWBTA south of the Percy Islands south to Stockyard Point and the Duke Island Group between Wild Duck Island and the Marble Group remains unsurveyed. It is expected that this unsurveyed area will contain *N. depressus* and *C. mydas* rookeries.	The loss or prolonged absence (>5 successive years) of flatback nesting within the beaches of the site	Moderate
	Threatened species – green turtle	Specific feeding areas, prey types and prey densities required to support turtles unknown. Limpus *et al.* (2005) suggests that seagrass represents ~86% of turtle volume of turtle diet, followed by red algae (~10% by volume). Presently no data on red algae distribution and abundance. Limpus *et al.* (2005) found over an 18 year monitoring period the following breeding rates: ♀ Mean = 0.119 ± 0.026 S.E.; ♂ Mean = 0.34 ± 0.072 S.E. There is comparatively fewer pre-listing data (n = 7-11 years): ♀ Mean = 0.118 ± 0.032 S.E.; ♂ Mean = 0.39 ± 0.010 S.E. Insufficient empirical data to derive definitive LACs. There is a need to develop baseline data describing variability in key turtle food resources within and adjacent to the site in order to develop empirical LACs. It is not possible at this stage to provide guidance on these limits as, to a large extent, these will be dependent on the adopted sampling methodology and levels of natural variability. There is also insufficient empirical data to derive empirical, threshold-based LACs that are meaningful in the context of maintaining turtle populations.	Information presently insufficient for proposing any LACs	
	Threatened species – Honey blue-eye	This species typically has low population densities hence empirical population estimated have not been determined. There is insufficient empirical data to derive definitive LAC.	Presence of Honey blue-eye	Moderate
	Threatened species – lesser swamp orchid	There are no available data on water requirements of the lesser swamp orchid, nor are there suitable baseline data describing water regimes/water levels at particular locations supporting the threatened plant species. No information is available regarding the population sizes, dynamics and viability of the threatened plant species within the site. Should an adequate baseline be established, such as watering requirements of each species, LACs could be calculated based on the range of variability at representative sites. It is not possible at this stage to provide guidance on these limits as, to a large extent, these will be dependent on the adopted sampling methodology and levels of natural variability, and will vary across locations.	Presence of lesser swamp orchid	Moderate
Criteria 3	Biodiversity	The site supports 18 Ramsar wetland types (9 coastal/marine; 9 inland). In terms of wetland dependent species, the site supports 22 frog species, 77 waterbird species and 32 shorebird species. Surveys have recorded 428 estuarine and marine fishes and 17 freshwater fishes, not including records of the Honey blue-eye.The Queensland State Government WildNet database records 909 species of native	No direct LAC has been developed and instead the critical component will be assessed indirectly through	

		plants. Changes in LAC for wetland habitats and threatened species could be used as surrogate measures for this component.	changes in wetland habitats and threatened species. See LAC above.	
Criteria 4	Habitat for critical life stages	The site provides the following critical life stage processes: • Feeding and roosting habitat for 77 waterbird species; • Non-breeding, feeding and roost habitat for 26 migratory shorebird species including 26 and 27 species protected under the JAMBA and CAMBA agreements respectively; • Habitat for 22 frog species; • Feeding and breeding habitat for wetland-dependent raptor species; • Habitat for honey blue-eye freshwater fish (entire life-cycle); and • Nesting habitat for flatback turtles. While an ecological condition assessment was done by Wetlands International (refer Jaensch 2008a) for the SWBTA, there is no analogous ecological condition assessment across the site. Changes in LAC for wetland habitats and threatened species could be used as surrogate measures for this component. The ecological condition assessment by Wetlands International (refer Jaensch 2008a) provides the baseline for assessment of this LAC at SWBTA. There is no analogous ecological condition assessment for Corio Bay. Changes in LAC for wetland habitats and threatened species could be used as surrogate measures for this component.	No direct LAC has been developed and instead the critical component will be assessed indirectly through changes in wetland habitats and threatened species.	
Criteria 5 and Criteria 6	Waterbirds – numbers of species	Key shorebird species include grey-tailed tattler, bar-tailed godwit, eastern curlew, whimbrel, terek sandpiper and Australian pied oystercatcher. There is insufficient time series sequence to assess natural population variability of resident shorebird breeding success (pied oystercatcher only). Interpretation of changes in abundance for migratory species need to be assessed against potential external factors (potential variability in breeding success) and in particular, anthropogenic impacts to key sites within other parts of the flyway. As a result there in insufficient empirical data to derive definitive LACs. There is a need to develop a sequence of population estimates and measures of breeding success within site in order to develop empirical LACs.	Information presently insufficient for proposing any LACs	
Criteria 7	Fish	There are currently no recent baseline data (collected using systematic sampling techniques) to determine patterns in fish assemblages at representative locations and habitats in the site. Until such time as these data become available, this LAC cannot be directly assessed. Undertaking a marine and freshwater fish survey in similar locations and using a similar methodology to Trnski *et al.* (1993) may provide an adequate baseline from which to derive a LAC for this component. Refer survey by Trnski *et al.* (1993) as the baseline for fish diversity at the time of listing in 1996 which noted 428 marine species were present and 17 freshwater species.	Information presently insufficient for proposing any LACs	

4 CHANGES TO ECOLOGICAL CHARACTER AND THREATS

4.1 Introduction

'Ecological character' is defined as a combination of the wetland ecosystem services/benefits, components and processes that underpin wetland systems at any given point in time. In assessing changes to ecological character for Shoalwater and Corio Bays, as required by the National Framework, the relevant timescales for the assessment of ecological character are taken to include 1996 (when the site was listed as a wetland of international importance) and 2009 (the time of preparation of this first ECD).

Being a large site with significant intra-site spatial variability and significant temporal and spatial variability, the analyses below attempt to characterise whole-of-site changes but also rely on specific investigations and information about particular waterbodies of the site where relevant.

4.2 Ecological Character Changes

When considering the ecological condition of the site, the National Framework requires the ECD to examine any changes to ecological character that have occurred since the listing date in 1996.

To do this, two general approaches have been employed and are discussed in the sections below. These are:

1. based on the documentation reviewed and Ramsar nomination criteria listed as part of the 1999 RIS, an assessment of whether these listing criteria continue to apply
2. based on the critical services/benefits, components and processes and LACs identified in Chapter 3, whether there has been a measurable change to ecological character that is the likely result of anthropogenic activities in either SWBTA or Corio Bay.

4.2.1 Assessment of Potential Ecological Character Changes: Shoalwater

Some of the key findings from the latest landscape assessment of condition (undertaken annually since 2002) (refer GHD 2007) were as follows:

- 'There have been no observable trends in the general landscape health of SWBTA attributable to Defence activities'.
- 'Over the wider landscape fire regimes have maintained the general status quo, with impacts only particularly evident in the vulnerable minor communities and ecosystems– riparian areas and rainforest patches in particular. It is acknowledged that management of some of these impacting events has been beyond the possibility of Defence to control'.
- 'The majority of parameters analysed in sediments were below the laboratory limits of reporting and compliant with the ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines (where available). Discussions relating to potential sources of low concentrations of hydrocarbons and pesticides identified in selected sediment samples concluded that the sources of these compounds

were likely to be natural and that defence activities were not having an adverse impact on sediment quality at the training Area'.

- 'The results of the past monitoring events (2004, 2005, 2006, 2007) indicated that parameters such as conductivity, dissolved oxygen, pH, turbidity, ammonia, total nitrogen and total phosphorus consistently exceeded or were outside the ANZECC/ARMCANZ (2000) trigger value/range at a number of monitoring sites. The ANZECC/ARMCANZ (2000) guidelines acknowledge that tropical ecosystems are characterised by elevated seasonal temperatures and high seasonal variability in rainfall and stream flow (ANZECC 2000). The large range in physicochemical and chemical parameters within and between monitoring sites over the six monitoring events highlights the large natural variability in water quality in ephemeral water bodies.'
- 'The concentrations of heavy metals recorded in the 2007 monitoring event were within the ranges recorded in previous monitoring events and no trends of consistent increase or decrease in concentrations at a particular site were identified. Despite some monitoring sites exceeding the 95% trigger values for one or more heavy metals, no additional investigation is recommended as these exceedances are consistent across the bay and over time. These parameters may also become more concentrated in water bodies as a result of low flows due to lack of rainfall.'

A more topical condition assessment of wetlands and waterbirds was commissioned and carried out by Wetlands International in 2007–2008 (refer Jaensch 2008b). Key findings from that assessment relevant to ecological character of the Ramsar site are as follows –

- 'Mangrove wetlands at SWBTA generally appeared to be in good condition with no evidence of significant direct or indirect disturbance by human activity. The surveys recorded localised death of frontal mangroves, mainly in the western sectors. There were localised, small areas of dead mangrove thicket at some landward edges and bordering salt flats, probably caused by heightened salinity due to drought, which would be part of a natural process of salt-flat formation. Dead mangroves were absent or rare in inner parts of the mangrove blocks.'

- 'Erosion of beaches/shore, manifest in collapse of fringing dryland trees, was evident in several areas, especially in western sectors. These changes to mangroves and beaches can be attributed to natural processes of erosion, accretion and other change in the coastal zone.'

- 'Human-built infrastructure is negligible in the freshwater swamps of SWBTA and vehicle and on-foot access is rare or non-existent. No significant human impacts on these wetlands were recorded.'

- 'Prolonged dry conditions have exposed peat deposits to catastrophic loss from wildfire. Extensive wildfire across most of the Clinton Lowlands in 2004 destroyed surface peat in the largest swamp, illustrating the potential loss at other sites such as (the much larger, not recently burnt) Dismal Swamp.'

- 'The survey team observed that about 70 ha of wooded swamp, over five sites close to Island Head Creek and Port Clinton, being approximately 25% of the total area of this wetland type at SWBTA, had been destroyed, leaving groves of dead trunks. The combined and interrelated effects of reduced freshwater inflow (due to drought) and saline groundwater intrusion are thought to be the likely causes though this needs to be confirmed. Mangroves and salt tolerant plants had invaded some of the sites but regeneration of *Melaleuca* trees was widespread. No specific remediation is

proposed; return of years of average or above average rainfall is likely to facilitate (slow) natural restoration.'

- 'Weeds and feral animals currently seem to be minor to non-existent impacts on the freshwater swamps of SWBTA.'
- 'Stream banks were mostly very stable primarily because of well vegetated riparian zones. Natural stream flow appeared to be the major cause of erosion, and sites with high stream bank erosion or slumping appeared to be at natural floodplain cuttings.'
- 'Pump stations for water extraction on Sandy Creek (Water Park catchment) and Werribee Creek (Werribee catchment) are used only intermittently and appear to have very limited impacts on local stream flows, even during the recent period of prolonged drought. The Defence extractions on Sandy Creek represent approximately 0.006% of a minimum environmental flow nominated for Water Park Creek weir downstream in the catchment.'
- Results from 2007 shorebird surveys have shown that the intertidal wetlands of SWBTA continue to support at least 20,000 waterbirds and at least 1% of the flyway population of six waterbird species/subspecies.
- There has been no net loss of high tide roosts, or of important roosts, at SWBTA since the 1995 survey. There may have been a minor shift from west to east in relative importance of roosts but this may be attributable to natural variation.

Possible changes to ecological character since listing of the site in 1996 were briefly discussed with members of the KMC workshop. From these discussions the following matters were raised:

- Patches of paperbark (*Melaleuca*) communities in the lowlands/riparian areas that have been affected by dieback are likely the result of the recent drought.
- *Lyngbya* blooms which occurred in 2002 have not recurred at similar levels and are not considered a significant threat to marine environmental values.
- Reduced commercial fishing pressure as a result of revision of marine park zoning and other initiatives has likely led to a positive change in ecological character in terms of fisheries recruitment.
- The imposition of the Dugong Protection Area and associated plan of management by GBRMPA has likely reduced the potential for dugong strike through better management of boating activities.

In summarising these assessments, the overall ecological character of SWBTA is considered to be stable and seems unlikely to be altered by present training activities and associated impacts, under the present environmental management regime.

4.2.2 Assessment of potential Ecological Character Changes: Corio Bay

Changes to the ecological character of Corio Bay are more problematic to assess given the lack of more regular assessments of habitat or wildlife condition. Notwithstanding, recent baseline surveys of Corio Bay of macrobenthic invertebrates and fish by Melzer *et al.* (2007) showed species diversity values, biotic abundances and the dominance of particular species that were broadly comparable to

the survey results reported in previous surveys by Habitat (1974). Water quality data (refer Appendix F) does not show values considered to be outside of natural variability over several years of sampling.

Land use changes that have occurred in the Corio Bay catchment over time include a general reduction in agricultural activity, an increase in forest plantation, some increased urbanisation and associated increased nutrients from stormwater runoff. None of these land use changes however, are at a scale or intensity to warrant significant changes to character.

Most of the development which influences the bay and its tributaries has been in place significantly prior to the Ramsar listing including the Water Park Creek weir (1988) and Iwasaki Resort (early 1980s).

The effect of the existing weir on ecological character of Corio Bay has not been comprehensively assessed. However, some assessment of current and potential impacts to riparian and wetland values from increased water extraction were considered in the context of assessment of an additional weir in Sandy Creek as outlined in Cardno (2005). From this work a sustainable environmental flow requirement was developed and has been determined as appropriate to protect the downstream environmental values of Corio Bay.

A series of bunds occur along the southern boundary of the Ramsar site at Corio Bay. These bunds were built to stop the intrusion of saltwater into pasture land associated with prior grazing use of the site. Since the site was purchased and developed into a tourist resort by the Iwasaki Group in the early 1980s, the bunds have been maintained and improved, and the resultant freshwater wetlands are conserved and managed by the operators of the resort and have since been listed as a nationally important wetland (the Iwasaki wetlands - DIWA).

Although the bund structures significantly pre-date Ramsar nomination and listing, the extent to which these bunds have had long term impact on the ecological condition of Corio Bay are unknown and represent an information gap. However, work to improve the connectivity of the wetlands is currently underway (see ‘Knowledge Gaps’ section below).

Increased recreational vehicle usage is also thought to be a concern for the ecological character of the site. Houston and Mitchell (1997) specifically raised concern about off road vehicle (ORV) usage along the Sandy Point area disturbing high tide roost areas of waders and terns and breeding usage of the site by beach stone-curlew and little tern. Limited vehicle impact mitigation measures including a boarded beach access road and interpretive signage have since been introduced by QPWS using a CoastCare grant, but no systematic assessment of impacts from recreational usage have been carried out (Melzer *et al.* 2007).

Based on discussions with the KMC as part of the current study, other potential changes to ecological character in Corio Bay and surrounds included:

- increased water extraction from Water Park Creek for urban use during drought conditions over the past decade that may have had impacts on downstream wetlands and wetland biota (such as fisheries)
- localised decline in riparian vegetation quality and some observed mangrove dieback (though this is likely a result of drought conditions over the past decade)
- some decline in condition of vegetation and erosion of dunal areas from ORV usage in the site on the northern shores of Corio Bay and at Sandy Point.

Based on the above information sources, there is a lack of systematic data to confirm that ecological character of the Corio Bay section of the site has been maintained, but the general views of the KMC members and on the basis of recent investigations is that the site has not experienced any significant changes to ecological character since listing in 1996.

4.2.3 Assessment of Potential Ecological Character Changes Against LACs

The National Framework also requires that the assessment of changes to ecological character make reference to whether or not any limits of acceptable change have been exceeded.

Table 4-1 provides this assessment and concludes that no limits of acceptable change have been exceeded. However, in some cases there is insufficient information from which to make a definitive assessment which forms an information gap for future ECD assessments.

Table 4-1 Assessment of Ecological Character changes against LAC

Limit of Acceptable Change[5]	*LAC exceeded?*	*Comments*
Critical services/benefits, components and processes		
Wetland habitats (Marine) – Seagrass (Type A, B, F) - Presence of habitat.	No	Seagrass assessment has not been conducted since Lee Long *et al*. 1997 but is likely to remain in excellent condition.
Wetland habitats (Marine) – Mangroves (Wetland Type F, G, H, I) - Presence of habitat.	No	Limited data, noting that significant impacts to wetland ecosystems have not been observed (e.g. see GHD 2007, DoD 2009).
Wetland habitats (Marine) – Saltmarsh (Wetland Type G, H, I) - Presence of habitat.	No	Limited data, noting that significant impacts to wetland ecosystems have not been observed (e.g. see GHD 2007, DoD 2009).
Wetland habitats (Marine) – Rocky reef coral communities (Wetland Type C, D) – Presence of habitat.	No	Insufficient data to assess but unlikely to have been exceeded given controls in the GBR Marine Park and low levels of recreational use.
Wetland habitats (Marine) – Sandy shores (Wetland Type E, G) - Presence of habitat.	No	Limited data, noting that significant impacts to wetland ecosystems have not been observed (e.g. see GHD 2007, DoD 2009).
Wetland habitat (Freshwater) – marshes, Peat swamps (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y) - Presence of habitat.	No	The condition and extent of peat swamps reported in Jaensch to be 'very good' (refer Jaensch 2009). Exact changes to extent unknown but the systems have low natural variability and appear to have had no change.
Hydrology – freshwater flows (e.g. Waterpark Creek, Peat swamps, saltmarsh) (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y) – No LAC developed, see wetland habitats.	Unknown but unlikely	Insufficient data to determine.
Hydrology – groundwater dynamics (e.g. Freshwater wetlands, Peat swamps) (Wetland Type M, N, Tp, Ts, U, W, Xf, Tp, Y) – No LAC developed, see wetland habitats.	Unknown but unlikely	Insufficient data to determine.
Threatened species - water mouse - Presence of species.	No	DoD (2009) reports that these key habitats are in good condition with the possible exception of some natural dieback of mangroves from drought and possible impacts on saltmarsh from feral pigs. The condition of similar habitat in Corio Bay is expected to be good. The presence and abundance of water mouse on the site is not known.
Threatened species – dugong – No LAC developed.	Unknown but unlikely	Insufficient data to determine but unlikely based on habitat extent.

[5] For the full text of the LAC refer to the tables in Section 3.

Limit of Acceptable Change[5]	*LAC exceeded?*	*Comments*
Threatened species - flatback turtle - The loss or prolonged absence (>5 successive years) of flatback nesting within the beaches of the site	Unknown but unlikely	While sporadic flatback turtles continue to use the site for nesting at select locations – further baseline assessment needed to establish patterns of usage. Flatback turtle nesting has not been surveyed on the site but is likely to be occurring at levels equivalent to those at the time of listing (no new threats are evident).
Threatened species - green turtles – No LAC developed.	Unknown but unlikely	Insufficient data to determine – but unlikely to have been exceeded based on findings of Limpus *et al.* 2005. Green turtle nesting has not been surveyed on the site but is likely to be occurring at levels equivalent to those at the time of listing (no new threats are evident).
Threatened species - honey blue-eye - Presence of species.	Unknown but unlikely	Insufficient data to determine – there has been limited aquatic fish sampling events on the site that pre-date listing.
Threatened species - lesser swamp orchid - Presence of species.	Unknown but unlikely	Insufficient data to determine – noting that there have been no works or other scheme that have diverted or otherwise significantly impacted flows for the species. Water extraction for Defence use is low, and monitored and restricted when necessary (DoD 2009).
Biodiversity – No LAC developed, see wetland habitats and threatened species.	No	There is no evidence to suggest any broad scale changes to the diversity of habitat or species since listing.
Habitats for critical life stages – No LAC developed, see wetland habitats and threatened species.	No	Wetlands continue to remain in good condition (e.g. see GHD 2007, DoD 2009) with evidence that key life cycle attributes such as roosting sites continue to be used by substantial numbers of birds. Targeted surveys for threatened species have not recently been conducted, but species are presumed to be present and at abundances similar to the time of listing based on the provision of suitable habitat that is in good condition. Based on condition assessment and lack of works that affect frog habitats. Drought over the last decade has likely put these habitats under increased stress but this is not related to any anthropogenic impact
Waterbirds – numbers of species – No LAC developed.	No	The site continues to support large populations of several key shorebird species (see Driscoll 1996, WIO 2006, Jaensch 2008a, Bamford *et al.* 2008) in the context of the flyway. The site continues to support a high abundance of waterbirds well above the Ramsar criterion threshold of 20 000 (see Jaensch 2008a). While count data over time is insufficient to make a definitive judgement, ecological character change is but not considered likely based on relevant reports (e.g. Jaensch 2008a).
Fish – No LAC developed.	Unknown but likely	There is a lack of adequate baseline data to assess this but it is considered unlikely that there has been a reduction in abundance of key commercial or recreational species or overall species diversity due to the near pristine (undisturbed) condition of key habitats, low fishing pressure and conservation zoning of surrounding waters.

4.3 Threats

Threats to a wetland can be used as pointers for areas of focus under the management plan, and as initial guidance in assessing the likely impacts of potential developments under the EPBC Act. Given

the size and diversity of wetland habitats present, the threats to the values of the Shoalwater and Corio Bays Area Ramsar site vary greatly across multiple spatial and temporal scales and in terms of their potential severity. Some of these threats are discussed in the above section in relation to changes to ecological character and a range of threats have also been identified for each of the critical services/benefits, components and processes (refer Appendix B).

Broad scale threats to the ecological character of the site are summarised in Table 4-2 and discussed below. In characterising the key threats identified in Table 4-2, the likelihood of individual threats was assessed based on categories presented in Table 4-3.

