
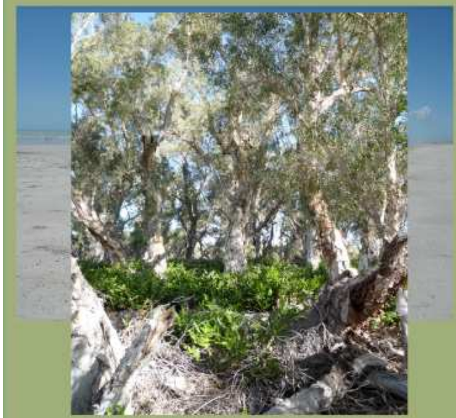


Ecological Character Description of the Eighty-mile Beach Ramsar Site

A Report to the
Department of Environment and Conservation

March 2009

Australian Government

Department of
Environment and Conservation

Our environment, our future

Jennifer Hale and Rhonda Butcher

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Glossary

Definitions of words associated with ecological character descriptions (DEWHA 2008a and references cited within).

Benefits	benefits/services are defined in accordance with the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). See also "Ecosystem Services".
Biogeographic region	a scientifically rigorous determination of regions as established using biological and physical parameters such as climate, soil type, vegetation cover, etc (Ramsar Convention 2005).
Biological diversity	the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species (genetic diversity), between species (species diversity), of ecosystems (ecosystem diversity), and of ecological processes. This definition is largely based on the one contained in Article 2 of the Convention on Biological Diversity (Ramsar Convention 2005).
Change in ecological character	is defined as the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005a, Resolution IX.1 Annex A).
Community	an assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000).
Community Composition	all the types of taxa present in a community (ANZECC and ARMCANZ 2000).
Conceptual model	wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems (Gross 2003)
Contracting Parties	are countries that are Member States to the Ramsar Convention on Wetlands; 153 as at September 2006. Membership in the Convention is open to all states that are members of the United Nations, one of the UN specialized agencies, or the International Atomic Energy Agency, or is a Party to the Statute of the International Court of Justice
Critical stage	meaning stage of the life cycle of wetland-dependent species. Critical stages being those activities (breeding, migration stopovers, moulting etc.) which if interrupted or prevented from occurring may threaten long-term conservation of the species. (Ramsar Convention 2005).
Ecological character	is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.
Ecosystems	the complex of living communities (including human communities) and non-living environment (Ecosystem Components) interacting (through Ecological Processes) as a functional unit which provides inter alia a variety of benefits to people (Ecosystem Services). (Millennium Ecosystem Assessment 2005).
Ecosystem components	include the physical, chemical and biological parts of a wetland (from large scale to very small scale, e.g. habitat, species and genes) (Millennium Ecosystem Assessment 2005).
Ecosystem processes	are the changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological. (Ramsar Convention 1996, Resolution VI.1 Annex A). They include all those processes that occur between organisms and within and between populations and communities, including interactions with the non-living environment, that result in existing ecosystems and bring about changes in ecosystems over time (Australian Heritage Commission 2002)
Ecosystem services	are the benefits that people receive or obtain from an ecosystem. The components of ecosystem services are provisioning (e.g. food & water), regulating (e.g. flood control), cultural (e.g. spiritual, recreational), and supporting (e.g nutrient cycling, ecological value). (Millennium Ecosystem Assessment 2005). See also "Benefits".
Geomorphology	the study of water-shaped landforms (Gordon et al. 1999)
Indigenous species	a species that originates and occurs naturally in a particular country (Ramsar Convention 2005).
Limits of Acceptable Change	the variation that is considered acceptable in a particular component or process of the ecological character of the wetland without indicating

	change in ecological character which may lead to a reduction or loss of the criteria for which the site was Ramsar listed' (modified from definition adopted by Phillips 2006).
List of Wetlands of International Importance ("the Ramsar List")	the list of wetlands which have been designated by the Ramsar Contracting Partiy in which they reside as internationally important, according to one or more of the criteria that have been adopted by the Conference of the Parties.
Ramsar	city in Iran, on the shores of the Caspian Sea, where the Convention on Wetlands was signed on 2 February 1971; thus the Convention's short title, "Ramsar Convention on Wetlands".
Ramsar Criteria	Criteria for Identifying Wetlands of International Importance, used by Contracting Parties and advisory bodies to identify wetlands as qualifying for the Ramsar List on the basis of representativeness or uniqueness or of biodiversity values.
Ramsar Convention	Convention on Wetlands of International Importance especially as Waterfowl Habitat. Ramsar (Iran), 2 February 1971. UN Treaty Series No. 14583. As amended by the Paris Protocol, 3 December 1982, and Regina Amendments, 28 May 1987. The abbreviated names "Convention on Wetlands (Ramsar, Iran, 1971)" or "Ramsar Convention" are more commonly used.
Ramsar Information Sheet (RIS)	the form upon which Contracting Parties record relevant data on proposed Wetlands of International Importance for inclusion in the Ramsar Database; covers identifying details like geographical coordinates and surface area, criteria for inclusion in the Ramsar List and wetland types present, hydrological, ecological, and socioeconomic issues among others, ownership and jurisdictions, and conservation measures taken and needed.
Ramsar List	the List of Wetlands of International Importance
Ramsar Sites	wetlands designated by the Contracting Parties for inclusion in the List of Wetlands of International Importance because they meet one or more of the Ramsar Criteria
Wetlands	are 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 (Ramsar Convention 1987).
Wetland types	as defined by the Ramsar Convention's wetland classification system [http://www.ramsar.org/ris/key_ris.htm#type].

List of Abbreviations

CALM	Department of Conservation and Land Management (former Western Australian government department)
CAMBA	China Australia Migratory Bird Agreement
CMS	Convention on the Conservation of Migratory Species of Wild Animals
DEC	Department of Environment and Conservation (Western Australia)
DEWHA	Department of Environment, Water, Heritage and the Arts (Commonwealth)
DoW	Department of Water (Western Australia)
ECD	Ecological Character Description
EPBC Act	Environment Protection and Biodiversity Conservation Act, 1999 (Commonwealth)
JAMBA	Japan Australia Migratory Bird Agreement
LAC	Limits of Acceptable Change
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement

Executive Summary

The Eighty-mile Beach Ramsar site is located in north Western Australia. The site comprises of two separate areas: 220km of beach and associated intertidal mudflats from Cape Missiessy to Cape Keraudren ("the beach") and Mandora Salt Marsh 40km to the east (Figure E1).

The beach is characterised by extensive intertidal mudflats comprised of fine silt and clay, ranging in width from 1 to 4km. At the landward extent of the mudflats is a narrow strip of coarse quartz sand bounded by coastal dunes to the east. The beach is a relatively uninterrupted linear stretch with a few tidal creeks to the south lined with a small extent of Grey Mangroves (*Avicennia marina*).

The intertidal zone supports an abundance of macroinvertebrates, which provide food for very large numbers of shorebirds. To date over 100 species of birds have been recorded at the beach, including 97 waterbirds and 42 species of migratory shorebird. The site is considered one of the most important in Australia for numbers of shorebirds supported (Bamford et al. 2008). The beach is also an important nesting site for a number of species of marine turtles (Chapman in prep.).

Mandora Salt Marsh comprises of a series of floodplain depressions within a linear dune system (Semeniuk and Semeniuk 2000). The site contains two large seasonal depressional wetlands (Lake Walyarta and East Lake) and a series of small permanent mound springs. Low paperbark thickets and samphire extend on clay soils adjacent to the lakes and surrounding the wetlands are expanses of arid zone plains on red soils (Graham 1999).