Table 4-2 Summary of broad scale threats

Threat	Potential impacts to wetlands	Likelihood	Timing*	Within or surrounding the area
Future infrastructure development	• Vegetation clearance/ land conversion. • Changes to water quality and hydrodynamics. • Roads and railroads. • Housing and urban areas. • Tourism and recreation areas.	Low	Medium to long term	Surrounding Within
Water regulation	• Water abstraction. • Interruption of surface water/groundwater flow paths.	Low		Surrounding area
Agriculture and aquaculture	• Wood and pulp plantations. • Livestock farming and ranching.	Unknown		Surrounding area
Biological resource use	• Logging and wood harvesting. • Fishing and harvesting aquatic resources.	Unknown Low		Surrounding area Within
Energy production and mining	• Mining and quarrying.	unknown		Surrounding area
Fire	• Altered structure/composition of vegetation. • Altered suitability of fauna habitat. • Destruction of peat swamps. • Fire and fire suppression.	Medium **depends on continued fire management regime* Low	Short to long term	Within and surrounding
Climate change	• Reduction of freshwater species. • Reduction of suitable fauna habitat. • Greater fire risk. • Increased storms and flooding.	Medium	Long term	Within and surrounding
Pest plants and animals	• Reduced regeneration of native flora. • Introduced invasive non-native/alien species.	Low to medium	Medium term	Within and surrounding
Recreation and tourism	• ORV damage to coastal ecosystems. • Wildlife disturbance and vessel strike. • Trampling of native vegetation.	Low	Short to medium term	Within and surrounding
Pollution	• Injury/fatality of marine species and communities. • Impacts from industrial and military effluents. • Impacts from illegal, abandoned or derelict structures on wetland values.	Low to Medium	Short to long term	Within and surrounding

Threat	Potential impacts to wetlands	Likelihood	Timing*	Within or surrounding the area
	• Agricultural and forestry effluents. • Garbage and solid waste.			

*Timing: medium term ~five years, long term ~ decades

Table 4-3 Threat likelihood categories

Threat likelihood category	Interpretation
High	• Irreversible impacts at the broad scale or regional scale. • Medium term impact at the broad scale.
Medium	• Irreversible impact at a local scale. • Medium term impacts at the regional scale. • Short term impact at a broad scale.
Low	• Irreversible impact at the individual scale. • Medium term impact at a local scale. • Short term impact at a regional scale.

Future Infrastructure Development

Over the past 30 years, a number of potential infrastructure development options within or nearby the Ramsar site have been put forward. In 2008, a proposal to construct and operate a coal rail line and shipping port within SWBTA was rejected by the Commonwealth Minister for the Environment under the EPBC Act (Peter Garrett, 2008).

In addition to native vegetation removal and introduction of weed species, future development of linear infrastructure (e.g. transport corridors, roads, rail, and pipelines) could potentially impact freshwater wetlands through interruption of natural surface water and groundwater flow paths by:

- altering localised rainfall-runoff relationships by increasing the impervious fraction of catchment surface, thereby creating more frequent runoff events
- compacting local soils, thereby reducing local hydraulic conductivity, potentially elevating groundwater tables upstream of transport corridors leading to reduced infiltration capacity and consequently greater surface runoff potential
- creating preferential groundwater and surface water flow paths through alteration of hydraulic conductivity and/or drainage infrastructure, thereby increasing the localised drainage efficiency, concentrating surface water/groundwater discharge, and increasing localised discharge velocities and pollutant transport capacity
- altering upstream and or downstream groundwater elevations due to increased or decreased groundwater discharge potential, thereby impacting the water balance of shallow pools, swamps and waterways and causing habitat degradation and/or fragmentation.

Future port development and the associated dredging could potentially place a number of threats on estuarine and marine values of the Ramsar site such as:

- removal of marine vegetation, possibly including valuable habitats such as mangroves and seagrass (and corresponding impacts on usage of the site by dugong and turtles)
- disturbance or removal of benthic fauna communities
- short-term increases in turbidity due to increases in suspended sediments (and smothering of coral or seagrass communities as sediments settle)
- degradation of water and sediment quality

- changes to the local hydrodynamic regime.

Fire

Although fire is a natural component of the landscape, anthropogenic interactions with the landscape over time have led to modified natural fire regimes, and continue to alter fire regimes. Such alterations may be exacerbated by other factors such as changes in drainage regimes. Furthermore, predicted changes in climate (see below) are likely to result in further changes to fire regimes.

Altered fire regimes threaten vegetation communities as regeneration processes are directly impacted and often controlled by fire. Consequently, fires experienced at inappropriate (too high or too low) frequencies, intensities or seasonality may lead to substantial changes in community composition and/or structure. In turn, threats may be exerted on fauna species that are dependent on these habitats.

Changed fire regimes threaten terrestrial vegetation within the site, including ecologically significant vegetation communities and habitats of listed migratory species. In particular, peat swamps are notably susceptible to fire, especially when the peat swamps are dry. Burning may release large quantities of stored carbon and create substantial cavities in the peat, thereby destroying the peat swamp beyond recovery (Jaensch 2008b).

Planned fire management is critical to reduce the risks associated with fire. Management activities by DoD include controlled burning in adherence with a fire management strategy that was developed specifically for SWBTA (see PB 2003).

Climate Change

Taking into consideration the coastal location of the Ramsar site, climate change represents a salient threat to ecological character. Potential impacts of climate change on coastal ecosystems are described in Voice *et al.* (2006). The following climate change impacts are considered most relevant to the site:

- increased coastal flooding and sea level rise
- changes to freshwater flow regimes due to changes in rainfall and runoff
- increased frequency and intensity of storm events
- increased temperatures.

In turn, these impacts are expected to affect the ecological character of the site. Potential implications may include, for example:

- mortality or reduced abundance of freshwater flora and fauna species due to saltwater intrusion
- reduced suitability of habitats for fauna due to changes in vegetation and/or structural damage
- landward migration of mangrove and saltmarsh wetlands
- greater fire risks due to increased temperatures and reduced rainfall
- proliferation of invasive weeds and/or feral animals better suited to new habitats
- impaired reproduction for species reliant on water or ground temperatures
- gender imbalances for species reliant on temperature for sex-determination of offspring
- coral bleaching due to increased temperatures and water acidification.

Climate change is considered a specific threat to freshwater wetland areas within the site as extensive tree deaths in ecotonal situations in eastern SWBTA were observed in 2007, presumably caused by saline intrusion in the absence of sufficient fresh groundwater during the prolonged regional drought (R Jaensch pers. comm. 2009). Such impacts may be exacerbated by sea level rise associated with climate change.

However, unlike many coastal sites, the Shoalwater and Corio Bays Area Ramsar site provides opportunities for ecological adaptation to climate change given the size of the site, the topographical variation and lack of fragmentation or modification (DoD 2009).

Pest Plants and Animals

Pest plants have the potential to reduce opportunities for regeneration of native flora through competitive growth, as well as by changing soil conditions required for successful germination. Although the relatively undisturbed nature of the site provides a defence against weed infestation, many small disturbed areas (e.g. roads, tracks, camps) provide opportunities for weed invasion (DoD 2009). As such, identification and control of weeds is an ongoing management task and a site-specific weed management strategy has been developed (see Childs 2003). While weed control over the last decade has successfully controlled or eradicated certain weed species, other weed species remain naturalised across the landscape (DoD 2009).

A number of introduced animal species have been recorded within the site, including feral pig, fox, cane toad and feral cat. Feral animals can exert a variety of impacts on ecosystems including land degradation, predation on native wildlife and overgrazing. Pest animal management programs for the site are in place and are largely aimed at reducing population sizes down to levels thought to be ecologically sustainable (DoD 2009). Furthermore, FQ is currently undertaking pest fish surveillance within the Shoalwater Bay area (N. Moore, pers. comm. 2009).

Marine pest incursion through ballast water or on the hulls of foreign ships is a further potential threat to the values of the Ramsar site.

Recreation and Tourism (ORV Usage)

Due to the nature of land-use within SWBTA, public entry is prohibited and recreation/tourism activities are therefore not undertaken within the Shoalwater Bay section of the Ramsar site. However, trespass into the south-eastern corner of the Shoalwater Bay section of the Ramsar site is problematic, with ORV usage resulting in damage to vegetation, destabilisation of sand dunes and introduction of pest plants (Childs 2003, DoD 2009). ORV usage within the Corio Bay section of the Ramsar site presents similar issues.

The coastal dunes and headlands in ‘The Three Rivers’ area at the northern end of the Five Rocks beach has been identified as a priority site for erosion control by the DoD. The cause of this erosion is largely thought to be anthropogenic (use of ORVs, camping and other damage to vegetation). Likewise, the spit associated with Sandy Point at the mouth of Corio Bay is a naturally dynamic landform that is under heavy pressure from ORV and recreational usage (C. Mulville pers. comm. 2009) which threatens waterbird and shorebird nesting and roosting as already discussed.

Boating and jetski use in the site has also been identified as a growing threat in terms of impacts on the wilderness values of the site and potential impacts from boatstrike on dugong and turtles.

Should future development (see above) improve public access to the area, it is expected that the values of the Ramsar site will be further compromised through recreation/tourism impacts such as wildlife disturbance, vessel strike on marine mega-fauna and trampling of native vegetation.

Oil Spill or Marine Incident and Presence of Marine Structures

Oil spills and other forms of marine pollution such as debris and wastes have the potential to cause devastating impacts on marine ecosystems, particularly with regards to injury or fatality of marine megafauna due to ingestion or entanglement. Navy ships, as well as coastal shipping activities along the Queensland coast, have the potential to cause oil spills or marine incidents that may impact on the Ramsar site. However, Defence activities have been assessed by DEWHA and GBRMPA and have been assigned a low probability of occurrence. Nevertheless, a regional oil spill response plan is in place. Furthermore, strategies to reduce the risk of oil spills and their impacts on the Great Barrier Reef Marine Park are delivered jointly between the GBRMPA, the Australian Maritime Safety Authority, Maritime Safety Queensland and Queensland Transport.

Fisheries Queensland is currently undertaking a project titled 'Inventory of Instream Structures impacting on Ramsar Wetlands'. The aim of the project is to identify the threats to mapped wetlands within two Ramsar sites (Corio/Shoalwater Bay and Bowling Green Bay) from the impacts of instream structures. Placement of instream structures (including jetties, revetments, bund walls, road crossings etc.) can have a number of impacts on natural tidal and subtidal wetland ecosystems including destruction, loss and modification of wetland habitats important for fish and a range of other aquatic species. While the threat of individual structure impacts on the ecological character of the Ramsar site appears to be relatively minor, the threat that cumulative structure impacts present can be significant.

Preliminary results indicate 26 instream structures exist within the Shoalwater and Corio Bays Area Ramsar site, including boat ramps, dumped rubbish/material, revetments, permanently anchored houseboats, jetties and a derelict vessel. Accordingly, project data is planned to be used to develop a Response Action Plan in consultation with key stakeholders for rehabilitation and removal of high risk structures.

Change of Land Use / Future Urban Development

While urban development is currently not a threat within SWBTA, it could become a threat in the future should DoD cease to use the site for Defence training activity and sell (part of) the land. However, given the strategic importance of the Training Area for Defence Force activities this is considered a low risk at the current time.

For the Corio Bay section of the site, despite the low likelihood of urban development within the Ramsar site, urban encroachment may impact values within the site due to more intense surrounding land use. In this context, it is notable that significant further urban expansion and growth is predicted along the central Queensland coast. Urban land use changes that could impact upon the Corio Bay Ramsar site would be managed principally by the relevant local government which is the Rockhampton Regional Council.

The Iwasaki Sangyo Company that owns the Capricorn International Resort and adjacent wetlands (located to the south of the Corio Bay section of the Ramsar site) also announced plans to further expand and redevelop the tourist resort (Queensland Government 2008). Based on provisions within the Livingstone Shire Council Planning Scheme (refer section 3.24 – Capricorn International Resort Code) any development on this site is strictly controlled and would need to demonstrate no adverse impacts on the Corio Bay Wetlands or the declared Corio Bay Fish Habitat Area.

Future Changes in Military Usage Patterns

As discussed in the ecological character change section, the current military usage of SWBTA is strictly controlled, managed and monitored and has not caused any changes to the ecological character of the Ramsar site. This relies in part upon the fact that almost all training activities and associated infrastructure are outside the boundaries of the site. In this context, a future threat to ecological character may be if new facilities or activities were proposed in the Ramsar site (such as new air or watercraft landing platforms, fuel storage facilities or new gunnery or artillery ranges). However any such proposal would need to be fully assessed through the EPBC Act referral and approval process and therefore would be unlikely to be permitted if there was concern that the future ecological character of the site could be compromised. As such, future changes in military use patterns on the site as a threat to ecological character is considered to be a low risk.

5 INFORMATION GAPS, MONITORING AND EDUCATION

5.1 Information Gaps

The ECD preparation process promotes the identification of information or knowledge gaps about the Ramsar site that are principally derived through interrogation of the nominated ecosystem services/benefits, components and processes and associated understanding of natural variability and LACs.

In this context, information gaps presented below also reflect statements about information needs and monitoring recommendations in the reviewed literature including Jaensch (2008b), DoD (2009) and through discussions with the KMC.

In general, data and information gaps have been identified in this ECD in three broad areas:

- in relation to the natural variability and LACs (as outlined in the summary tables in Section 3)
- in relation to lack of information and data to support a more detailed assessment of ecological character change
- in the context of the detailed discussion of the critical services and underlying critical components and processes as set out in Section 3 and Appendix B.

In a general sense, better information and understanding about the natural variability of critical wetland habitats and fauna populations and the key attributes and controls on those populations are needed noting that any limits of acceptable change stated in the ECD should be revised as improved information becomes available. The collection of this baseline data and information is crucial to assessing trends in ecological condition which is fundamental to the assessment of ecological character.

More specifically, and based on the information reviewed as part of the current study, the following thematic information gaps are identified as priority areas for future consideration:

- The need for better information and data sets about the presence and natural history of critical wetland species and their habitat within the boundaries of the Ramsar site including for example:
    - the continued presence of honey blue-eye on the site, its likely habitats and its population dynamics
    - the extent of nest activity and diversity of nest areas as surrogate for water mouse distribution and abundance
    - the presence and population of vulnerable plant species
    - the presence of other species of conservation significance that have not been previously identified within the boundaries of the Ramsar site including Oxleyan pygmy perch, Australasian bittern, painted snipe and Byfield fern.
- Further survey is needed to identify any trends in usage or condition of marine fish and crustaceans based on these previous studies. Service 7 for the site which deals with fish diversity (and is the basis for Criterion 7) is based on survey work by Trnski *et al.* (1993) and fish species diversity listed

in Pusey *et al.* (2004) which in most cases pre-date listing of the site. Further survey should include where possible similar environments within the North East coast drainage division to determine the extent of fish endemism in the site including the three 'temperate' species identified as being endemic to the site (refer Trnski *et al.* 1993). It is noted that further information on native fish communities will be gathered as part of the pest fish surveillance that is being conducted within the Shoalwater Bay area (N. Moore, pers. comm. 2009).

- Further study is also needed on the sinkhole features in the south-eastern portion of SWBTA in terms of likely formation processes, identification of any associated flora or fauna that are wetland-dependent and possible uniqueness as a landform. The extent that these features also include springs makes them likely a rare wetland feature that further justifies listing of the site under Criterion 1. Likewise, further investigation of freshwater streams within the site is likely to demonstrate the streams and their adjoining riparian habitat are rare and representative in the bioregional division.
- The wetland components and processes of Corio Bay are far less studied than those of SWBTA and represent a broad information gap, noting that a range of studies about the ecological condition of Corio Bay are currently being undertaken by the Central Queensland University.
- In looking at specific threats to Corio Bay, the interaction between the Corio Bay and Iwasaki wetlands and the effects of the long term bunds between the wetlands is a particularly relevant issue. It is noted that FQ are currently conducting a two year project to construct two fish ways on Iwasaki Wetlands (N. Moore, pers. comm. 2009). While these fish ways will be situated outside the Ramsar site, they will improve connectivity within wetlands linking to the Ramsar site.
- Investigation of the existing Water Park Creek weir (used to supply water to the coastal urban communities outside the Ramsar site) in terms of its potential impacts on riparian vegetation, fish passage and environmental flows, and its continuing necessity in terms of the proposed Fitzroy pipeline, is also warranted. Funding has recently been obtain by FQ (through the Fitzroy Basin Association) to build a fish way on the Water Park Creek weir structure, with completion of this expected during 2010 (N. Moore, pers. comm. 2009).
- Better conceptual understanding of the groundwater processes that occur on the site is needed in the context of how these processes support critical wetland components such as the peat swamps, and how these processes could be affected by potential future infrastructure development.
- More specific assessment of the vulnerability of the site to the impacts from climate change, including exploration of adaptation options that could be employed to reduce future impacts. Similar to approaches in other jurisdictions, this is best done as part of a formal risk assessment process (AS:4360 or similar) in order to identify and treat the highest risks to the wetland values of the site.

5.2 Monitoring Needs

Identifying monitoring requirements for the site helps to provide input to management and monitoring programs, and ensures that these programs are linked to the ecological character of the wetland. The monitoring requirements may also provide further information that can be used to improve the understanding and description of the ecological character of the wetland (DEWHA, 2008).

Monitoring needs for the Ramsar site can be broadly categorised into two primary areas:

- baseline monitoring to gather baseline data to help determine the extent of any potential ecological character changes, natural variability and LACs for those components or processes where limits of acceptable change are presented
- specific monitoring to address specific information gaps that have been identified.

Each of these is discussed below. It is important to note that this does not represent a monitoring program. Rather it should help to inform monitoring in the site management plan.

5.2.1 Baseline Monitoring

Some level of baseline monitoring is required to assess the suitability of LACs, better understand natural variability over time and to assess more definitively if changes to ecological character have occurred or are being approached. Principally, this monitoring should relate to:

- provision of spatial data of wetland habitat extent such that a baseline for each wetland type represented in the site can be monitored over time (noting that a logical precursor to this would be to establish a better correlation between Queensland wetland mapping and the Ramsar wetland type classification system on the site)
- habitat condition monitoring (principally in the form of monitoring underlying wetland ecosystem processes such as water quality and hydrological process or surrogate biological indicators such as species or habitats)
- more targeted surveys of the threatened flora and fauna species to assess presence/absence or population changes of noteworthy species or communities
- more regular counts of breeding, roosting and feeding waterbirds with a particular emphasis on those species that meet the 1% population criteria
- surveys of freshwater aquatic and marine fish species diversity, endemism and nursery habitat quality as the key values of the site that underpin listing under Criteria 8 and 9.

Accordingly, a range of monitoring objectives and measures are recommended in Table 5-1.

For SWBTA a suitable baseline has already been provided through previous surveys carried out by the DoD (in terms of the landscape assessment and condition of wetlands and waterbirds), GBRMPA and Queensland Government studies related to seagrass surveys and turtles and dugong surveys. Continuation of these longer term studies are of direct relevance to the objectives of the ECD and care should be taken in the context of future monitoring to ensure similar processes and methods are used in order to obtain a continuous data set and linkages between monitoring objectives.

Likewise, future studies and monitoring of Corio Bay should build upon work undertaken by Habitat (1974) and Melzer *et al.* (2007).

Noting that the monitoring needs outlined in Table 5-1 are quite extensive, an ecosystem health-based monitoring programme may be most appropriate for the Ramsar site utilising lessons learned from similar approaches that have been implemented in similar environments in Moreton Bay and more recently in Port Curtis (refer to the Ecosystem Health Monitoring Program undertaken by the Healthy Waterways Partnership and the Port Curtis Integrated Monitoring Program undertaken by Central Queensland University). In both of these programmes, emphasis is placed on the collection of data and

information based on underlying ecosystem processes such as water quality, sediment quality and biotic indicators such as seagrass depth range as surrogates of ecosystem health. However, it is important that such a program also targets consideration of the specific Ramsar values of the site, notably waterbird and marine/freshwater fish usage.

Table 5-1 Monitoring Ecological Character

Basis of monitoring	Objectives of monitoring	Indicator/measure	Frequency	Priority
Nomination Criterion 1	Ensure extent and condition of near natural representative and rare wetland habitats are maintained	Establish site based monitoring programs to ensure the extent and condition of these wetlands is known and can be tracked over time.	Annually with monitoring at required intervals. Extent survey can likely be desktop using aerial survey or other high resolution imagery.	Medium - High
Nomination Criterion 2	Determine presence/absence of threatened wetland species	Continue long term studies of turtle and dugong. Undertake more detailed surveys of other nationally threatened species within the Ramsar site. Assess presence/absence with consideration of relevant LAC.	Species specific – generally studies will need to be undertaken every 5 – 10 years and may need to be undertaken over several seasons.	High
	Assess condition/change to populations	Undertake more detailed surveys of species populations within the Ramsar site Assess any changes to population (e.g. breeding success, mortality rates, health etc.) and any applicable underlying wetland processes (e.g. water quality of key habitats – refer relevant species-based LACs).	Initial surveys to be undertaken opportunistically and then at more regular intervals (5 – 10 years).	Medium
Nomination Criterion 3	Ensure current diversity of wetland types are maintained	Establish reference sites for each Ramsar wetland type and record observations about extent and condition.	Every 3 – 5 years with particular consideration of likely climate change impacts.	High
	Ensure current levels of biodiversity are maintained	Utilise indicator/measures from Criteria 1 and 2.	See above.	Medium
Nomination Criterion 4	Use of the site as refugia habitat and for key life cycle processes	Survey and monitor key life cycle functions of targeted wetland-dependent fauna species.	Specific monitoring programs for functions in particular wetland areas to be developed – monitoring to occur during key usage periods. Follow methods developed by Jaensch for roost sites. Undertake initial survey of flatback turtle nesting usage.	High
Nomination Criterion 5	Use of the site by at least 20 000 waterbirds	Ensure regular surveys of waterbird usage of the site during key visitation periods.	Undertake comprehensive counts of waterbird usage of the site every 3 – 10 years.	High
Nomination Criterion 6	The site supports the 1% of individuals of populations for the key avifauna species in the ECD	Undertake more detailed surveys of 1% species of avifauna listed in the ECD.	Specific monitoring programs for each species to be developed in same frequency as above (e.g. every 3 – 10 years).	High
Nomination Criterion 7	Update the baseline of fish species diversity	Undertake monitoring of fish assemblages at representative	Initial surveys to be undertaken opportunistically	High

Basis of monitoring	Objectives of monitoring	Indicator/measure	Frequency	Priority
	in the site and any endemism	sites (diversity and structure and degree of endemism).	and then at more regular intervals (5 – 10 years).	
Nomination Criterion 8	Assess reduction in the extent or condition of wetlands or other areas and a corresponding measurable impact on important nursery habitats	Assess changes in the extent and condition of seagrass and other key nursery habitats to commercially and recreationally important species within the site.	Medium to long term (>5 years).	Medium
Nomination Criterion 9	Determine if any non-avian wetland species meet the 1% threshold	Undertake targeted surveys of candidate species (dugong and honey blue eye). Determine appropriate definition of populations in the context of relevant bioregional information (e.g. within the drainage division).	Medium to long term (>5 years).	Medium to Low

5.2.2 Specific Monitoring Needs

Specific monitoring needs have been identified within the discussion on critical services/benefits and other critical elements as outlined in the preceding section on information gaps. Some of the key recommendations in this context include:

- monitoring the condition of freshwater peat swamps over time including associated flora and fauna species and water quality and correlating this information with parameters such as climatic variables. This should also include an assessment of the risk and extent of saltwater intrusion
- continue survey and studies of green turtle and dugong, noting information gaps exist for flatback and green turtle nesting on the site and the extent to which the dugong population may represent greater than 1% of that population at a bioregional scale
- carrying out targeted surveys of freshwater fish populations including the presence of honey blue-eye and confirmation of the presence of Oxleyan pygmy perch
- monitoring the location and population viability of the two key threatened wetland flora species (vanilla lily and swamp orchid) to obtain a better understanding of underlying processes and controls on these populations, vulnerability to threatening processes and to inform future management
- monitoring the recreational usage of the site, especially in relation to access and activities in and around waterbird roost and breeding sites (especially Sandy Point and northern islands). A better understanding of the carrying capacity/appropriateness of use of the site in terms of ORV and recreational vessels is needed
- monitoring feral animals to inform eradication programs (especially feral pigs in saltmarsh and freshwater wetlands, and foxes around waterbird roosts and breeding sites)
- monitoring fire-prone dryland habitats surrounding freshwater swamps in order to inform fire management planning (especially peatlands within Dismal Swamp and Clinton Lowlands)

- monitoring water quantity and quality within the Water Park catchment, in order to inform management planning for freshwater wetlands
- continuing to monitor waterbird populations (implementing methods and timing as employed by Jaensch 2008a) including identification of the location and condition of links between roosting and feeding areas and the usage of the site by resident shorebirds.

5.3 Communication, Education and Public Awareness Messages

A set of messages relevant to the ECD can be used to communicate the importance of the site, why it was listed as a Wetland of International Importance, the threats to the site and future actions required. In this context, the key communication messages for the Shoalwater and Corio Bays Area Ramsar site that have been identified in preparing this ECD are as follows:

- the Ramsar site, while defined over only part of SWBTA and the estuarine areas within Corio Bay, contains a broad diversity of wetlands habitat types that range from open, high-energy coastlines, to sheltered estuarine areas and rare and unusual freshwater habitats in the bioregion.
- these habitats support a range of important wetland species and life history functions such as nesting, roosting and breeding, noting that the Convention and the significance of the site extends to a range of wetland flora and fauna populations that use the site such as water mouse, dugong, marine turtles and fish and invertebrate species of commercial and recreational significance – not just waterbirds.
- the ECD outlines the most critical ecosystem services/benefits, components and processes that underpin its listing as a Wetland of International Importance. These elements and LACs set in the ECD form the basis for future management of the Ramsar site and would need to be considered in future development proposals within or near the Ramsar site.
- there have been no significant changes to the ecological character of the site since listing in 1996 which reflects in part the roles of the Australian Department of Defence, the Great Barrier Reef Marine Park Authority and the Queensland Government have played in ensuring SWBTA, surrounding marine areas and Corio Bay are sustainably managed.
- continued investment in these management activities is required to ensure threats to the ecological character of the site are appropriately controlled and that longer term threats from climate change such as saltwater intrusion are monitored.

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7 GLOSSARY OF TERMS

Acceptable change, means the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. Acceptable variation is that variation that will sustain the service, component or process to which it refers.

Aeolian sedimentation, means deposition of material transported by wind.

Aquatic/marine fauna, the context of this report relates to fauna species that spend all or the majority of their life cycle in or underwater. As such this grouping primarily relates to fish, marine reptiles, aquatic mammals such as dugong and cetaceans, and aquatic/marine invertebrates.

Bed load, means the load (mass per unit time) of material transported by a river being carried on the bed by the process of rolling or siltation.

Bed material, means the sediment on the bed of a river that is transported as bed load during certain hydraulic conditions, but which may be immobile for much of the time.

Berm, means a nearly horizontal or landward-sloping portion of a beach, formed by the deposition of sediment by storm waves.

Congener, means species within the same genus.

Ecological character, defined under Resolution IX.1 Annex A: 2005 of the Ramsar Convention as, the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.

Epibenthic fauna, means relatively large mobile invertebrates associated loosely with seagrass beds.

Epiphytes, means algae, larger in size than periphyton, which grows on seagrass leaves.

Expert opinion, in the context of interpreting LACs relates to competent, experienced, independent individuals that have formal qualifications or otherwise expert knowledge in the disciplines of wetland ecology, hydrology or associated fields.

IBRA bioregion, refers to Interim Biogeographic Regionalisation for Australia (IBRA). IBRA is a biogeographic regionalisation of Australia developed by the Australian Government's Department of the Environment, Water, Heritage and the Arts. It was developed for use as a planning tool, for example for the establishment of a National Reserve System.

IMCRA bioregion, refers to the Interim Marine and Coastal Regionalisation for Australia (Mesoscale) to the 200 meter isobath and derived from biological and physical data, (e.g. coastal geomorphology, tidal attributes, oceanography, bathymetry and intertidal invertebrates). IMCRA is the marine equivalent of IBRA.

Infauna, means invertebrates that inhabit the spaces between sand and sediment.

Mangrove, means mangrove habitat consisting of mangrove trees and shrubs and their associated faunal communities.

Meroplankton, organisms that are planktonic for only a part of their life cycles.

Mesotidal, means the tidal area between high and low tide marks.

Microphytobenthos, means the surface biofilms of phytosynthetic micro-algae and bacteria.

Mobile epifauna, means the small, mobile invertebrates associated with the surface of the sediment.

National Framework document, refers to the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008) and its successive documents as endorsed by the Natural Resource Management (NRM) Ministerial Council.

Nektobenthic, refers to organisms that swim near the bottom of a sea or lake.

Nekton, refers to an aggregate of actively swimming aquatic organisms in a body of water that is able to move independently of water currents.

Parapatry speciation, is a form of speciation that occurs due to variations in mating frequency of a population within a continuous geographical area.

Periphyton, means thin biofilms of microbes growing on seagrass leaves.

Podsol, means a soil having an upper organic layer overlying a light coloured layer leached of fines and nutrients by downwards percolation of water.

Prograding, with respect to a shoreline, means one that is being built seaward, or outwards to a lake or embayment, by accumulation of sediment.

Ramsar Criteria, refers to the nine criteria for the listing of a site as internationally significant under the provisions of the Ramsar Convention. Also referred throughout the report as the 'Nomination Criteria' for the site.

Sedimentation, means the process of deposition of sediment of any size. This is often colloquially referred to as siltation, but this term implies that only silt-sized material is deposited.

Sessile epifauna, means small invertebrates attached permanently to seagrass stems or leaves.

Shorebirds, as used in this report, refer to both resident and migratory species which are ecologically dependent upon wetlands from the following families: Scolopacidae; Burhinidae; Haematopodidae; Recurvirostridae; Charadriidae; and Glareolidae. Shorebirds form a sub-set of the waterbird grouping.

Suspended sediment load, means the load (mass per unit time) of material transported by a river being carried in suspension.

Values, means the perceived benefits to society, either direct or indirect that result from wetland functions. These values include human welfare, environmental quality and wildlife support.

Waterbirds, as used in this report, refers to those species which are ecologically dependent upon wetlands from the following families: Anseranatidae, Anatidae, Podicipedidae, Anhingidae, Phalacrocoracidae, Pelecanidae, Ardeidae, Threskiornithidae, Ciconiidae, Gruidae, Rallidae, Scolopacidae, Rostratulidae, Jacanidae, Burhinidae, Haematopodidae, Recurvirostridae,

Charadriidae, Glareolidae, Laridae and Sternidae (after Kingsford and Norman 2002; Wetlands International 2006). Only those species of gulls (Laridae) and terns (Sternidae) which make extensive use of shallow, inshore waters or inland wetlands are included. Whilst at least some other species of other families traditionally regarded as "seabirds" (i.e. Spheniscidae, Phaethontidae, Sulidae, Fregatidae, Stercorariidae and Alcidae) also make use of shallow, inshore waters (and thus could be therefore be considered as waterbirds), these have not been included in the waterbird group (following precedent within Wetlands, 2006).

Wetlands, is used in this report in the context of the definition under the Ramsar Convention which includes, areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

Wetland-dependent terrestrial fauna, in the context of this report relates to fauna species that occur within or otherwise are dependent on wetland habitats but do not spend the majority of their life cycle underwater (e.g. non-aquatic species). As such this grouping primarily relates to birds, amphibians such as frogs, non-aquatic mammals such as water mouse, non-aquatic reptiles and terrestrial invertebrates.

Wetland flora, in the context of this report relates to flora species that are characterised as wetland or wetland-dependent species or populations.

Wetland ecosystem components, as defined in the ECD National Framework document, are the physical, chemical and biological parts or features of a wetland.

Wetland ecosystem processes, as defined in the National Framework document, are the dynamic forces within the ecosystem between organisms, populations and the non-living environment. Interactions can be physical, chemical or biological.

Wetland ecosystem benefits or services (includes the term ecosystem services), as defined in the National Framework document, are the benefits that people receive from wetland ecosystems. In general, benefits and services are based on or underpinned by wetland components and processes and can be direct (e.g. food for humans or livestock) or indirect (e.g. wetland provides habitat for biota which contribute to biodiversity).

APPENDIX A: METHODOLOGY USED IN SELECTION OF CRITICAL ELEMENTS

This Appendix provides a discussion on how the critical ecosystem services/benefits, critical components and critical processes were selected.

A1 Methodology – Information Collation and Review Stage

The first step in ECD preparation outlined in the National Framework document is to identify the wetland services/benefits, wetland components and wetland processes present in the Ramsar site. These key terms are defined in Section 1 of the Report and the Glossary (refer Section 7). This was initiated by undertaking a process of information collation and literature review.

As part of the information collation phase, literature and existing data relevant to the study area (site boundary and surrounds) were collated and reviewed. Relevant existing information was sourced from the following:

- published scientific papers
- database records (e.g. EPBC, Wildnet.)
- mapping products developed by the DERM (e.g. RE mapping, wetland mapping)
- management plans, strategies and other policy documents
- grey literature from internet searches and other sources of data.

Each article of information was collated to a cursory level sufficient to determine its relevance to the study. The collected information was then reviewed to prioritise and identify information of direct relevance to the ECD.

As part of the information collation phase, key information sources to be used in the study were presented to the project KMC and gaps were identified on the basis of these reviews. In some cases, additional information was supplied directly by Knowledge Committee representatives.

Some experts and researchers in relevant fields were also contacted and interviewed as part of the study as outlined in Appendix A.

A2 Methodology – Selection of Critical Services

Following the information collation and review phase, the study team collectively identified the potential ecosystem services/benefits of the wetland. This process was based primarily upon a review of the literature and professional opinion. Wetland ecosystem benefits/services were identified first as a means of facilitating the identification of the wetland ecosystem processes and wetland specific components (e.g. wetland habitat types and noteworthy flora and fauna species) that underpin these services.

Using the categories and list of services/benefits from the National Framework as a guide, it was apparent that the Shoalwater and Corio Bays Area Ramsar site provides a broad spectrum of ecosystem services/benefits. This included: provisioning services such as provision of food in the form

of fisheries resources, regulatory services such as erosion protection and water quality maintenance, cultural services such as scientific research, and supporting services such as biodiversity and the presence of endangered and vulnerable species.

With the full range of ecosystem services/benefits, components and processes represented, there was a need to identify the most important or critical in the context of the Ramsar site, and the supporting critical components and processes that contribute to delivery of those services.

Following the methodology within the National Framework, the assignment of a given wetland process, component or service/benefit as critical was guided by the following considerations:

- the service or underlying component/process is important for supporting one or more of the Ramsar nomination criteria under which the site was listed
- the service or component/process is an important determinant of the uniqueness of the site
- the service or component/process may be subject to change in short to medium time frames (<100 years) and/or the change will cause potentially significant consequences (e.g. change the ecological character).

As such, the Ramsar nomination criteria for the site were used as the primary consideration in selecting the critical services/benefits (principally relating to the wetland's ecological values) along with the selection of several cultural services such as site's recreation and tourism values and scientific research value which are considered to be important determinants of the site's uniqueness.

To supplement the criteria from the National Framework, additional consideration was given to suggestions or recommendations regarding critical services, components or processes by the Steering Committee and other wetland experts (particularly where such information was documented in scientific literature). Accordingly, the set of draft critical services/benefits were workshopped with the KMC at its 1st meeting in February 2009 and verified with minor revisions made as part of presentation of the services/benefits at its 2nd Meeting in April 2009.

A3 Methodology – Selection of Critical Components

The critical services/benefits are underpinned by the identification of critical component flora and fauna species and populations. In selecting these species/groups the following methodology was employed:

Flora Species

In nominating particular wetland flora species or communities for consideration under the critical components, the following considerations were applied:

- species should generally occur in aquatic environments (e.g. macrophytes) or are otherwise considered to be wetland-associated species or communities
- species or communities should be listed as threatened (i.e. vulnerable or endangered) at the National (threatened under EPBC Act) and/or International (i.e. IUCN) level or are considered to be particularly noteworthy or critical from a regional biodiversity perspective (i.e. refer to nomination criteria 3). This includes species or communities that are perceived by the authors to be iconic to the site, or are designated as threatened under Queensland legislation (i.e. endangered or vulnerable at a State scale).

Fauna Species

In nominating particular fauna species/groups for consideration under the critical components, the following considerations were applied:

- species should generally occur in aquatic or marine environments or are otherwise considered to be wetland-dependent terrestrial species (refer Glossary in Section 7 for definitions of these terms). Key wetland-dependent terrestrial species are listed in the species list in Appendix C of the ECD

- species should be either:

    a. designated as threatened (e.g. endangered or vulnerable) at a national-level (listed as threatened under the EPBC Act) or international-level (i.e. threatened under IUCN Red List)

    b. particularly noteworthy or critical from a regional biodiversity perspective (i.e. refer to nomination criteria 3 or 7). This includes species that are perceived by the authors to be iconic to the site, or are designated as threatened under Queensland legislation (i.e. endangered or vulnerable at a State-level under the NCA).

- given the boundaries of the Ramsar site are largely confined to near-shore areas or internal waters, emphasis has been placed on inclusion of those species that use the site as core habitat, have significant population numbers and spend a large proportion of their life cycle within the site boundaries. This excludes vagrant species of conservation significance such as whales, sharks and migratory seabirds that may only occur in the Ramsar site infrequently but for which species records within the site exist.

Populations

Populations of wetland biota that form the critical components are more generic groupings that recognise the abundance and diversity of animals that utilise the various wetland habitats of the site. This includes for example, amphibians, reptiles, mammals, fish, birds and aquatic invertebrates.

A4 Methodology – Selection of Critical Processes

As wetland ecosystem processes listed in the National Framework tend to be generic and applicable to all wetland systems, critical ecosystem processes were selected as critical in this ECD on the basis that they underpin a critical service/benefit or component or are otherwise considered to be an important determinant of the site's unique character.

APPENDIX B: SUMMARY TABLES FOR CRITICAL SERVICES/ BENEFITS, COMPONENTS AND PROCESSES

This Appendix contains summary tables of information supporting the text in Section 3 of the report with respect to critical services/benefits.

Table B-1 Summary – 1

Summary Table	Representative Wetland Types
Justification for inclusion as 'critical'	The representativeness of habitats as a critical service is underpinned by Ramsar Nomination Criterion 1.
Description of service (quantify if possible)	The Ramsar site supports a diversity of wetland habitat types that are representative of the bioregion, display a high degree of connectivity and are in a natural or near-natural condition.
Spatial application (if relevant)	Whole of site
Critical components underpinning this service	Nine coastal and nine inland wetland types
Critical processes underpinning this service	Broad-scale wetland processes; noting that individual wetland habitats will be influenced by a range of local/site specific processes.
Natural variability (if relevant)	The geomorphology and biotic components of the wetland habitats of the Bay have formed over thousands of years, in a sedimentary environment that is characterised by major fluctuations in sea level. The near natural and representative environments that occur in the site and lack of direct threats are indicative that there is natural stability in the system that will retain these habitats in the long term in the absence of anthropogenic influences. Notwithstanding, wetland environments can show significant seasonal/local variation depending on key drivers such as rainfall, hydrological inputs, nutrients, and sedimentation. Particular habitats will be more susceptible to temporary disturbance (be it natural or of anthropogenic origin) than others. For example, seagrass, coral reefs, freshwater swamps and similar environments are highly dependent on stable water quality conditions whereas mangroves and saltmarsh will be highly resilient to more intense and even persistent impacts.
Potential changes to ecological character since listing	This service/benefit continues to be provided by the site at the time of preparation of this ECD and no ecological character change is perceived to have occurred,
Key threats	Potential threats are listed above. Given the history of controlled usage and management of the site for largely conservation purposes, the largest threat to the ecological condition of habitats is likely climate change noting specific impacts could occur from establishment of new uses within or adjacent to the site in the future such as port infrastructure or sand mining activities.
Information/ knowledge gaps	There needs to be further guidance about the identification of the Ramsar wetland types such that more exact spatial data can be obtained or developed. This should be compatible where possible with State mapping methodologies such as that employed by DERM. In the meantime, the DERM dataset (using RE types as surrogates for vegetated Ramsar wetland types) provides a baseline for measuring the extent of various wetland types across the site in addition to detailed mapping of terrestrial and marine vegetation presented within DoD 2009.
Monitoring needs	Assignment of more detailed definitions and provision of spatial data for each of the wetland types in the Ramsar site such that a baseline for each wetland type represented in the site can be monitored over time.

Table B-2 Summary – 2

Summary Table	Rare Wetland Types
Justification for inclusion as 'critical'	The site supports a rare wetland type in a natural condition (Criterion 1)
Description of service (quantify if possible)	A suite of peat-based sedge/heath wetlands (fens) that are a rare wetland type in the bioregion occur within the site.
Spatial application (if relevant)	Dismal Swamp; Freshwater Beach swamps and Clinton Lowlands
Critical components underpinning this service	Dense sedge-heath communities
Critical processes underpinning this service	• Freshwater wetland geomorphology (topography). • Freshwater wetland hydrology (groundwater). • Climate (precipitation). • Freshwater wetland energy and nutrient cycling (decomposition). • Freshwater wetland physico-chemical processes (pH).
Natural variability (if relevant)	Peat lands probably become dry at a multi-decadal time-scale
Potential changes to ecological character since listing	None known – refer Jaensch (2008b).
Key threats	Fire, peat removal, alteration to hydrology, ignorance, climate change
Information/ knowledge gaps	Little or no information is known about the fauna (frogs and fishes) supported by peat swamps within the site, and limited information is available on their flora. As such, a comprehensive inventory of peat swamp flora and fauna species forms a major knowledge gap for this service. Additionally, investigation is required on patterned areas in the larger swamps in order to establish whether or not these are 'patterned fens' which are extra-high conservation value assets, particularly under tropical conditions where average ambient temperatures and decomposition rates are much higher (Jaensch 2008b).
Monitoring needs	• Determine fauna and flora communities associated with peat lands. • Assess condition of peat lands over time and correlate with parameters such as climatic variables. • Investigate extent of patterned fens within the site.

Table B-3a Summary – 3a

Summary Table	Terrestrial Wetland Fauna Species
Justification for inclusion as 'critical'	Key services provided by the site in regards to threatened fauna comply with the Ramsar Nomination Criteria 2, and Criteria 4, in respect to support for animal species at critical life stages in their life cycles.
Description of service (quantify if possible)	There is a site record for water mouse *Xeromys myoides,* and potentially suitable habitat for Australasian bittern *Botaurus poiciloptilus*
Spatial application (if relevant)	This service applies to the whole site, though important habitats and localities are: • intertidal habitats especially those backed by wide swathes of mangroves (water mouse, e.g. western side of Shoalwater Bay) • mangrove wetlands (water mouse feeding/refuge/breeding habitat, e.g. eastern Shoalwater Bay, Port Clinton, and Shoalwater Creek area) • freshwater marshes and wooded swamps (Australasian bittern, e.g. Dismal Swamp, and Clinton Lowlands area).
Critical components underpinning this service	• habitat - mangrove forest and associated intertidal areas (water mouse), fresh and brackish sedgeland (water mouse and Australasian bittern), supralittoral wetlands (including saltmarsh and sedgelands) (water mouse and Australasian bittern). • food – intertidal crustaceans, pulmonate snails, marine gastropods and other invertebrates (water mouse); and crustaceans, aquatic invertebrates and small aquatic vertebrates (Australasian bittern).
Critical processes underpinning this service	• water quality • hydrology – maintenance of natural patterns of tidal inundation (water mouse) and freshwater flows to intertidal and supralittoral wetland systems (Australasian bittern and water mouse).
Natural variability (if relevant)	No suitable data available for either species. The combination of unpredictable occurrence and cryptic habits of the Australasian bittern create significant constraints to the assessment of abundance and natural variability.
Potential changes to ecological character since listing	No available data.
Key threats	Impacts to required habitat resources (including food) and conditions through water quality degradation, altered freshwater inflows, and changes to native vegetation cover.
Information/ knowledge gaps	• no target surveys for water mouse or Australian bittern • extent of populations of water mouse within site and outside/adjoining site boundaries.
Monitoring needs	Identify full extent of water mouse habitat within, and outside/adjacent to, the site and monitor nest activity and diversity of nest types as surrogate for species distribution and abundance (annual and during breeding period). As previously described, the combination of unpredictable occurrence and cryptic habits of the Australasian bittern create significant constraints to assessment of this species within the site. Use of surrogates such as mapped extent of potentially suitable habitat may be more useful.

Table B-3b Summary – 3b

Summary Table	Aquatic/Marine Fauna Species
Justification for inclusion as 'critical'	Dugong, green turtles and other turtle species and honey blue eye are listed under the EPBC Act as nationally threatened species. These species underpin the site's listing under the Convention with respect to Nomination Criterion 2.
Description of service (quantify if possible)	With respect to the aquatic/marine species of conservation significance, the site supports: • a critically important dugong population estimated to be one quarter of the regional population • one of the largest and least impacted foraging populations of green turtles in eastern Australia and is a key index site for monitoring green turtle populations. • populations of honey blue eye and contains possible habitat for Oxleyan pygmy perch.
Spatial application (if relevant)	Dugong – present primarily in the proximity of seagrass assemblages present in the shallow waters of Shoalwater Bay and Port Clinton Green Turtle – see above noting some evidence of habitat partitioning amongst foraging green turtle with smaller turtles occurring mostly in upper intertidal mangrove areas, rocky habitats and draining gutters Freshwater fish –freshwater swamps and lakes in the Dismal and Freshwater sector
Critical components underpinning this service	Seagrass is the key habitat type that underpins the usage of the site by foraging dugongs and green turtles The presence of wallum (acidic) freshwater swamps, lakes and streams support the populations of honey blue eye and possible Oxleyan pygmy perch
Critical processes underpinning this service	Ecosystem processes that underpin the populations include those processes that affect habitat availability which in the context of seagrass include hydrodynamics, water quality (principally water clarity), nutrient cycling and climate (temperature stress). Green turtles in the area also feed on mangrove fruit/seedlings and red algae that occur on mangrove trunks. Freshwater ecosystem processes that underpin the freshwater fish populations include groundwater processes such as maintenance of the water table, water quality (pH, dissolved oxygen and salinity) and geomorphology in terms of natural drainage patterns and soils.
Natural variability (if relevant)	There are no accurate estimates of population at a local scale for any of the key species noting that the populations of both dugong and green turtles are notable and significant at a regional level. Dugong populations are estimated to be 12 000 in the GBRMPA of which about 1700 are found in the Southern Region of the park (GBRMPA 1997). Honey blue eye populations have not been extensively studies on the site but as evidenced elsewhere will tend to be discrete within and between freshwater waterbodies on the site.
Potential changes to ecological character since listing	Based on the surveys undertaken to date and the low level of anthropogenic impacts, it is unlikely there have been any changes to the ecological character of these populations since listing
Key threats	Key threats to the key species are as follows: Dugong – historical net fishing caused mortality but has since been prohibited in most areas of SWBTA by establishment of a Dugong Protected Area and plan of management, Increased boat traffic in the area may increase the incidence of unintentional boat strike and propeller trauma. Turtle – boat strike, entanglement and propeller cuts; possible impact of *Lyngbya* blooms on food availability; papilloma disease and parasitic infection. Honey blue eye – change to groundwater or surface water hydrology and water quality; uncontrolled fire and/or access regimes; introduction of exotics (none are currently present on the site).
Information/ knowledge gaps	The extent and condition of dugong and turtle populations are largely known to the extent practicable as a result of continuing survey work. A possible gap here is the extent to which the beaches and islands of the Ramsar site are used by nesting turtles. The extent of honey blue eye and possible use of the freshwater habitats of the site by Oxleyan pygmy perch continues to be an information gap.
Monitoring needs	• Continue surveys of turtle and dugong. • Undertake survey of freshwater fish populations including to determine the presence/absence of the Oxleyan pygmy perch.

Table B-3c Summary – 3c

Summary Table	Flora Species
Justification for inclusion as 'critical'	Site supports nationally threatened wetland flora species (Criterion 2)
Description of service (quantify if possible)	Site supports one nationally endangered and one nationally vulnerable wetland-dependent flora species
Spatial application (if relevant)	Freshwater swamp forests and sedgelands
Critical components underpinning this service	*Phaius australis* (less swamp orchid)
Critical processes underpinning this service	• Freshwater wetland hydrology (surface water inflows/interaction, groundwater inflows/interaction). • Climate (precipitation, evaporation). • Freshwater biological processes (reproduction, recruitment, dispersal).
Natural variability (if relevant)	Unknown
Potential changes to ecological character since listing	None known
Key threats	Weeds, fire, feral animals, changes to hydrology, climate change
Information/ knowledge gaps	• Ecologic and biologic requirements of these two species within the site, e.g. habitats, fire, population dynamics, breeding biology. • Location and extent of populations of these two species within the site. • Targeted surveys for other threatened wetland species.
Monitoring needs	Conduct population surveys and investigate population viability

Table B-4 Summary – 4

Summary Table	Biodiversity
Justification for inclusion as 'critical'	Site supports populations of fauna and flora species important for maintaining the biological diversity of a particular biogeographic region (Criterion 3)
Description of service (quantify if possible)	Site supports significant biodiversity: • four hundred vertebrate species, including 22 frog species, 77 waterbird species and 32 shorebird species • at least 800 plant species • eight 'Of Concern' Regional Ecosystems.
Spatial application (if relevant)	Whole of site
Critical components underpinning this service	Nine coastal and nine inland Ramsar wetland types
Critical processes underpinning this service	• Hydrology. • Energy and nutrient dynamics. • Physico-chemical. • Climate.
Natural variability (if relevant)	Not known
Potential changes to ecological character since listing	None known
Key threats	• Land degradation and/or changes in land-use. • Changes to natural hydrology. • Inappropriate fire regimes. • Climate change.
Information/ knowledge gaps	• Spatial data on the extent of wetland types. • Datasets about the presence, natural history and natural variability of critical wetland flora and fauna species and their habitats within the Ramsar site.
Monitoring needs	• Establish site based monitoring programs to ensure the diversity and condition of wetlands is maintained. • Undertake surveys of populations within the Ramsar site. • Assess changes to populations (e.g. breeding success, mortality rates, health) and any applicable underlying wetland processes (e.g. water quality of key habitats).

Table B-5 Summary – 5

Summary Table	Critical Life Stages
Justification for inclusion as 'critical'	Key services provided by the site in regards to fauna comply with the Ramsar Nomination Criterion 4, in respect to support for wetland-dependent fauna at critical life stages in their life cycles.
Description of service (quantify if possible)	The site supports: • feeding and roosting habitat for 77 waterbird species and an abundance of more than 20,000 birds • non-breeding feeding and roost habitats for 26 migratory shorebird species including five species which exceed 1% population threshold which demonstrates an importance for shorebird migration • breeding habitat for a variety of waterbirds, including several species listed as threatened at the State level and/or occurring in significant numbers • feeding and breeding habitats for 22 frog species • feeding and breeding for a variety wetland-dependent raptors • feeding habitat for dugong and green turtle • nesting habitat for flatback turtles.
Spatial application (if relevant)	This service applies to the whole site, though important habitats and localities are: • intertidal habitats (shorebird feeding habitat, e.g. Shoalwater Bay, Island Head Creek, Port Clinton, around Leicester Island and on the western side of Townshend Island), especially those backed by wide swathes of mangroves (water mouse feeding habitat) • sand spits and beaches (shorebird and tern roosts, e.g. Sandy Point, Shoalwater Creek estuary, Island Head Creek estuary, Ross Creek estuary, West Point and Sandy Point; and little tern breeding sites, e.g. Port Clinton, Island Head Creek estuary, and Sandy Point) • off shore islands (tern and pelican breeding sites, e.g. northern islands, especially Akens Island; and beach stone-curlew feeding/roost/breeding habitat, especially Leicester Island) • mangrove wetlands (shorebird feeding/roost habitat and water mouse refuge/feeding/breeding habitat, e.g. eastern Shoalwater Bay, Port Clinton, and Shoalwater Creek area) • freshwater marshes (frog feeding/breeding habitat, e.g. Dismal Swamp, Manifold Hills area (Dismal Sector), Water Park Creek catchment, and Clinton Lowlands area) and wooded swamps (frog feeding/breeding habitat, and raptor breeding habitat) • seagrass beds for dugong and green turtle feeding • shores of Akens Island for flatback turtle nesting.
Critical components underpinning this service	Maintenance of the following: • diversity of feeding habitats (e.g. intertidal flats, protected shallow open waters, mangroves, saltmarsh, and rocky shores) and a diversity of feeding substrates (e.g. soft muds and sands, including intertidal substrates supporting seagrass) • diversity of disturbance-free roost sites, above and below HAT (e.g. exposed sand banks, sand spits, clay pans, saltmarsh) which are spatially proximate to suitable feeding grounds, and disturbance-free beach nesting sites above HAT • diversity of freshwater marshes and wooded swamps • water quality to a level required to support high primary and secondary bioproductivity • seagrass beds.

Summary Table	Critical Life Stages
Critical processes underpinning this service	Maintenance of the following: • maintenance of natural patterns of tidal inundation. Tidal inundation influences intertidal feeding habitat characteristics, i.e. overall extent, bioproductivity and daily availability to shorebirds. Tidal and wave regimes influence the biophysical processes in the development and maintenance of feeding and roost habitats • freshwater flow regimes to support freshwater wetland characteristics and buffers to increasing salinity levels • primary and secondary bioproductivity of aquatic flora (including sea grass), algae and micro- and macro-invertebrates within shallow saline, brackish and freshwater wetland habitats are crucial processes in supporting adequate food requirements.
Natural variability (if relevant)	Patterns in abundances of all fauna species are thought to vary across a range of spatial and temporal scales, though suitable site-specific data is either absent or is not sufficiently robust to assess natural variability (though noting that there is comparatively more data for shorebirds and terns than any other species or fauna group subject to this service; see also comments within table relevant to service 6 in regards to shorebirds and off-site influences on site shorebird population).
Potential changes to ecological character since listing	Data is either not available or inconclusive in regards to determining potential changes to ecological character of the site which in turn, have relevance to vertebrate fauna subject to this service.
Key threats	A summary of the conclusions in regards to fauna subject to this service (and the habitat relied upon) within the site, are as follows (though see further detail in service 6): • Shoalwater Bay section: no significant disturbances or threats to migratory shorebirds identified; minor disturbance to intertidal habitats due to human activities; restricted and localised areas of disturbance to mangrove wetlands on the western side some coastal erosion noted (though linked to "natural" causes); presence of weeds and feral animals noted within freshwater swamps though no significant impacts; and evidence of fire damage to notable areas of peat in the central swamp on the Clinton Lowlands constitutes a significant disturbance (but presumably linked to "natural" causes) though recognising there is a high potential for fire (arising from adjoining dryland habitats) to result in significant damage to peat deposits within freshwater swamps during dry conditions. (Jaensch 2008a and b); presence of foxes recorded near shorebird roost sites (though abundance considered to be low and ongoing fox control program has been implemented (Mulville 2006 in DoD 2009); restricted and localised disturbance associated with Defence low-flying aircraft activities around Townshend Island (though significance considered to be relatively minor (O'Neill and Holmes 2000, DoD 2009) • Corio Bay section - disturbance to waterbirds resulting from recreational activities, including off-road vehicles. Disturbance to roosting shorebirds and terns and breeding shorebirds and terns at the Sandy Point is considered to be significant (Houston and Mitchell 1997). Freshwater stream and associated habitat within the upper Water Park Creek catchment, the systems of parabolic dunes, swamps and sink • holes in the Manifold Hills area (Dismal Sector) are the only stream habitats included within site (Lee Long 2007). The Water Park Creek catchment drains south from the site through forestry plantations and freehold semi-rural lands before re-entering the Corio Bay section of the site. As a result, there is potential for water quality degradation of inflows to the Corio Bay section of the site (Lee Long 2007). • recreational boating has markedly increased in recent years throughout the site (DoD 2009, C. Mulville pers. comm. 2009). These activities have the potential to generate disturbances to feeding and roosting shorebirds. Whilst no formal monitoring is currently undertaken to investigate impacts to waterbirds, anecdotal information indicates that at present, impacts are considered to be low in the Shoalwater Bay section, though potentially of greater significance within the Corio Bay section where activity levels are higher (C. Mulville pers. comm. 2009).
Information/ knowledge gaps	• Abundance and distribution of water mouse within site. • Systematic and seasonal data on waterbird populations within the Corio Bay section. • Measures of breeding success for waterbirds (northern islands, especially Akens Island), little tern (sites at Port Clinton, Island Head Creek estuary, and Sandy Point), northern islands, and beach stone-curlew (especially on Leicester Island). • Impact to waterbirds (disturbance at roosts and breeding sites) arising from increasing levels of recreational activity (boating, off-road vehicles, human activity and companion animals).

Summary Table	Critical Life Stages
Monitoring needs	• Monitoring of recreational usage of site, especially in relation to access and activities in and around waterbird roost and breeding sites (especially areas including Sandy Point and northern islands). • Feral animal monitoring to inform eradication programs, especially feral pigs in the freshwater wetlands and foxes (especially around waterbird roosts and breeding sites). • Fire prone dryland habitats surrounding freshwater swamps, especially those peat wetlands within the Clinton lowlands, in order to inform potential fire management planning. • Water quality within Water Park catchment, in order to inform management planning for freshwater wetlands, especially within the Corio Bay section of the site.

Table B-6 Summary – 6

Summary Table	Waterbird Populations
Justification for inclusion as 'critical'	Key services provided by the site in regards to migratory shorebirds complies with Ramsar Nomination Criterion 5 in regards to shorebird abundance, and Criterion 6, in regards to exceeding the 1% species population threshold for six shorebird species (five migratory and one resident species).
Description of service (quantify if possible)	The site supports: • feeding and roosting habitat for 32 shorebirds species, and an abundance of in excess 20,000 birds (mainly shorebirds, though including other waterbirds) • feeding and roost habitats for 26 migratory shorebird species including five species which exceed 1% population threshold for the flyway, i.e. grey-tailed tattler *Heteroscelus brevipes*, bar-tailed godwit *Limosa liponica*, eastern curlew *Numenius madagascariensis*, whimbrel *Numenius phaeopus*, and terek sandpiper *Xenus cinereus* • feeding, roost and breeding habitats for the resident shorebird species, the Australian pied oystercatcher *Haematopus longirostris*, which has been recorded in numbers which exceed 1% population threshold for the flyway • feeding, roost and breeding habitats for a notable population of beach stone-curlew *Esacus magnirostris* which has been recorded in numbers which exceed the 1% threshold for the Australian population, though less than the 1% threshold for whole flyway population.
Spatial application (if relevant)	This service applies to the whole site, though important habitats and localities are: • intertidal feeding habitats, especially Shoalwater Bay, Island Head Creek, Port Clinton, around Leicester Island and on the western side of Townshend Island • sand spits and beaches - roost sites, especially Shoalwater Creek estuary, Island Head Creek estuary, Ross Creek estuary, West Point and Sandy Point (though also as breeding sites for pied oystercatcher and beach stone-curlew) • off shore islands – feeding and roost sites. Leicester Island being of particular importance for beach stone-curlew • mangrove wetland shorebird feeding and roost habitat, e.g. eastern Shoalwater Bay, Port Clinton, and Shoalwater Creek area.
Critical components underpinning this service	• Diversity of feeding habitats (e.g. intertidal flats, protected shallow open waters, mangroves, saltmarsh, and rocky shores) and a diversity of feeding substrates (e.g. soft muds and sands, including intertidal substrates supporting seagrass). • Diversity of disturbance-free roost sites, above and below HAT (e.g. exposed sand banks, sand spits, clay pans, saltmarsh) which are spatially proximate to suitable feeding grounds, and disturbance-free beach nesting sites above HAT for resident shorebirds.
Critical processes underpinning this service	• Natural patterns of tidal inundation. Tidal inundation influences intertidal feeding habitat characteristics, i.e. overall extent, bioproductivity and daily availability to shorebirds. Tidal and wave regimes influence the biophysical processes in the development and maintenance of feeding and roost habitats. • Freshwater flow regimes to support freshwater wetland characteristics and buffers to increasing salinity levels. • Primary and secondary productivity of aquatic flora (including seagrass), algae and micro- and macro-invertebrates within shallow saline, brackish and freshwater wetland habitats are crucial processes in supporting adequate food requirements.
Natural variability (if relevant)	Patterns in abundances of both resident and migratory shorebirds are known to vary across a range of spatial and temporal scales, though suitable site-specific data is either absent or is not sufficiently robust to use. In regards to migratory shorebirds, populations are known to fluctuate between seasons and are likely to change between years (though in regards to the latter, current data does not indicate any significant change in abundance or species richness between 1995 and 2007 surveys). The causes for potential change in abundance may be influenced by local factors and/or by external factors (i.e. declines linked the loss of habitat at critical stopover locations on migration routes; Gosbell and Clemens 2006). Such losses may eventually reduce the numbers of migratory shorebirds using Shoalwater Bay and monitoring of migratory shorebirds within the site will need to take account of disturbances external to the site though liaison with researchers in the Flyway.
Potential changes to ecological character since listing	Data is either not available or inconclusive in regards to determining potential changes to ecological character of the site which in turn, have relevance to shorebirds, though noting the findings of Jaensch (2008a) that current data does not indicate any significant change in shorebird abundance or species richness between 1995 and 2007 surveys.

Summary Table	Waterbird Populations
Key threats	A summary of the conclusions of Jaensch (2008a) of relevance to shorebirds (and the habitat relied upon) within the Shoalwater Bay section of the site, are as follows: • no significant disturbances or threats to migratory shorebirds identified • direct human impact on intertidal habitats almost negligible (minor damage to the edges of some salt flats – vehicle tracks). Condition of the mangrove wetlands exceptionally good, and where subject to damage/loss (occurrence rare), degradation was limited to exposed or high stress situations on the western side with losses/degradation linked to "natural" causes. Some localised areas of coastal erosion noted (manifest in damage to some beaches and adjacent dryland vegetation, particularly on the western side), though losses can be explained by "natural" causes. Other threats include: • feral animals - Foxes have been recorded near shorebird roost sites within the Shoalwater Bay section of the site (DoD 2009). Whilst there are no measures of abundance, fox numbers may be low and an ongoing fox control program has been implemented through the marine parks management program at six coastal sites with the Shoalwater Bay section (Mulville 2006 in DoD 2009). The area between the Shoalwater Bay and Corio Bay sections of the site (forestry plantations and rural lands of the Water Park Creek catchment) are a potential source of feral animal invasion into the site, though at present, the extent of potential impact has not been fully assessed (Lee Long 2007). • recreational impacts – Recreational boating has markedly increased in recent years and these activities have the potential to generate disturbances to feeding and roosting shorebirds (DoD 2009). Whilst no monitoring is currently undertaken to investigate what impacts may be occurring, impacts are considered to be relatively minor in the Shoalwater Bay section and potentially of greater significance within the Corio Bay section where activity is higher C. Mulville pers. comm. 2009). Recreational activities, including use of off-road vehicles, create significant disturbances to roosting waders and terns at the Sandy Point, and potentially affect breeding success of resident shorebirds and terns, including beach stone-curlew and little tern (Houston and Mitchell 1997). Disturbance to feeding and roosting shorebirds resulting from defence low-flying aircraft activities are mainly focused on the two aircraft target sites on Townshend Island. Monitoring of shorebirds to investigate the behavioural responses to over-flying jet aircraft has been undertaken (O'Neill and Holmes 2000). The findings of this work suggests that responses were minor and temporary, with birds lifting into the air and circling around for less than one minute before landing and continuing to feed. No response was recorded from any bird roosting in mangroves. It was concluded that the present levels and type of aircraft use at Townshend Island cause only biologically insignificant disturbance to shorebirds in surrounding areas, and probably cause no more impact than boat traffic. Due to the irregularity of flights over Townshend Island, it is unlikely that birds have become habituated to aircraft. Given the documented condition and status of migratory shorebird and other bird populations in SWBTA it is considered that any threat posed by low-flying aircraft in the Area is minimal, and cannot be regarded as a current pressure (DoD 2009).
Information/ knowledge gaps	• Systematic and seasonal data on shorebird populations within the Corio Bay section. • Measures of abundance and breeding success for beach stone-curlew (especially on Leicester Island) and Australian pied oystercatcher. • Impact to shorebirds (particularly disturbance at roosts and breeding sites) arising from increasing levels of recreational activity (boating, off-road vehicles, human activity and companion animals).
Monitoring needs	• Monitoring of recreational usage of site, especially in relation to access and activities in and around waterbird roosts and breeding sites (especially areas including Sandy Point and northern islands). • Feral animal monitoring to inform eradication programs, especially feral pigs in the freshwater wetlands and foxes (especially around waterbird roosts and breeding sites). • Corio Bay section – implement shorebird population monitoring to complement program methods and timing as employed by Jaensch (2008a). The first systematic "baseline" event should be implemented ASAP, then every 3-10 years (and to be synchronised with continuation of monitoring program within the Shoalwater Bay section so as to create an integrated "whole of site" approach). • Shoalwater Bay section – implement shorebird population monitoring every 3-10 years, based on methods and timing employed by Jaensch (2008a) (e.g. large sample of high tide roosts through helicopter surveys complemented by ground-truthing at selected sites).

Table B-7 Summary – 7

Summary Table	Fish Diversity and Endemism
Justification for inclusion as 'critical'	The site (particularly in the Shoalwater Bay section) shows considerable fish species diversity (at a bioregional and national scale) and also includes species that may be endemic to the site. These are key considerations in the context of Criterion 7.
Description of service (quantify if possible)	Refer text – The Shoalwater Bay section of the site supports 12% of Australia's marine fish fauna and 14.6% of Australia's freshwater fish fauna. Less species diversity is present at Corio Bay.
Spatial application (if relevant)	Coastal waters of the Ramsar site
Critical components underpinning this service	Fish diversity is underpinned by habitat availability and quality. For marine fish and invertebrates, the presence of extensive seagrass, mangroves, saltmarsh and similar habitats provide nursery habitat that support fish diversity and abundance. The diversity and quality of freshwater habitats is documented as the key supporter of freshwater fish diversity as well as the absence of exotic/invasive pest species.
Critical processes underpinning this service	Key processes that underpin fish diversity include hydrological and hydrodynamic processes, water quality, geomorphology including the topography and diversity of habitat types, groundwater processes for freshwater habitats and climate.
Natural variability (if relevant)	Studies of fish and invertebrate diversity in Corio Bay between 1974 and 2007 showed similar levels of diversity and dominant taxa. There have not been comparable surveys of fish and invertebrate diversity within the Shoalwater Bay section since the 1993 surveys by Trnski.
Potential changes to ecological character since listing	Given the lack of anthropogenic impacts on the coastal waters of the site and the conservation regime of the waters of the site in marine parks and declared fish habitat areas, it is unlikely that there have been any negative changes to ecological character since listing in terms of fisheries condition and diversity.
Key threats	Threats to fisheries diversity are considered to be minor given the presence of strong conservation controls in the coastal waters of the site. Commercial and recreational fishing can occur in Pearl Bay (outside of the green zones of the Marine Park) as well as recreational fishing within the declared Fish Habitat Area of Corio Bay but there is not any documented evidence or discussion of significant impacts in the literature from commercial and/or recreational fishing on fish abundance and diversity.
Information/ knowledge gaps	Since the Trnski survey of fishes in 1993, there has not been a follow up survey of fish diversity in SWBTA. There has only been a limited survey of marine macroinvertebrates in the Triangular Island area in 1981. In order to confirm that ecological character has not changed and to better define natural variability, further surveys are warranted. This survey should also follow up on the presence/absence of more temperate species found by Trnski whose distribution may also now be affected by initial climate change warming trends. Follow up studies of the ecological health of Corio Bay currently being undertaken by the Central Queensland University (funded by the Fitzroy Basin Association) should provide much needed baseline information about the condition and trends with respect to Corio Bay
Monitoring needs	See above – fish and broad scale invertebrate surveys within the Shoalwater Bay area are likely to be the most significant monitoring need

Table B-8 Summary – 8

Summary Table	Fisheries Nursery Habitat Values
Justification for inclusion as 'critical'	The site supports critical nursery habitat for species of recreational and commercial significance which is a key element of Ramsar nomination criteria 8.
Description of Service (quantify if possible)	Key habitats that support nursery functions for fisheries and macroinvertebrates include seagrass, mangroves and saltmarsh, and rocky reefs.
Spatial Application (if relevant)	Seagrasses are found extensively within the Shoalwater Bay, Island Head Creek and Port Clinton areas of the Shoalwater Bay section. Extensive mangroves and saltmarsh are found along both banks of Shoalwater Bay, the eastern margin of Townshend Island, Island Head Creek and Port Clinton. Mangroves and saltmarsh are also present throughout Corio Bay and its main tributaries. Rocky Reefs are found along the headlands of the Shoalwater Bay section and in the deeper channels of Port Clinton and Shoalwater Bay.
Critical components underpinning this service	Critical component habitat types are listed above.
Critical processes underpinning this service	Critical processes that underpin fish nursery habitat quality include hydrological and hydrodynamic processes (including freshwater flows), water quality, geomorphology including the topography and diversity of habitat types, groundwater processes for freshwater habitats and climate.
Natural Variability (if relevant)	The natural variability of key habitat types is not generally known but likely to be stable given the lack of anthropogenic impacts. The extent of seagrass communities did not change markedly between 1997 and 2007 surveys but some species distribution changes were detected. Local dieback or stress is likely the result of natural hydrodynamic and sediment transport processes or coastal storm events. DoD 2009 reports that the mangrove communities of the site have not been grossly modified and remain in excellent condition as do the saltmarsh communities.
Potential changes to ecological character since listing	Given the lack of anthropogenic impacts on the coastal waters of the site and the conservation regime of the waters of the site in marine parks and declared fish habitat areas, it is unlikely that there have been any negative changes to ecological character since listing in terms of fisheries habitat condition. Some stressed melaleuca swamps along the Eastern coastal fringe of SWBTA were observed as part of recent condition assessments by Jaensch (2008) but are likely the result of drought and lack of freshwater flows and are currently recovering following wetter summer seasons. Naturally occurring Lyngbya blooms are also a threat to seagrass assemblages in the area though no significant blooms have occurred since 2002 (DoD 2009). Some impacts to saltmarsh habitats have been observed from feral pigs (DoD 2009). ORV usage in saltmarsh areas in the Corio Bay area may also be a potential threat.
Key threats	Threats to fisheries habitat are considered to be minor given the presence of strong conservation controls in the coastal waters of the site and use of the site and the lack of urban development pressure adjacent to the Shoalwater and Corio Bay sections of the site.
Information/ Knowledge gaps	The extent and condition of key habitats is generally well known. A possible information gap is setting up some monitoring to assess any impacts on key fisheries habitats in terms of climate change including for example, the extent of mangrove migration, the change in the mangrove to saltmarsh ratio and the extent and distribution of seagrass and rocky reefs.
Monitoring needs	See above

Table B-9 Summary – 9

Summary Table	Scientific Research
Justification for inclusion as 'critical'	The scientific values are unique determinants of the ecological character
Description of service (quantify if possible)	The site has scientific research values in terms of the pristine/near-natural condition of the wetlands.
Spatial application (if relevant)	Whole of site
Critical components underpinning this service	Nine coastal and nine inland Ramsar wetland types
Critical processes underpinning this service	• Hydrology. • Geomorphology. • Energy and nutrient dynamics. • Physico-chemical. • Biological. • Climate.
Natural variability (if relevant)	N/A
Potential changes to ecological character since listing	N/A – the service provided continues to be relevant since the time of listing.
Key threats	• Accessibility of the site for researchers. • Funding to support research.
Information/ knowledge gaps	Scientific research should aim to address knowledge gaps, such as: • investigating peat lands (e.g. inhabitant flora and fauna communities, extent, condition) • conducting threatened species surveys and assessments • collecting systematic and seasonal shorebird data • measuring breeding success and abundance of specific targeted species.
Monitoring needs	Research studies should continue to monitor wetland condition within the site. Specific monitoring studies could potentially include: • feral animal monitoring • water quality monitoring • population monitoring (e.g. abundance, breeding success of certain species).

Table B-10 Summary – 10

Summary Table	Water Supply
Justification for inclusion as 'critical'	The water supply values are unique determinants of the ecological character.
Description of service (quantify if possible)	The site has values in terms of the supply of water for Capricorn Coast communities as well as for domestic use by Defence
Spatial application (if relevant)	Water Park Creek catchment.
Critical components underpinning this service	• Ramsar wetland Type M (permanent rivers, streams or creeks). • Water quality.
Critical processes underpinning this service	• Freshwater wetland hydrology (surface water inflows/interaction). • Freshwater wetland physico-chemical processes (water quality). • Climate (precipitation, evaporation).
Natural variability (if relevant)	Variation within years (i.e. seasonally) and between years.
Potential changes to ecological character since listing	None known
Key threats	• Defence training activities (Shoalwater Bay section).
Information/ knowledge gaps	Establish local water quality guidelines using SWBTA water quality monitoring sites as references
Monitoring needs	Continue and review the water quality monitoring program

Table B-11 Summary –11

Summary Table	Wilderness Values
Justification for inclusion as 'critical'	The wilderness values are unique determinants of the ecological character.
Description of service (quantify if possible)	The site has wilderness values in terms of being a large, unfragmented natural landscape.
Spatial application (if relevant)	Whole of site.
Critical components underpinning this service	Nine coastal and nine inland Ramsar wetland types.
Critical processes underpinning this service	• Hydrology. • Geomorphology. • Energy and nutrient dynamics. • Physico-chemical. • Biological. • Climate.
Natural variability (if relevant)	N/A
Potential changes to ecological character since listing	N/A – the service provided continues to be relevant since the time of listing
Key threats	A variety of threatening processes have the potential to degrade the wilderness values of the site, for example: • lack of investment in land management activities including inappropriate fire regimes, invasion by weeds and feral animals. • alterations to hydrology. • climate change.
Information/ knowledge gaps	N/A
Monitoring needs	Monitoring requirements as outlined for other services are applicable.

APPENDIX C: SPECIES LIST

Table C-1 Angiosperms: Native dicotyledons recorded within SWBTA

Family	Scientific Name	Common Name
Acanthaceae	*Acanthus ilicifolius*	
	Brunoniella acaulis	
	Brunoniella acaulis subsp. *ciliata*	
	Brunoniella australis	blue trumpet
	Graptophyllum excelsum	
	Harnieria hygrophiloides	white karambal
	Hygrophila angustifolia	
	Hypoestes floribunda	
	Pseuderanthemum variabile	pastel flower
	Rostellularia adscendens	
	Rostellularia adscendens var. *juncea*	
Aizoaceae	*Carpobrotus glaucescens*	pigface
	Sesuvium portulacastrum	sea purslane
	Tetragonia tetragonioides	New Zealand spinach
Alangiaceae	*Alangium villosum*	
	Alternanthera denticulata	lesser joyweed
	Alternanthera nana	hairy joyweed
	Deeringia amaranthoides	redberry
	Nyssanthes diffusa	barbed-wire weed
Anacardiaceae	*Euroschinus falcatus*	
	Pleiogynium timorense	Burdekin plum
Annonaceae	*Fitzalania bidwillii*	
	Melodorum leichhardtii	
	Polyalthia nitidissima	
Apiaceae	*Apium prostratum* var. *filiforme*	
	Centella asiatica	
	Eryngium plantagineum	long eryngium
	Platysace ericoides	
	Platysace linearifolia	
Apocynaceae	*Alstonia constricta*	bitterbark
	Alyxia ilicifolia	
	Alyxia magnifolia	
	Alyxia ruscifolia	
	Alyxia spicata	
	Alyxia stellata	
	Carissa ovata	currantbush
	Cerbera dumicola	
	Cerbera manghas	
	Melodinus australis	southern melodinus
	Parsonsia eucalyptophylla	gargaloo
	Parsonsia lanceolata	northern silkpod
	Parsonsia larcomensis	
	Parsonsia leichhardtii	black silkpod
	Parsonsia longipetiolata	
	Parsonsia plaesiophylla	
	Parsonsia straminea	monkey rope
	Parsonsia velutina	hairy silkpod
Araliaceae	*Astrotricha intermedia*	
	Astrotricha longifolia	star hair bush
	Mackinlaya macrosciadea	

	Polyscias australiana	ivory basswood
	Polyscias elegans	celery wood
	Schefflera actinophylla	umbrella tree
Aristolochiaceae	*Aristolochia* sp.	
	Aristolochia thozaetii	
Asclepiadaceae	*Cynanchum bowmanii*	bowman's milkvine
	Cynanchum carnosum	
	Gymnanthera oblonga	
	Hoya australis	native hoya
	Hoya australis subsp. *australia*	native hoya
	Marsdenia brevis	
	Marsdenia fraseri	narrow-leaved milk vine
	Marsdenia rostrata	common milk vine
	Sarcostemma viminale subsp. *brunonianum*	
	Secamone elliptica	corky milk vine
	Tylophora sp.	
Asteraceae	*Actites megalocarpus*	
	Blumea saxatilis	
	Brachyscome microcarpa	
	Camptacra barbata	
	Cassinia subtropica	
	Centipeda minima	
	Centratherum australianum	
	Chrysocephalum apiculatum	yellow buttons
	Conyza aegyptiaca	
	Conyza leucantha	
	Cyanthillium cinereum	
	Eclipta prostrata	white eclipta
	Epaltes australis	spreading nutheads
	Glossocardia bidens	native cobbler's pegs
	Gynura drymophila	
	Helichrysum boormanii var. *tryonii*	
	Helichrysum lanuginosum	
	Helichrysum rupicola	
	Ixiolaena sp.	
	Langenifera sp.	
	Olearia canescens	
	Olearia nernstii	Ipswich daisy
	Ozothamnus cassinioides	
	Peripleura bicolor	
	Peripleura hispidula	
	Peripleura hispidula var. *setosa*	
	Picris angustifolia subsp. *carolorum-henricorum*	
	Podolepis arachnoidea	clustered copper-wire daisy
	Podolepis longipedata	tall copper-wire daisy
	Pseudognaphalium	
	Pterocaulon redolens	
	Pterocaulon serrulatum	
	Pterocaulon serrulatum var. *serrulatum*	
	Pterocaulon sphacelatum	applebush
	Rhodanthe polyphylla	
	Sigesbeckia orientalis	Indian weed
	Vittadinia sulcata	native daisy

	Wedelia spilanthoides	
	Wollastonia biflora	
	Xerochrysum bracteatum	golden everlasting daisy
Balanopaceae	*Balanops australiana*	
Balanophoraceae	*Balanophora fungosa*	
Bignoniaceae	*Pandorea jasminoides*	bower of beauty
	Pandorea pandorana	wonga vine
Bixaceae	*Cochlospermum gillivraei*	
Boraginaceae	*Argusia argentea*	octopus bush
	Cordia dichotoma	
	Heliotropium peninsulare	
	Heliotropium vagum	
	Trichodesma zeylanicum	
	Trichodesma zeylanicum var. *zeylanicum*	
Burseraceae	*Cananrium australascium*	mango bark
Caesalpiniaceae	*Caesalpinia bonduc*	nicker bean
	Caesalpinia nitens	
	Cassia brewsteri	
	Cassia sp. (Paluma Range G.Sankowsky+ 450)	
	Cassia tomentella	
	Chamaecrista absus var. absus	
	Chamaecrista concinna	
	Chamaecrista mimosoides	dwarf cassia
	Chamaecrista nomame	
	Chamaecrista nomame var. *nomame*	
	Senn planitiicola	
	Senna gaudichaudii	
	Senna surattensis	
	Senna x floribunda	
Campanulaceae	*Lobelia alata*	angled lobelia
	Lobelia membranacea	
	Lobelia stenophylla	
	Wahlenbergia gracilis	sprawling bluebell
Capparaceae	*Apophyllum anomalum*	broom brush
	Capparis arborea	brush caper berry
	Capparis canescens	
	Capparis sarmentosa	scrambling caper
	Capparis sepiaria	
Caryophyllaceae	*Polycarpaea breviflora*	
	Polycarpaea corymbosa	
	Polycarpaea spirostylis subsp. *compacta*	
Casuarinaceae	*Allocasuarina littoralis*	
	Allocasuarina luehmannii	bull oak
	Allocasuarina torulosa	
	Casuarina cunninghamiana	
	Casuarina equisetifolia	
	Casuarina equisetifolia subsp. *incana*	
Celastraceae	*Celeastrus subspicata*	large-leaved staff vine
	Denhamia pittosporoides	
	Elaeodendron melanocarpum	
	Hippocratea barbata	knotvine
	Maytenus disperma	orange boxwood
	Pleurostylia opposita	

	Siphonodon australis	ivorywood
Chenopodiaceae	*Atriplex semibaccata*	creeping saltbush
	Chenopodium carinatum	green crumbweed
	Dysphania littoralis	red crumbweed
	Einadia hastata	
	Einadia nutans subsp. *linifolia*	
	Einadia trigonos	
	Enchylaena tomentosa	
	Halosarcia sp.	
	Salsola kali	
	Sarcocornia quinqueflora subsp. *quinqueflora*	
	Suaeda australis	
	Tecticornia australasica	
Clusiaceae	*Calophyllum australianum*	
	Calophyllum inophyllum	beach calophyllum
	Hypericum gramineum	
Combretaceae	*Lumnitzera littorea*	
	Macropteranthes fitzalanii	
	Terminalia porphyrocarpa	
	Terminalia sericocarpa	damson
Convolvulaceae	*Convolvulus* sp.	
	Evolvulus alsinoides	
	Evolvulus alsinoides var. *decumbens*	
	Ipomoea littoralis	
	Ipomoea pes-caprae subsp. *brasiliensis*	goatsfoot
	Ipomoea plebeia	bellvine
	Ipomoea polymorpha	
	Jacquemontia paniculata	
	Polymeria calycina	pink bindweed
	Xenostegia tridentata	
Cucurbitaceae	*Mukia maderaspatana*	
	Neoachmandra cunninghamii	
Dilleniaceae	*Hibbertia diffusa*	
	Hibbertia hendersonii	
	Hibbertia linearis	
	Hibbertia linearis var. *floribunda*	
	Hibbertia linearis var. *obtusifolia*	
	Hibbertia salicifolia	
	Hibbertia scandens	
	Hibbertia sp.	
	Hibbertia stricta	
	Hibbertia velutina	
	Hibbertia vestita	
	Hibbertia vestita var. *vestita*	
Droseraceae	*Drosera angustifolia*	
	Drosera binata	forked sundew
	Drosera burmanni	
	Drosera indica	
	Drosera peltata	pale sundew
	Drosera pygmaea	
	Drosera spatulata	
Ebenaceae	*Diospyros australis*	black plum
	Diospyros fasciculosa	grey ebony

	Diospyros geminata	scaly ebony
	Diospyros humilis	small-leaved ebony
	Diospyros pentamera	myrtle ebony
Elaeagnaceae	*Elaeagnus triflora*	
	Elaeagnus triflora var. *triflora*	
Elaeocarpaceae	*Elaeocarpus eumundi*	Eumundi quandong
	Elaeocarpus grandis	blue quandong
	Elaeocarpus kirtonii	silver quandong
	Elaeocarpus obovatus	blueberry ash
	Elaeocarpus reticulatus	ash quandong
	Sloanea macbrydei	
Epacridaceae	*Acrotriche aggregata*	red cluster heath
	Brachyloma daphnoides	
	Brachyloma daphnoides subsp. *daphnoides*	
	Epacris microphylla var. *microphylla*	
	Leucopogon cuspidatus	
	Leucopogon flexifolius	
	Leucopogon imbricatus	
	Leucopogon leptospermoides	
	Melichrus ureolatus	jam tarts
	Monotoca scoparia	prickly broom heath
	Sprengelia sprengelioides	sprengelia
	Styphelia viridis	green five fingers
Euphorbiaceae	*Acalypha eremorum*	
	Acalypha sp.	soft acalypha
	Actephila bella	
	Actephila latifolia	
	Actephila lindleyi	
	Alchornea ilicifolia	native holly
	Alchornea thozetiana	
	Baloghia inophylla	scrub bloodwood
	Breynia oblongifolia	dwarf's apple
	Bridelia leichhardtii	scrub ironbark
	Chamaesyce alsiniflora	
	Chamaesyce dallachyana	mat spurge
	Chamaesyce macgillivrayi	asthma plant
	Chamaesyce mitchelliana	
	Chamaesyce psammogeton	
	Chamaesyce vachellii	
	Claoxylon tenerifolium	Queensland brittlewood
	Croton acronychioides	thick-leaved croton
	Croton insularis	Queensland cascarilla
	Croton phebalioides	narrow-leaved croton
	Croton stigmatosus	white croton
	Drypetes seplanchei	
	Euphorbia tannensis subsp. eremophila	
	Euphorbia tannensis subsp. tannensis	
	Excoecaria agallocha	milky mangrove
	Flueggea leucopyrus	
	Glochidion apodogynum	
	Glochidion disparipes	pin flower tree
	Glochidion ferdinandi	cheese tree
	Glochidion ferdinandi var. pubens	cheese tree

	Glochidion lobocarpus	cheese tree
	Glochidion sumtranum	
	Homalanthus nutans	
	Homalanthus stillingiifolius	
	Macaranga involucrata var. mallotoides	
	Macaranga tanarius	macaranga
	Mallotus claoxyloides	green kamala
	Mallotus discolor	white kamala
	Mallotus ficifolius	
	Mallotus mollissimus	
	Mallotus philippensis	red kamala
	Monotaxis macrophylla	
	Petalostigma pubescens	quinine
	Petalostigma triloculare	long-leaved bitter bark
	Phyllanthus carpentariae	
	Phyllanthus fuernrohrii	spurge
	Phyllanthus gunnii	
	Phyllanthus microcladus	
	Phyllanthus novae-hollandiae	
	Phyllanthus subcrenulatus	
	Phyllanthus virgatus	
	Poranthera microphylla	small poranthera
	Pseudanthus orientalis	
	Ricinocarpos ledifolius	
	Ricinocarpos pinifolius	wedding bush
	Sauropus albiflorus	snow bush
	Tragia novae-hollandiae	stinging-vine
Fabaceae	*Abrus precatorius* subsp. *precatorius*	
	Aeschynomene brevifolia	
	Aeschynomene micranthos	
	Alysicarpus aurantiacus	swe*et al*ys
	Aotus lanigera	pointed aotus
	Austrosteenisia blackii	bloodvine
	Bossiaea brownii	
	Bossiaea carinalis	
	Bossiaea rhombifolia subsp. *concolor*	
	Cajanus marmoratus	
	Cajanus reticulatus var. *reticulatus*	
	Canavalia papuana	wild jack bean
	Canavalia rosea	coastal jack bean
	Chorizema parviflorum	eastern flame pea
	Crotalaria brevis	
	Crotalaria calycina	
	Crotalaria medicaginea	trefoil rattlepod
	Crotalaria mitchellii	
	Crotalaria mitchellii subsp. *mitchellii*	
	Crotalaria montana	
	Crotalaria montana var. *angustifolia*	
	Daviesia ulicifolia	native gorse
	Daviesia umbellulata	
	Desmodium brachypodum	large ticktrefoil
	Desmodium gangeticum	
	Desmodium gunnii	
	Desmodium heterocarpon	

	Desmodium heterocarpon var*. strigosum*	
	Desmodium microphyllum	
	Desmodium muelleri	
	Desmodium rhytidophyllum	
	Desmodium trichostachyum	
	Desmodium varians	slender tick trefoil
	Erythrina vespertilio	
	Flemingia lineata	
	Flemingia parviflora	flemingia
	Galactia tenuiflora	
	Galactia tenuiflora var*. lucida*	
	Glycine clandestina	
	Glycine cyrtoloba	
	Glycine latifolia	
	Glycine tabacina	glycine pea
	Glycine tomentella	woolly glycine
	Gompholobium foliolosum	fern-leaved burtonia
	Gompholobium pinnatum	poor mans gold
	Gompholobium virgatum	
	Gompholobium virgatum var*. aspalathoides*	
	Hardenbergia violacea	
	Hovea clavata	
	Hovea longifolia	purple bush pea
	Hovea longipes	brush hovea
	Hovea pannosa	rusty bush pea
	Indigofera australis	
	Indigofera colutea	sticky indigo
	Indigofera hirsuta	hairy indigo
	Indigofera linifolia	
	Indigofera linnaei	Birdsville indigo
	Indigofera pratensis	
	Indigofera tryonii	
	Isotropis filicaulis	
	Jacksonia scoparia	
	Jacksonia stackhousei	wallum dogwood
	Leptosema oxylobioides	
	Millettia pinnata	pongamia tree
	Mirbelia rubiifolia	
	Mucuna gigantea	burny bean
	Phyllota phylicoides	yellow peabush
	Pultenaea rariflora	
	Pultenaea retusa	
	Pultenaea spinosa	
	Pycnospora lutescens	pycnospora
	Rhynchosia acuminatissima	
	Rhynchosia minima var. amaliae	
	Rhynchosia minima var. minima	
	Smithia sensitiva	
	Sophora tomentosa subsp*. australis*	
	Swainsona galegifolia	smooth Darling pea
	Swainsona queenslandica	
	Tephrosia astragaloides	
	Tephrosia brachyodon	
	Tephrosia filipes	

	Tephrosia filipes subsp*. filipes*	
	Tephrosia juncea	
	Tephrosia leptoclada	
	Tephrosia purpurea var. *sericea*	
	Uraria lagopodioides	
	Uraria picta	
	Vigna marina	dune bean
	Zornia dyctiocarpa var. *dyctiocarpa*	
	Zornia dyctiocarpa var. *filifolia*	
	Zornia floribunda	
	Zornia muriculata	
	Zornia muriculata subsp*. muriculata*	
Flacourtiaceae	*Homalium alnifolium*	brown boxwood
	Homalium sp. (South Molle Island J.A.Gresty AQ208995)	
	Scolopia braunii	flintwood
	Xylosma ovatum	
Geniostomaceae	*Geniostoma rupestre* var. *australianum*	
Gentianaceae	*Centaurium spicatum*	spike centaury
	Schenkia australis	
Goodeniaceae	*Brunonia australis*	blue pincushion
	Dampiera ferruginea	velvet beauty-bush
	Dampiera purpurea	
	Goodenia glabra	
	Goodenia grandiflora	
	Goodenia rotundifolia	
	Goodenia sp. (Mt Castletower M.D.Crisp 2753)	
	Scaevola ramosissima	purple fan flower
	Scaevola taccada	Cardwell cabbage
	Velleia pubescens	
	Velleia spathulata	wild pansies
Grossulariaceae	*Abrophyllum ornans*	native hydrangea
Haloragaceae	*Gonocarpus chinensis* subsp*. verrucosus*	
	Gonocarpus micranthus subsp*. micranthus*	
	Gonocarpus micranthus subsp*. ramosissimus*	
	Gonocarpus tetragynus	
	Haloragis heterophylla	rough raspweed
	Myriophyllum crispatum	
	Myriophyllum muricatum	
	Myriophyllum striatum	
Lamiaceae	*Ajuga australis*	Australian bugle
	Anisomeles malabarica	
	Basilicum polystachyon	
	Callicarpa pedunculata	velvet leaf
	Callicarpa thozetii	
	Clerodendrum floribundum	
	Clerodendrum inerme	coastal lolly bush
	Clerodendrum tomentosum	
	Glossocarya hemiderma	
	Gmelina sp.	white beech
	Pityrodia salviifolia	pityrodia
	Plectranthus graveolens	flea bush
	Plectranthus parviflorus	
	Premna serratifolia	

	Prostanthera ovalifolia	
	Teucrium sp. (Ormeau G.Leiper AQ476858)	
	Vitex rotundifolia	
	Vitex trifolia	
	Vitex trifolia var. *trifolia*	
Lauraceae	*Beilschmiedia obtusifolia*	
	Cassytha filiformis	dodder laurel
	Cassytha glabella forma glabella	
	Cassytha pubescens	downy devil's twine
	Cinnamomum oliveri	Oliver's sassafras
	Cryptocarya bidwillii	yellow laurel
	Cryptocarya hypospodia	north Queensland purple laurel
	Cryptocarya macdonaldii	McDonald's laurel
	Cryptocarya onoprienkoana	
	Cryptocarya triplinervis	
	Cryptocarya vulgaris	
	Endiandra discolor	domatia tree
	Endiandra hypotephra	blue walnut
	Endiandra muelleri subsp. *bracteata*	
	Endiandra sieberi	hard corkwood
	Litsea fawcettiana	
	Litsea glutinosa	
	Litsea leefeana	
	Neolitsea brassii	
	Neolitsea dealbata	white bolly gum
Lecythidaceae	*Planchonia careya*	cockatoo apple
Lentibulariaceae	*Utricularia australis*	yellow bladderwort
	Utricularia bifida	
	Utricularia biloba	moth bladderwort
	Utricularia caerulea	blue bladderwort
	Utricularia dichotoma	fairy aprons
	Utricularia gibba	floating bladderwort
	Utricularia lateriflora	small bladderwort
	Utricularia sp.	
	Utricularia uliginosa	asian bladderwort
Loganiaceae	*Mitrasacme alsinoides*	
	Mitrasacme brachystemonea	
	Mitrasacme nummularia	
	Mitrasacme paludosa	
	Mitrasacme pygmaea	
Loranthaceae	*Amyema congener*	
	Amyema mackayensis	
	Amylotheca dictyophleba	
	Dendrophthoe falcata	
	Dendrophthoe glabrescens	
	Diplatia furcata	
	Muerllerina sp.	
Lythraceae	*Pemphis acidula*	
Malvaceae	*Abutilon asiaticum* var. *australiense*	
	Abutilon auritum	Chinese lantern
	Abutilon micropetalum	
	Abutilon oxycarpum	
	Abutilon oxycarpum var. *oxycarpum*	

	Hibiscus divaricatus	
	Hibiscus diversifolius	swamp hibiscus
	Hibiscus heterophyllus	
	Hibiscus meraukensis	Merauke hibiscus
	Hibiscus splendens	pink hibiscus
	Hibiscus sturtii	
	Hibiscus tiliaceus	cotton tree
	Hibiscus vitifolius	
	Sida fibulifera	
	Sida subspicata	spiked sida
	Sida trichopoda	
	Thespesia populnea	
Melastomataceae	*Melastoma malabathricum* subsp*. malabathricum*	
	Memecylon pauciflorum var. *pauciflorum*	
Meliaceae	*Aglaia brownii*	
	Aglaia elaeagnoides	
	Dysoxylum gaudichaudianum	ivory mahogany
	Dysoxylum mollissimum subsp. *molle*	miva mahogany
	Dysoxylum rufum	
	Melia azedarach	white cedar
	Synoum glandulosum	scentless rosewood
	Turraea pubescens	native honeysuckle
	Xylocarpus granatum	cedar mangrove
Menispermaceae	*Hypserpa decumbens*	
	Legnephora moorei	
	Pleogyne australis	
	Sarcopetalum harveyanum	
	Stephania japonica	
	Stephania japonica var*. discolor*	
	Tinospora smilacina	snakevine
Menyanthaceae	*Nymphoides aurantiaca*	
	Nymphoides exiliflora	
	Nymphoides indica	water snowflake
Mimosaceae	*Acacia ambylgona*	prickly wattle
	Acacia aulacocarpa	
	Acacia bidwillii	
	Acacia concurrens	black wattle
	Acacia conferta	crowded-leaved wattle
	Acacia crassa	
	Acacia crassa subsp. *longicoma*	
	Acacia cretata	
	Acacia decora	pretty wattle
	Acacia disparrima subsp. *disparrima*	
	Acacia excelsa	
	Acacia falciformis	broad-leaved hickory
	Acacia fasciculifera	scaly bark
	Acacia fimbriata	Brisbane golden wattle
	Acacia flavescens	toothed wattle
	Acacia holosericea	
	Acacia holosericea var*. holosericea*	
	Acacia implexa	lightwood
	Acacia julifera	
	Acacia julifera subsp*. curvinervia*	

	Acacia julifera subsp*. julifera*	
	Acacia juncifolia	
	Acacia leiocalyx	
	Acacia leiocalyx	
	Acacia leptocarpa	north coast wattle
	Acacia maidenii	Maiden's wattle
	Acacia melanoxylon	blackwood
	Acacia penninervis	
	Acacia quadrilateralis	
	Acacia rhodoxylon	
	Acacia salicina	doolan
	Acacia simsii	
	Acacia sp.	
	Acacia sparsiflora	currawong
	Acacia spirorbis subsp. *solandri*	
	Acacia ulicifolia	
	Acacia whitei	
	Albizia canescens	
	Albizia sp. (South Percy Island G.N.Batianoff+ 11444)	
	Archidendropsis thozetiana	
	Neptunia gracilis forma gracilis	
	Pararchidendron pruinosum	
	Paraserianthes toona	Mackay cedar
Molluginaceae	*Macarthuria neocambrica*	
Monimiaceae	*Palmeria scandens*	anchor vine
	Tetrasynandra laxiflora	tetra beech
	Tetrasynandra pubescens	tetra beech
Moraceae	*Ficus adenosperma*	
	Ficus congesta var*. congesta*	
	Ficus copiosa	
	Ficus coronata	creek sandpaper fig
	Ficus fraseri	white sandpaper fig
	Ficus hispida var. *hispida*	
	Ficus obliqua	
	Ficus opposita	
	Ficus platypoda	
	Ficus racemosa var*. racemosa*	
	Ficus rubiginosa forma rubiginosa	
	Ficus virens	
	Ficus virens var*. sublanceolata*	
	Ficus virens var. *viriens*	
	Streblus brunonianus	whalebone tree
	Trophis scandens subsp*. scandens*	
Myoporaceae	*Eremophila debilis*	winter apple
	Myoporum acuminatum	coastal boobialla
	Myoporum boninense subsp. *australe*	
	Myoporum sp.	boobialla
Myristicaceae	*Myristica globulosa* subsp*. muelleri*	
	Myristica insipida	
Myrsinaceae	*Aegiceras corniculatum*	river mangrove
	Embelia australiana	embelia
	Myrsine crassifolia	
	Myrsine porosa	

	Myrsine sp.	
	Myrsine subsessilis	
	Myrsine variabilis	
	Tapeinosperma pseudojambosa	tapeinosperma
Myrtaceae	*Acmena hemilampra*	
	Acmena smithii	lillypilly satinash
	Babingtonia bidwillii	
	Babingtonia collina	
	Baeckea frutescens	
	Callistemon sp.	
	Callistemon viminalis	red bottlebrush
	Corymbia citriodora	spotted gum
	Corymbia clarksoniana	
	Corymbia dallachiana	
	Corymbia erythrophloia	variable-barked bloodwood
	Corymbia gummifera	red bloodwood
	Corymbia intermedia	pink bloodwood
	Corymbia tessellaris	Moreton Bay ash
	Corymbia trachyphloia subsp. trachyphloia	
	Eucalyptus acmenoides	
	Eucalyptus crebra	narrow-leaved red ironbark
	Eucalyptus crebra x E.moluccana	
	Eucalyptus crebra x E.populnea	
	Eucalyptus drepanophylla	
	Eucalyptus drepanophylla x platyphylla	
	Eucalyptus exserta	Queensland peppermint
	Eucalyptus fibrosa subsp. fibrosa	
	Eucalyptus latisinensis	
	Eucalyptus melanophloia	
	Eucalyptus moluccana	gum-topped box
	Eucalyptus platyphylla	poplar gum
	Eucalyptus platyphylla x E.tereticornis	
	Eucalyptus populnea	poplar box
	Eucalyptus portuensis	
	Eucalyptus resinifera	red mahogany
	Eucalyptus robusta	swamp mahogany
	Eucalyptus sp.	
	Eucalyptus suffulgens	
	Eucalyptus tereticornis subsp. *tereticornis*	
	Gossia bidwillii	
	Homoranthus virgatus	twiggy homoranthus
	Leptospermum juniperinum	prickly tea-tree
	Leptospermum liversidgei	
	Leptospermum neglectum	
	Leptospermum polygalifolium	tantoon
	Leptospermum sericatum	
	Leptospermum sp.	
	Lithomyrtus obtusa	
	Lophostemon confertus	brush box
	Lophostemon suaveolens	swamp box
	Lysicarpus angustifolius	budgeroo
	Melaleuca dealbata	swamp tea-tree
	Melaleuca fluviatilis	
	Melaleuca leucadendra	broad-leaved tea-tree

	Melaleuca nervosa	
	Melaleuca quinquenervia	swamp paperbark
	Melaleuca trichostachya	
	Melaleuca viridiflora	
	Melaleuca viridiflora var*. viridiflora*	
	Ochrosperma lineare	
	Osbornia octodonta	myrtle mangrove
	Rhodamnia rubescens	scrub turpentine
	Rhodamnia trineura subsp*. trineura*	guava
	Syncarpia glomulifera	
	Syzygium australe	scrub cherry
	Syzygium oleosum	blue cherry
Nyctaginaceae	*Boerhavia pubescens*	
	Boerhavia sp.	
	Pisonia aculeata	thorny Pisonia
	Pisonia umbellifera	birdlime tree
Nymphaeceae	*Nymphaea gigantea*	giant waterlily
Oleaceae	*Chionanthus ramiflora*	northern olive
	Jasminum didymum	
	Jasminum didymum subsp*. didymum*	
	Jasminum didymum subsp*. racemosum*	
	Jasminum simplicifolium subsp*. australiense*	
	Notelaea microcarpa	
	Olea paniculata	
Onagraceae	*Ludwigia octovalvis*	willow primrose
Oxalidaceae	*Oxalis perennans*	
	Oxalis rubens	
Passifloraceae	*Passiflora aurantia*	
Phytolaccaceae	*Monococcus echinophorus*	burr bush
Piperaceae	*Peperomia blanda* var*. floribunda*	
	Piper hederaceum	
Pittosporaceae	*Bursaria incana*	
	Bursaria spinosa subsp. *spinosa*	
	Hymenosporum flavum	native frangipani
	Pittosporum ferrugineum	
	Pittosporum ferrugineum subsp*. linifolium*	
	Pittosporum revolutum	yellow pittosporum
	Pittosporum venulosum	
Plumbaginaceae	*Aegialitis annulata*	club mangrove
	Limonium solanderi	
Polygalaceae	*Comesperma defoliatum*	leafless milkwort
	Comesperma esulifolium	match heads
	Comesperma oblongatum	
	Persicaria attenuata	
	Persicaria decipiens	slender knotweed
	Polygonum plebeium	
Portulacaceae	*Portulaca bicolor*	
	Portulaca oleracea	pigweed
Primulaceae	*Anagallis pumila*	
Proteaceae	*Banksia integrifolia*	
	Banksia integrifolia subsp*. compar*	
	Banksia robur	broad-leaved banksia
	Banksia spinulosa	

	Banksia spinulosa var. *spinulosa*	
	Grevillea banksii	
	Grevillea hilliana	
	Grevillea parallela	
	Grevillea pteridfolia	
	Grevillea striata	beefwood
	Grevillea venusta	grevillea
	Hakea lorea	
	Persoonia amaliae	
	Persoonia virgata	small-leaved geebung
Ranunculaceae	*Clematis glycinoides*	headache vine
Rhamnaceae	*Alphitonia excelsa*	soap tree
	Colubrina asiatica	
	Pomaderris canescens	
	Pomaderris ferruginea	
	Pomaderris queenslandica	
	Rhamnella vitiensis	
	Ventilago pubiflora	
Rhizophoraceae	*Bruguiera exaristata*	
	Bruguiera gymnorhiza	large-fruited orange mangrove
	Carallia brachiata	carallia
	Ceriops tagal	yellow mangrove
	Rhizophora apiculata	
	Rhizophora lamarckii	
	Rhizophora stylosa	spotted mangrove
Rosaceae	*Rubus moluccanus*	
	Rubus moluccanus var. *trilobus*	
	Rubus parvifolius	native raspberry
	Rubus probus	
	Rubus rosifolius	
	Rubus x novus	
Rubiaceae	*Aidia racemosa*	
	Cyclophyllum coprosmoides var. *coprosmoides*	
	Dentella repens	dentella
	Hedyotis auricularia var. *melanesica*	
	Hodgkinsonia ovatiflora	golden ash
	Ixora beckleri	
	Ixora queenslandica	
	Morinda canthoides	
	Morinda jasminoides	morinda
	Morinda umbellata	
	Nauclea orientalis	Leichhardt tree
	Oldenlandia subulata	
	Opercularia diphylla	
	Pavetta australiensis	
	Pavetta australiensis var. *australiensis*	
	Pogonolobus reticulatus	
	Pomax umbellata	
	Psychotria daphnoides	
	Psychotria loniceroides	hairy psychotria
	Psychotria poliostemma	
	Psydrax attenuata	
	Psydrax lamprophylla	

	Psydrax odorata	
	Psydrax oleifolia	
	Psydrax sp.	
	Scyphiphora hydrophylacea	
	Spermacoce brachystema	
	Spermacoce multicaulis	
	Tarenna dallachiana	
	Timonius timon	
	Timonius timon var. *timon*	
Rutaceae	*Acronychia imperforata*	beach acronychia
	Acronychia laevis	glossy acronychia
	Boronia bipinnata	rock boronia
	Boronia occidentalis	
	Bosistoa medicinalis	
	Bouchardatia neurococca	
	Flindersia schottiana	bumpy ash
	Geijera salicifolia	brush wilga
	Glycosmis trifoliata	
	Melicope elleryana	
	Micromelum minutum	clusterberry
	Murraya ovatifoliolata	
	Phebalium nottii - P.woombye	
	Phebalium woombye	wallum phebalium
	Philotheca difformis	
	Philotheca difformis subsp. *smithiana*	
	Sarcomelicope simplicifolia subsp. *simplicifolia*	yellow aspen
	Zanthoxylum brachyacanthum	
	Zieria laxiflora	wallum zieria
	Zieria minutiflora	
	Zieria minutiflora subsp. *trichocarpa*	
	Zieria smithii	
	Zieria smithii subsp. *smithii*	
Santalaceae	*Exocarpos cupressiformis*	native cherry
	Exocarpos latifolius	
	Santalum lanceolatum	
Sapindaceae	*Alectryon connatus*	grey birds-eye
	Alectryon subdentatus	
	Alectryon tomentosus	
	Arytera divaricata	coogera
	Atalaya rigida	
	Cupaniopsis anacardioides	tuckeroo
	Cupaniopsis simulata	
	Cupaniopsis wadsworthii	
	Diploglottis obovata	blunt-leaved tamarind
	Districhostemon dodecandrus	
	Dodonaea lanceolata	
	Dodonaea lanceolata var. *subsessilifolia*	
	Dodonaea triquetra	large-leaved hop bush
	Dodonaea viscosa	
	Dodonaea viscosa subsp. *burmanniana*	
	Dodonaea viscosa subsp. *viscosa*	
	Elattostachys xylocarpa	white tamarind
	Ganophyllum falcatum	
	Harpullia hillii	

	Harpullia pendula	
	Jagera pseudorhus	
	Jagera pseudorhus var. *pseudorhus*	
	Mischarytera lautereriana	corduroy tamarind
	Mischocarpus anodontus	veiny pearfruit
	Mischocarpus pyriformis subsp. *pyriformis*	
Sapotaceae	*Mimusops elengi*	
	Niemeyera antiloga	brown pearwood
	Planchonella chartacea	
	Planchonella cotinifolia	
	Planchonella cotinifolia var. *pubescens*	
	Planchonella pohlmaniana	
	Pouteria pohlmaniana	
	Pouteria queenslandica	
	Pouteria sericea	
Scrophulariaceae	*Bacopa monnieri*	
	Limnophila brownii	
Scrophulariaceae	*Lindernia crustacea*	
Simaroubaceae	*Quassia bidwillii*	quassia
Solanaceae	*Lycianthes shanesii*	
	Solanum ellipticum	potato bush
	Solanum erianthum	potato tree
	Solanum stelligerum	devil's needles
Sonneratiaceae	*Sonneracia alba*	mangrove apple
Stackhousiaceae	*Stackhousia monogyna*	creamy candles
	Stackhousia nuda	
	Stackhousia sp.	
	Stackhousia viminea	slender stackhousia
Sterculiaceae	*Argyrodendron trifoliolatum*	booyong
	Brachychiton australis	broad-leaved bottle tree
	Brachychiton bidwillii	little kurrajong
	Brachychiton populneus subsp. *populneus*	
	Brachychiton populneus subsp. *trilobus*	
	Commersonia bartramia	brown jurrajong
	Keraudrenia lanceolata	
	Melhania oblongifolia	velvet hibiscus
	Seringia corollata	
	Sterculia quadrifida	peanut tree
	Wltheria indica	
Strychnaceae	*Strychnos psilosperma*	threaded boxwood
Stylidiaceae	*Stylidium eglandulosum*	
	Stylidium eriorhizum	
Symplocaceae	*Symplocos cochinchinensis* var. *pilosiuscula*	
	Symplocos stawellii	
	Symplocos thwaitesii	buff hazelwood
Thymelaeaceae	*Pimelea linifolia*	
	Pimelea linifolia subsp. *linifolia*	
	Thecanthes cornucopiae	
	Wikstroemia indica	tie bush
Tiliaceae	*Grewia australis*	
	Grewia latifolia	
	Grewia retusifolia	
	Grewia scabrella	

	Triumfetta repens	
Ulmaceae	*Aphananthe philippinensis*	
	Celtis paniculata	native celtis
	Trema orientalis	tree peach
	Trema tomentosa	
	Trema tomentosa var. *viridis*	
Urticaceae	*Dendrocnide photinophylla*	shiny-leaved stinging tree
	Pipturus argenteus	white nettle
Verbenaceae	*Phyla nodiflora*	carpetweed
Violaceae	*Hybanthus enneaspermus*	
	Hybanthus monopetalus	
	Hybanthus stellarioides	
	Viola hederacea	
Viscaceae	*Notothixos subaureus*	golden mistletoe
	Viscum articulatum	flat mistletoe
Vitaceae	*Cayratia acris*	hairy grape
	Cayratia clematidea	slender grape
	Cissus antarctica	
	Cissus hastata	
	Cissus hypoglauca	
	Cissus oblonga	
	Cissus opaca	
	Cissus repens	
	Cissus sterculiifolia	
	Tetrastigma nitens	shining grape
Winteraceae	*Tasmannia insipida*	brush pepperbush
Zygophyllaceae	*Tribulus cistoides*	bulls head vine

Table C-2 Angiosperms: Native monocotyledons recorded within SWBTA

Family	Scientific Name	Common Name
Amaryllidaceae	*Crinum flaccidum*	Murray lily
Araceae	*Alocasia brisbanensis*	
	Epipremnum pinnatum	
	Gymnostachys anceps	settler's flax
Arecaceae	*Archontophoenix alexandrae*	Alexandra palm
	Archontophoenix cunninghamiana	piccabeen palm
	Calamus australis	hairy mary
	Calamus muelleri	
	Livistona decora	
	Ptychosperma elegans	solitaire palm
Asparagaceae	*Asparagus racemosus*	native asparagus
Asphodelaceae	*Bulbine bulbosa*	native leek
Burmanniaceae	*Burmannia disticha*	
Centrolepidaceae	*Centrolepis exserta*	
Colchicaceae	*Iphigenia indica*	
Commelinaceae	*Aneilema acuminatum*	
	Commelina diffusa	wandering jew
	Commelina ensifolia	
	Commelina lanceolata	
	Murdannia graminea	murdannia
	Pollia macrophylla	
Cyperaceae	*Abildgaardia ovata*	
	Abildgaardia vaginata	
	Baumea articulata	jointed twigrush
	Baumea juncea	bare twigrush
	Baumea muelleri	
	Baumea rubiginosa	soft twigrush
	Baumea teretifolia	
	Bulbostylis barbata	
	Carex horsfieldii	
	Caustis pentandra	
	Caustis recurvata	
	Chorizandra cymbaria	
	Cyperus alopecuroides	
	Cyperus alterniflorus	
	Cyperus aquatilis	
	Cyperus bowmannii	
	Cyperus conicus	
	Cyperus conicus var. *conicus*	
	Cyperus cuspidatus	
	Cyperus cyperoides	
	Cyperus decompositus	
	Cyperus dietrichiae var. *brevibracteatus*	
	Cyperus dietrichiae var. *dietrichiae*	
	Cyperus difformis	rice sedge
	Cyperus distans	
	Cyperus eglobosus	
	Cyperus enervis	
	Cyperus exaltatus	
	Cyperus fulvus	

	Cyperus gracilis	
	Cyperus haspan	
	Cyperus haspan subsp. *juncoides*	
	Cyperus iria	
	Cyperus javanicus	
	Cyperus laevis	
	Cyperus leiocaoulon	
	Cyperus lucidus	
	Cyperus pedunculatus	
	Cyperus polystachyos	
	Cyperus polystachyos var. *laxiflorus*	
	Cyperus polystachyos var. *polystachyos*	
	Cyperus scaber	
	Cyperus scariosus	
	Cyperus squarrosus	bearded flatsedge
	Cyperus stradbrokensis	
	Cyperus subulatus	
	Cyperus tetracarpus	
	Cyperus tetraphyllus	
	Cyperus trinervis	
	Eleocharis cylindrostachys	
	Eleocharis equisetina	
	Eleocharis geniculata	
	Eleocharis ochrostachys	
	Eleocharis philippinensis	
	Eleocharis plana	ribbed spikerush
	Eleocharis spiralis	
	Eleocharis tetraquetra	
	Fimbristlyis polytrichoides	
	Fimbristylis acicularis	
	Fimbristylis bisumbellata	
	Fimbristylis cinnamometorum	
	Fimbristylis cymosa	
	Fimbristylis depauperata	
	Fimbristylis dichotoma	common fringe-rush
	Fimbristylis ferruginea	
	Fimbristylis littoralis	
	Fimbristylis nuda	
	Fimbristylis nutans	
	Fimbristylis oxystachya	
	Fimbristylis pauciflora	
	Fimbristylis tetragona	
	Fuirena ciliaris	
	Fuirena umbellata	
	Gahnia aspera	
	Gahnia sieberiana	sword grass
	Isolepis nodosa	knobby club rush
	Lepidosperma	
	Lepidosperma elatius	
	Lepidosperma laterale	
	Lepidosperma laterale var. *laterale*	
	Lepidosperma longitudinale	pithy swordsedge

	Lepironia articulata	
	Lipocarpha microcephala	
	Rhynchospora brownii	beak rush
	Rhynchospora corymbosa	
	Rhynchospora heterochaeta	
	Rhynchospora rubra	
	Schoenoplectus articulatus	
	Schoenoplectus lateriflorus	
	Schoenoplectus litoralis	
	Schoenus apogon	
	Schoenus brevifolius	
	Schoenus calostachyus	
	Schoenus melanostachys	
	Schoenus ornithopodioides	
	Schoenus paludosus	
	Schoenus sparteus	
	Schoenus vaginatus	
	Schoenus yarrabensis	
	Scleria brownii	
	Scleria ciliaris	
	Scleria levis	
	Scleria mackaviensis	
	Scleria polycarpa	
	Scleria rugosa	
	Scleria sphacelata	
	Scleria terrestris	
	Scleria tricuspidata	
	Tetraria capillaris	
	Trachystylis stradbrokensis	
Dioscoreaceae	*Dioscorea transversa*	native yam
Eriocaulaceae	*Eriocaulon nanum*	
	Eriocaulon australe	
	Eriocaulon scariosum	
Flagellariaceae	*Flagellaria indica*	whip vine
Hemerocallidaceae	*Dianella caerulea*	
	Dianella caerulea var. *aquilonia*	
	Dianella caerulea var. *vannata*	
	Dianella crinoides	
	Dianella longifolia	
	Dianella longifolia var. *longifolia*	
	Dianella rara	
	Dianella revolute	
	Dianella revoluta var. *revoluta*	
	Geitonoplesium cymosum	scrambling lily
	Tricoryne anceps	rush lily
	Tricoryne anceps subsp *anceps*	
	Tricoryne anceps subsp. *pterocaulon*	
	Tricoryne elatior	
	Tricoryne muricata	
Hydrocharitaceae	*Ottelia ovalifolia*	swamp lily
Hypoxidaceae	*Hypoxis pratensis* var. *pratensis*	
Iridaceae	*Patersonia fragilis*	

	Patersonia glabrata	
	Patersonia sericea var. sericea	
Juncaceae	*Juncus continuus*	
	Juncus kraussii	sea rush
	Juncus polyanthemus	
	Juncus usitatus	
Juncaginaceae	*Triglochin procerum*	
	Triglochin striatum	streaked arrowgrass
Laxmanniaceae	*Cordyline cannifolia*	
	Cordyline manners-suttoniae	
	Cordyline murchisoniae	
	Cordyline petiolaris	large-leaved palm lily
	Eustrephus latifolius	wombat berry
	Laxmannia gracilis	slender wire lily
	Lomandra confertifolia subsp*. confertifolia*	
	Lomandra confertifolia subsp*. pallida*	
	Lomandra filiformis	
	Lomandra hystrix	
	Lomandra leucocephala subsp*. leucocephala*	
	Lomandra longifolia	
	Lomandra multiflora subsp*. multiflora*	
	Sowerbaea subtilis	
	Thysanotus tuberosus subsp*. tuberosus*	
Orchidaceae	*Acianthus amplexicaulis*	
	Acianthus exsertus	
	Acianthus fornicatus	pixie caps
	Bulbophyllum schillerianum	red rope orchid
	Caladenia carnea	
	Caladenia carnea var. *carnea*	
	Caladenia catenata	
	Calanthe triplicata	christmas orchid
	Caleana major	flying duck orchid
	Corybas aconitiflorus	
	Corybas barbarae	helmet orchid
	Cryptostylis erecta	bonnet orchid
	Cymbidium canaliculatum	
	Cymbidium madidum	
	Cymbidium suave	tailed helmet orchid
	Dendrobium canaliculatum	
	Dendrobium discolor	
	Dendrobium speciosum	
	Dendrobium tetragonum	tree spider orchid
	Dipodium variegatum	
	Diuris alba	
	Diuris alba x D.chrysantha	
	Diuris sp.	
	Dockrillia bowmanii	scrub pencil orchid
	Genoplesium sp.	
	Geodorum densiflorum	pink nodding orchid
	Oberonia complanata	
	Plectorrhiza sp.	
	Phaius australis	lesser swamp orchid

	Pseudovanilla foliata	giant climbing orchid
	Pterostylis ophioglossa	
	Taeniophyllum muelleri	
Pandanaceae	*Freycinetia excelsa*	climbing pandanus
	Freycinetia scandens	
	Pandanus brookei	
	Pandanus sp.	
	Pandanus tectorius	
Philydraceae	*Philydrum lanuginosum*	frogsmouth
Poaceae	*Alloteropsis semialata*	cockatoo grass
	Ancistrachne uncinulata	hooky grass
	Aristida acuta	
	Aristida calycina var. *calycina*	
	Aristida calycina var. *praealta*	
	Aristida gracilipes	
	Aristida holathera var. *holathera*	
	Aristida jerichoensis	
	Aristida lazaridis	feathertop wiregrass
	Aristida leptopoda	
	Aristida queenslandica var. *queenslandica*	
	Aristida racemosa	
	Aristida spuria	
	Aristida utilis var. utilis	
	Arundinella nepalensis	reedgrass
	Bothriochloa bladhii	
	Bothriochloa decipiens	
	Capillipedium parvilorum	spicytop
	Cenchrus caliculatus	hillside burrgrass
	Chloris divaricata	slender chloris
	Chrysopogon fallax	
	Chrysopogon subjuncea	
	Chrysopogon sylvaticus	
	Cymbopogon bombycinus	silky oilgrass
	Cymbopogon queenslanicus	
	Cymbopogon refractus	barbed-wire grass
	Dactyloctenium radulans	coast button grass
	Dichanthium sericeum	
	Digitaria ammophila	silky umbrella grass
	Digitaria baileyi	
	Digitaria breviglumis	
	Digitaria brownii	
	Digitaria leucostachya	
	Digitaria longiflora	
	Digitaria parviflora	
	Digitaria ramularis	
	Digitaria ramularis	
	Echinochloa dietrichiana	
	Ectrosia lasioclada	
	Ectrosia leporina	
	Elionurus citreus	lemon-scented grass
	Enneapogon lindleyanus	
	Enneapogon nigricans	niggerheads

	Enteropogon acicularis	curly windmill grass
	Entolasia marginata	bordered panic
	Entolasia stricta	wiry panic
	Eragrostis brownii	
	Eragrostis elongata	
	Eragrostis interrupta	
	Eragrostis lacunaria	
	Eragrostis parvifloa	
	Eragrostis pubescens	
	Eremochloa bimaculata	poverty grass
	Eriachne anomala	
	Eriachne glabrata	
	Eriachne insularis	
	Eriachne pallescens var. *gracilis*	
	Eriachne pallescens var. *pallescens*	
	Eriachne rara	
	Eriachne triseta	
	Eriochloa crebra	spring grass
	Eriochloa procera	slender cupgrass
	Eriochloa pseudoacrotricha	
	Eulalia aurea	silky browntop
	Hemarthria uncinata	
	Heteropogon contortus	black speargrass
	Heteropogon triticeus	giant speargrass
	Imperata cylindrica	blady grass
	Ischaemum australe	
	Ischaemum australe var. *villosum*	
	Ischaemum fragile	
	Ischaemum triticeum	
	Leersia hexandra	swamp rice grass
	Leptochloa decipiens	
	Leptochloa decipiens subsp. *decipiens*	
	Leptochloa fusca	
	Leptochloa fusca subsp. *fusca*	
	Lepturus repens	stalky grass
	Megathyrsus maximus var. *maximus*	
	Megathyrsus maximus var. *pubiglumis*	
	Oplismenus aemulus	creeping shade grass
	Oplismenus compositus	
	Oplismenus hirtellus subsp. *imbecillis*	
	Oplismenus undulatifolius var. *mollis*	
	Ottochloa gracillima	pademelon grass
	Ottochloa nodosa	
	Panicum decompositum	
	Panicum effusum	
	Panicum laromianum	
	Panicum queenslandicum	
	Panicum simile	
	Paspalidium constrictum	
	Paspalidium distans	shotgrass
	Paspalidium gausum	
	Paspalidium gracile	slender panic

	Paspalum longifolium	
	Paspalum scrobiculatum	ditch millet
	Perotis rara	comet grass
	Phragmites australis	common reed
	Pseudoraphis spinescens	
	Sacciolepis indica	Indian cupscale grass
	Schizachyrium fragile	firegrass
	Schizachyrium pachyarthron	
	Sehima nervosum	
	Setaria surgens	
	Sorghum nitidum	
	Sorghum nitidum forma aristatum	
	Spinifex sericeus	beach spinifex
	Sporobolus contiguus	
	Sporobolus elongatus	
	Sporobolus virginicus	sand couch
	Themeda triandra	kangaroo grass
	Thuarea involuta	tropical beachgrass
	Vacoparis laxiflorum	
	Zoysia macrantha	prickly couch
Pontederiaceae	*Monochoria cyanea*	
Restionaceae	*Baloskion pallens*	
	Baloskion tetraphyllum	
	Baloskion tetraphyllum subsp. *meiostachyum*	
	Dapsilanthus ramosus	
	Empodisma minus	spreading rope rush
	Sporadanthus interruptus	
Ripogonaceae	*Ripogonum album*	white supplejack
Ripogonaceae	*Ripogonum brevifolium*	small-leaved supplejack
Smilacaceae	*Smilax australis*	barbed-wire vine
	Smilax glyciphylla	sweet sarsaparilla
Typhaceae	*Typha domingensis*	
Xanthorrhoeaceae	*Xanthorrhoea fulva*	swamp grasstree
	Xanthorrhoea johnsonii	
	Xanthorrhoea latifolia subsp. *latifolia*	
	Xanthorrhoea pumilio	
Xyridaceae	*Xyris complanata*	yellow-eye
	Xyris juncea	dwarf yellow-eye
Zannichelliaceae	*Lepilaena australis*	
Zingiberaceae	*Alpinia arundelliana*	
	Alpinia caerulea	wild ginger

Table C-3 Native gymnosperms recorded within SWBTA

Family	Scientific Name	Common Name
Araucariaceae	*Araucaria cunninghamii*	hoop pine
Podocarpaceae	*Podocarpus elatus*	she pine
Cycadaceae	*Cycas media*	
	Cycas ophiolitica	Marlborough blue
Zamiaceae	*Bowenia serrulata*	Byfield fern
	Macrozamia miquelii	

Table C-4 Native ferns recorded within SWBTA

Family	Scientific Name	Common Name
Adiantaceae	*Adiantum aethiopicum*	
	Adiantum atroviride	
	Adiantum diaphanum	
	Adiantum hispidulum	
	Adiantum hispidulum var. *hispidulum*	
	Cheilanthes brownii	
	Cheilanthes distans	bristly cloak fern
	Cheilanthes nudiuscula	
	Cheilanthes sieberi	
	Cheilanthes tenuifolia	rock fern
	Doryopteris concolor	
	Pellaea falcata	
	Pellaea nana	
	Taenitis pinnata	morse fern
Aspleniaceae	*Asplenium australasicum*	
	Asplenium paleaceum	scaly asplenium
Azollaceae	*Azolla pinnata*	ferny azolla
Blechnaceae	*Blechnum cartilagineum*	gristle fern
	Blechnum indicum	swamp water fern
	Blechnum orientale	
	Doodia aspera	prickly rasp fern
	Doodia caudata	
	Doodia dissecta	
	Doodia media	
Cyatheaceae	*Cyathea australis*	
	Cyathea cooperi	
	Cyathea rebeccae	black tree fern
Davalliaceae	*Davallia pyxidata*	
Dennstaedtiaceae	*Pteridium esculentum*	common bracken
Dicksoniaceae	*Calochlaena dubia*	
Dryopteridaceae	*Arachniodes aristata*	prickly shield fern
	Lastreopsis microsora	
	Lastreopsis munita	
	Lastreopsis rufescens	
	Lastreopsis tenera	
Gleicheniaceae	*Dicranopteris linearis* var. *linearis*	
	Gleichenia dicarpa	pouched coral fern
	Sticherus flabellatus var. *flabellatus*	
Hymenophyllaceae	*Cephalomanes caudatum*	

	Cephalomanes obscurum	
	Selenodesmium elongatum	
Lindsaeaceae	*Lindsaea brachypoda*	
	Lindsaea ensifolia subsp*. agatii*	
	Lindsaea ensifolia subsp*. ensifolia*	
	Lindsaea linearis	screw fern
	Lindsaea microphylla	lacy wedge fern
	Lindsaea obtusa	
Lycopodiaceae	*Lycopodiella cernua*	
	Lycopodiella serpentina	
Marsileaceae	*Marsilea crenata*	
Nephrolepidaceae	*Arthropteris beckleri*	
	Arthropteris tenella	climbing fern
	Nephrolepis brownii	
	Nephrolepis cordifolia	fishbone fern
	Nephrolepis hirsutula	
Osmundaceae	*Todea barbara*	king fern
Parkeriaceae	*Ceratopteris thalictroides*	
Platyzomataceae	*Platyzoma microphyllum*	braid fern
Polypodiaceae	*Drynaria rigidula*	
	Drynaria sparsisora	
	Microsorum grossum	
	Microsorum punctatum	
	Platycerium bifurcatum	
	Platycerium superbun	
	Platycerium veitchii	
	Pyrrosia confluens	
Psilotaceae	*Psilotum nudum*	
Pteridaceae	*Acrostichum speciosum*	mangrove fern
	Pteris ensiformis	slender bracken
	Pteris tremula	
Schizaeaceae	*Lygodium microphyllum*	snake fern
	Lygodium reticulatum	
	Schizaea bifida	forked comb fern
	Schizaea dichotoma	branched comb fern
	Schizaea malaccana var*. malaccana*	
Thelypteridaceae	*Christella dentata*	creek fern
	Christella hispidula	
	Christella parasitica	
	Cyclosorus interruptus	
	Tmesipteris truncata	
Vittariaceae	*Vittaris sp.*	

Table C-5 Mammal list

Family	Scientific Name	Common Name
Canidae	*Canis lupus dingo*	dingo
Dasyuridae	*Planigale maculata*	common planigale
Emballonuridae	*Saccolaimus flaviventris*	yellow-bellied sheathtail bat
	Taphozous australis	coastal sheath-tail bat
	Taphozous georgianus	common sheathtail bat
Macropodidae	*Macropus agilis*	agile wallaby
	Macropus dorsalis	black-striped wallaby
	Macropus giganteus	eastern grey kangaroo
	Macropus parryi	whiptail wallaby
	Petrogale inornata	unadorned rock-wallaby
	Wallabia bicolor	swamp wallaby
Molossidae	*Chaerephon jobensis*	Northern Freetail-bat
	Mormopterus beccarii	Beccari's freetail bat
	Mormopterus loriae	little northern freetail-bat
Muridae	*Hydromys chrysogaster*	water rat
	Melomys burtoni	grassland melomys
	Melomys cervinipes	fawn-footed melomys
	Pseudomys delicatulus	delicate mouse
	Pseudomys gracilicaudatus	eastern chestnut mouse
	Rattus tunneyi	pale field-rat
	Xeromys myoides	false water-rat
Ornithorhynchidae	*Ornithorhynchus anatinus*	platypus
Peramelidae	*Isoodon macrourus*	northern brown bandicoot
Petauridae	*Petaurus australis*	yellow-bellied glider
	Petaurus breviceps	sugar glider
	Petaurus norfolcensis	squirrel glider
Phalangeridae	*Trichosurus vulpecula*	common brushtail possum
Potoroidae	*Aepyprymnus rufescens*	rufous bettong
Pseudocheiridae	*Petauroides volans*	greater glider
	Pseudocheirus peregrinus	common ringtail possum
Pteropodidae	*Nyctimene robinsoni*	eastern tube-nosed bat
	Pteropus alecto	black flying-fox
	Pteropus scapulatus	little red flying-fox
	Syconycteris australis	eastern blossom bat
Tachyglossidae	*Tachyglossus aculeatus*	short-beaked echidna
Vespertilionidae	*Chalinolobus dwyeri*	large-eared pied bat
	Chalinolobus gouldii	Gould's wattled bat
	Chalinolobus morio	chocolate wattled bat
	Chalinolobus nigrogriseus	hoary wattled bat
	Kerivoula papuensis	golden-tipped bat
	Miniopterus australis	little bent-wing bat
	Miniopterus schreibersii	eastern bent-wing bat
	Myotis macropus	large-footed myotis
	Nyctophilus bifax	northern long-eared bat
	Nyctophilus gouldi	Gould's long-eared bat
	Scotorepens greyii	little broad-nosed bat
	Scotorepens sanborni	northern broad-nosed bat
	Vespadelus troughtoni	eastern cave bat

Table C-6 Reptile list

Family	Scientific Name	Common Name
Agamidae	*Amphibolurus nobbi*	
	Chlamydosaurus kingii	frilled lizard
	Diporiphora australis	
	Physignathus lesueurii	eastern water dragon
Boidae	*Antaresia maculosus*	spotted python
	Aspidites melanocephalus	black-headed python
	Morelia spilota	carpet python
Chelidae	*Chelodina longicollis*	eastern snake-necked turtle
	Elseya latisternum	saw-shelled turtle
	Emydura macquarii krefftii	Krefft's river turtle
Colubridae	*Boiga irregularis*	brown tree snake
	Dendrelaphis punctulata	common tree snake
	Tropidonophis mairii	freshwater snake
Elapidae	*Brachyurophis australis*	coral snake
	Cacophis krefftii	dwarf crowned snake
	Cryptophis boschmai	Carpentaria whip snake
	Cryptophis nigrostriatus	black-striped snake
	Demansia torquata	collared whip snake
	Demansia vestigiata	black whip snake
	Furina diadema	red-naped snake
	Hoplocephalus bitorquatus	pale-headed snake
	Oxyuranus scutellatus	taipan
	Pseudonaja textilis	eastern brown snake
	Suta suta	Myall snake
	Vermicella annulata	bandy-bandy
Gekkonidae	*Diplodactylus steindachneri*	Steindachner's gecko
	Diplodactylus vittatus	wood gecko
	Gehyra dubia	
	Heteronotia binoei	Bynoe's gecko
	Oedura monilis	
	Oedura rhombifer	zig-zag gecko
	Oedura robusta	robust velvet gecko
Pygopodidae	*Delma tincta*	
	Lialis burtonis	Burton's legless lizard
	Pygopus lepidopodus	common scaly-foot
Scincidae	*Anomalopus brevicolous*	short-necked worm skink
	Anomalopus verreauxii	
	Calyptotis temporalis	
	Carlia foliorum	
	Carlia pectoralis	
	Carlia schmeltzii	
	Carlia vivax	
	Cryptoblepharus litoralis	
	Cryptoblepharus plagiocephalus	
	Cryptoblepharus virgatus	
	Ctenotus robustus	
	Ctenotus taeniolatus	copper-tailed skink
	Cyclodomorphus gerrardii	pink-tongued lizard
	Eulamprus brachysoma	
	Eulamprus quoyii	eastern water skink
	Eulamprus tenuis	

Family	Scientific Name	Common Name
	Glaphyromorphus punctulatus	
	Lampropholis adonis	
	Lampropholis couperi	
	Lampropholis delicata	
	Tiliqua scincoides	eastern blue-tongued lizard
Typhlopidae	*Ramphotyphlops ligatus*	
	Ramphotyphlops wiedii	
Varanidae	*Varanus gouldii*	sand monitor
	Varanus semiremex	rusty monitor
	Varanus tristis	black-tailed monitor
	Varanus varius	lace monitor

Table C-7 Frog list

Family	Scientific Name	Common Name
Hylidae	*Cyclorana alboguttata*	greenstripe frog
	Cyclorana novaehollandiae	eastern snapping frog
	Litoria caerulea	common green treefrog
	Litoria fallax	eastern sedgefrog
	Litoria gracilenta	graceful treefrog
	Litoria inermis	bumpy rocketfrog
	Litoria latopalmata	broad palmed rocketfrog
	Litoria nasuta	striped rocketfrog
	Litoria rothii	northern laughing treefrog
	Litoria rubella	ruddy treefrog
	Litoria wilcoxii	stony creek frog
Myobatrachidae	*Adelotus brevis*	tusked frog
	Crinia deserticola	chirping froglet
	Limnodynastes convexiusculus	marbled marsh frog
	Limnodynastes peronii	striped marshfrog
	Limnodynastes salmini	salmon striped frog
	Limnodynastes tasmaniensis	spotted grassfrog
	Limnodynastes terraereginae	scarlet sided pobblebonk
	Opisthodon ornatus	ornate burrowing frog
	Pseudophryne major	great brown broodfrog
	Uperoleia mimula	Torres gungan
	Uperoleia rugosa	chubby gungan

Table C-8 Bird list

Family	Scientific Name	Common Name
Accipitridae	*Accipiter cirrhocephalus*	collared sparrowhawk
	Accipiter fasciatus	brown goshawk
	Accipiter novaehollandiae	grey goshawk
	Aquila audax	wedge-tailed eagle
	Aviceda subcristata	Pacific baza
	Circus approximans	swamp harrier
	Circus assimilis	spotted harrier
	Erythrotriorchis radiatus	red goshawk
	Haliaeetus leucogaster	white-bellied sea-eagle
	Haliastur indus	brahminy kite
	Haliastur sphenurus	whistling kite
	Hieraaetus morphnoides	little eagle
	Lophoictinia isura	square-tailed kite
	Milvus migrans	black kite
	Pandion haliaetus	osprey
Aegothelidae	*Aegotheles cristatus*	Australian owlet-nightjar
Alaudidae	*Mirafra javanica*	singing bushlark
Alcedinidae	*Alcedo azurea*	azure kingfisher
	Ceyx pusilla	little kingfisher
Anhingidae	*Anhinga melanogaster*	darter
Anseranatidae	*Anseranas semipalmata*	magpie goose
Anatidae	*Anas castanea*	chestnut teal
	Anas gracilis	grey teal
	Anas superciliosa	Pacific black duck
	Aythya australis	hardhead
	Chenonetta jubata	Australian wood duck
	Cygnus atratus	black swan
	Dendrocygna arcuata	wandering whistling-duck
	Dendrocygna eytoni	plumed whistling-duck
	Nettapus coromandelianus	cotton pygmy-goose
	Tadorna radjah	radjah shelduck
Apodidae	*Apus pacificus*	fork-tailed swift
	Hirundapus caudacutus	white-throated needletail
Ardeidae	*Ardea alba*	great egret
	Ardea ibis	cattle egret
	Ardea intermedia	intermediate egret
	Ardea pacifica	white-necked heron
	Ardea sumatrana	great-billed heron
	Butorides striatus	striated heron
	Egretta garzetta	little egret
	Egretta novaehollandiae	white-faced heron
	Egretta sacra	eastern reef egret
	Ixobrychus flavicollis	black bittern
	Ixobrychus minutus	little bittern
	Nycticorax caledonicus	nankeen night heron
Artamidae	*Artamus cinereus*	black-faced woodswallow
	Artamus leucorynchus	white-breasted woodswallow
	Artamus minor	little woodswallow
	Cracticus nigrogularis	pied butcherbird
	Cracticus quoyi	black butcherbird
	Cracticus torquatus	grey butcherbird
	Gymnorhina tibicen	Australian magpie
	Strepera graculina	pied currawong

Family	Scientific Name	Common Name
Burhinidae	*Burhinus grallarius*	bush stone-curlew
	Esacus neglectus	beach stone-curlew
Cacatuidae	*Cacatua galerita*	sulphur-crested cockatoo
	Cacatua roseicapilla	galah
	Calyptorhynchus banksii	red-tailed black-cockatoo
	Calyptorhynchus lathami	glossy black-cockatoo
Campephagidae	*Coracina novaehollandiae*	black-faced cuckoo-shrike
	Coracina papuensis	white-bellied cuckoo-shrike
	Coracina tenuirostris	cicadabird
	Lalage leucomela	varied triller
	Lalage sueurii	white-winged triller
Caprimulgidae	*Caprimulgus macrurus*	large-tailed nightjar
	Eurostopodus mystacalis	white-throated nightjar
Casuariidae	*Dromaius novaehollandiae*	emu
Centropodidae	*Centropus phasianinus*	pheasant coucal
Charadriidae	*Charadrius bicinctus*	double-banded plover
	Charadrius leschenaultii	greater sand plover
	Charadrius mongolus	lesser sand plover
	Charadrius ruficapillus	red-capped plover
	Charadrius veredus	oriental plover
	Elseyornis melanops	black-fronted dotterel
	Pluvialis fulva	Pacific golden plover
	Pluvialis squatarola	grey plover
	Vanellus miles	masked lapwing
Ciconiidae	*Ephippiorhynchus asiaticus*	black-necked stork
Cinclosomatidae	*Psophodes olivaceus*	eastern whipbird
Climacteridae	*Climacteris affinis*	white-browed treecreeper
	Climacteris picumnus	brown treecreeper
Columbidae	*Columba leucomela*	white-headed pigeon
	Geopelia cuneata	diamond dove
	Geopelia humeralis	bar-shouldered dove
	Geopelia striata	peaceful dove
	Geophaps scripta scripta	squatter pigeon
	Leucosarcia melanoleuca	wonga pigeon
	Lopholaimus antarcticus	topknot pigeon
	Macropygia amboinensis	brown cuckoo-dove
	Ocyphaps lophotes	crested pigeon
	Phaps chalcoptera	common bronzewing
	Ptilinopus magnificus	wompoo fruit-dove
	Ptilinopus regina	rose-crowned fruit-dove
Coraciidae	*Eurystomus orientalis*	dollarbird
Corvidae	*Corvus orru*	Torresian crow
Cuculidae	*Cacomantis flabelliformis*	fan-tailed cuckoo
	Cacomantis variolosus	brush cuckoo
	Chrysococcyx basalis	Horsfield's bronze-cuckoo
	Chrysococcyx lucidus	shining bronze-cuckoo
	Chrysococcyx minutillus	little bronze-cuckoo
	Chrysococcyx osculans	black-eared cuckoo
	Chrysococcyx russatus	Gould's bronze-cuckoo
	Cuculus pallidus	pallid cuckoo
	Cuculus saturatus	oriental cuckoo
	Eudynamys scolopacea	common koel
	Scythrops novaehollandiae	channel-billed cuckoo
Dicaeidae	*Dicaeum hirundinaceum*	mistletoebird

Family	Scientific Name	Common Name
Dicruridae	*Dicrurus bracteatus*	spangled drongo
	Grallina cyanoleuca	magpie-lark
	Monarcha leucotis	white-eared monarch
	Monarcha melanopsis	black-faced monarch
	Monarcha trivirgatus	spectacled monarch
	Myiagra alecto	shining flycatcher
	Myiagra cyanoleuca	satin flycatcher
	Myiagra inquieta	restless flycatcher
	Myiagra rubecula	leaden flycatcher
	Myiagra ruficollis	broad-billed flycatcher
	Rhipidura fuliginosa	grey fantail
	Rhipidura leucophrys	willie wagtail
	Rhipidura rufifrons	rufous fantail
Falconidae	*Falco berigora*	brown falcon
	Falco cenchroides	nankeen kestrel
	Falco longipennis	Australian hobby
	Falco peregrinus	peregrine falcon
Fregatidae	*Fregata ariel*	lesser frigatebird
	Fregata minor	great frigatebird
Gruidae	*Grus rubicunda*	brolga
Haematopodidae	*Haematopus fuliginosus*	sooty oystercatcher
	Haematopus longirostris	pied oystercatcher
Halcyonidae	*Tanysiptera sylvia*	buff-breasted paradise-kingfisher
	Dacelo leachii	blue-winged kookaburra
	Dacelo novaeguineae	laughing kookaburra
	Todiramphus chloris	collared kingfisher
	Todiramphus macleayii	forest kingfisher
	Todiramphus sanctus	sacred kingfisher
Hirundinidae	*Hirundo ariel*	fairy martin
	Hirundo neoxena	welcome swallow
	Hirundo nigricans	tree martin
Jacanidae	*Irediparra gallinacea*	comb-crested jacana
Laridae	*Chlidonias leucopterus*	white-winged black tern
	Gelochelidon nilotica	gull-billed tern
	Larus novaehollandiae	silver gull
	Onychoprion anaethetus	bridled tern
	Sterna albifrons	little tern
	Sterna bengalensis	lesser crested tern
	Sterna bergii	crested tern
	Sterna caspia	Caspian tern
	Sterna hirundo	common tern
Maluridae	*Malurus lamberti*	variegated fairy-wren
	Malurus melanocephalus	red-backed fairy-wren
Megapodiidae	*Alectura lathami*	Australian brush-turkey
Megapodiidae	*Megapodius reinwardt*	Orange-footed scrubfowl
Meliphagidae	*Conopophila rufogularis*	rufous-throated honeyeater
	Entomyzon cyanotis	blue-faced honeyeater
	Lichenostomus fasciogularis	mangrove honeyeater
	Lichenostomus fuscus	fuscous honeyeater
	Lichenostomus leucotis	white-eared honeyeater
	Lichmera indistincta	brown honeyeater
	Manorina melanocephala	noisy miner
	Meliphaga lewinii	Lewin's honeyeater

Family	Scientific Name	Common Name
	Melithreptus albogularis	white-throated honeyeater
	Melithreptus gularis	black-chinned honeyeater
	Melithreptus lunatus	white-naped honeyeater
	Myzomela obscura	dusky honeyeater
	Myzomela sanguinolenta	scarlet honeyeater
	Philemon citreogularis	little friarbird
	Philemon corniculatus	noisy friarbird
	Phylidonyris nigra	white-cheeked honeyeater
	Ramsayornis fasciatus	bar-breasted honeyeater
Meropidae	*Merops ornatus*	rainbow bee-eater
Motacillidae	*Anthus novaeseelandiae*	Richard's pipit
Nectariniidae	*Nectarinia jugularis*	yellow-bellied sunbird
Neosittidae	*Daphoenositta chrysoptera*	varied sittella
Oriolidae	*Oriolus sagittatus*	olive-backed oriole
	Sphecotheres viridis	figbird
Otididae	*Ardeotis australis*	Australian bustard
Pachycephalidae	*Colluricincla harmonica*	grey shrike-thrush
	Colluricincla megarhyncha	little shrike-thrush
	Falcunculus frontatus	crested shrike-tit
	Pachycephala pectoralis	golden whistler
	Pachycephala rufiventris	rufous whistler
Pardalotidae	*Acanthiza chrysorrhoa*	yellow-rumped thornbill
	Acanthiza reguloides	buff-rumped thornbill
	Gerygone levigaster	mangrove gerygone
	Gerygone magnirostris	large-billed gerygone
	Gerygone olivacea	white-throated gerygone
	Gerygone palpebrosa	fairy gerygone
	Pardalotus punctatus	spotted pardalote
	Pardalotus striatus	striated pardalote
	Sericornis frontalis	white-browed scrubwren
	Sericornis magnirostris	large-billed scrubwren
	Smicrornis brevirostris	weebill
Passeridae	*Lonchura castaneothorax*	chestnut-breasted mannikin
	Neochmia temporalis	red-browed finch
	Taeniopygia bichenovii	double-barred finch
Pelecanidae	*Pelecanus conspicillatus*	Australian pelican
Petroicidae	*Eopsaltria australis*	eastern yellow robin
	Melanodryas cucullata	hooded robin
	Microeca fascinans	jacky winter
	Petroica rosea	rose robin
Phalacrocoracidae	*Phalacrocorax carbo*	great cormorant
	Phalacrocorax melanoleucos	little pied cormorant
	Phalacrocorax sulcirostris	little black cormorant
	Phalacrocorax varius	pied cormorant
Phasianidae	*Coturnix chinensis*	king quail
	Coturnix ypsilophora	brown quail
Pittidae	*Pitta versicolor*	noisy pitta
Podargidae	*Podargus strigoides*	tawny frogmouth
Podicipedidae	*Tachybaptus novaehollandiae*	Australasian grebe
Pomatostomidae	*Pomatostomus temporalis*	grey-crowned babbler
Procellariidae	*Ardenna tenuirostris*	wedge-tailed shearwater
	Ardenenna pacifica	short-tailed shearwater
Psittacidae	*Aprosmictus erythropterus*	red-winged parrot

Family	Scientific Name	Common Name
	Glossopsitta pusilla	little lorikeet
	Platycercus adscitus	pale-headed rosella
	Trichoglossus chlorolepidotus	scaly-breasted lorikeet
	Trichoglossus haematodus	rainbow lorikeet
Ptilonorhynchidae	*Ptilonorhynchus violaceus*	satin bowerbird
Rallidae	*Amaurornis olivaceus*	bush-hen
	Fulica atra	Eurasian coot
	Gallinula tenebrosa	dusky moorhen
	Gallinula ventralis	black-tailed native-hen
	Gallirallus philippensis	buff-banded rail
	Porphyrio porphyrio	purple swamphen
Recurvirostridae	*Himantopus himantopus*	black-winged stilt
Scolopacidae	*Actitis hypoleucos*	common sandpiper
	Arenaria interpres	ruddy turnstone
	Calidris acuminata	sharp-tailed sandpiper
	Calidris alba	sanderling
	Calidris canutus	red knot
	Calidris ferruginea	curlew sandpiper
	Calidris ruficollis	red-necked stint
	Calidris tenuirostris	great knot
	Heteroscelus brevipes	grey-tailed tattler
	Heteroscelus incanus	wandering tattler
	Limnodromus semipalmatus	Asian dowitcher
	Limosa lapponica	bar-tailed godwit
	Limosa limosa	black-tailed godwit
	Numenius madagascariensis	eastern curlew
	Numenius phaeopus	whimbrel
	Tringa nebularia	common greenshank
	Tringa stagnatilis	marsh sandpiper
	Xenus cinereus	terek sandpiper
Strigidae	*Ninox connivens*	barking owl
	Ninox novaeseelandiae	southern boobook
	Ninox strenua	powerful owl
Sulidae	*Morus serrator*	Australasian gannet
	Sula dactylatra	masked booby
	Sula leucogaster	brown booby
	Sula sula	red-footed booby
Sylviidae	*Acrocephalus stentoreus*	clamorous reed-warbler
	Cincloramphus cruralis	brown songlark
	Cincloramphus mathewsi	rufous songlark
	Cisticola exilis	golden-headed cisticola
	Megalurus timoriensis	tawny grassbird
Threskiornithidae	*Platalea flavipes*	yellow-billed spoonbill
	Platalea regia	royal spoonbill
	Threskiornis molucca	Australian white ibis
	Threskiornis spinicollis	straw-necked ibis
Turnicidae	*Turnix maculosa*	red-backed button-quail
	Turnix pyrrhothorax	red-chested button-quail
	Turnix varia	painted button-quail
	Turnix velox	little button-quail
Tytonidae	*Tyto alba*	barn owl
Zosteropidae	*Zosterops lateralis*	silvereye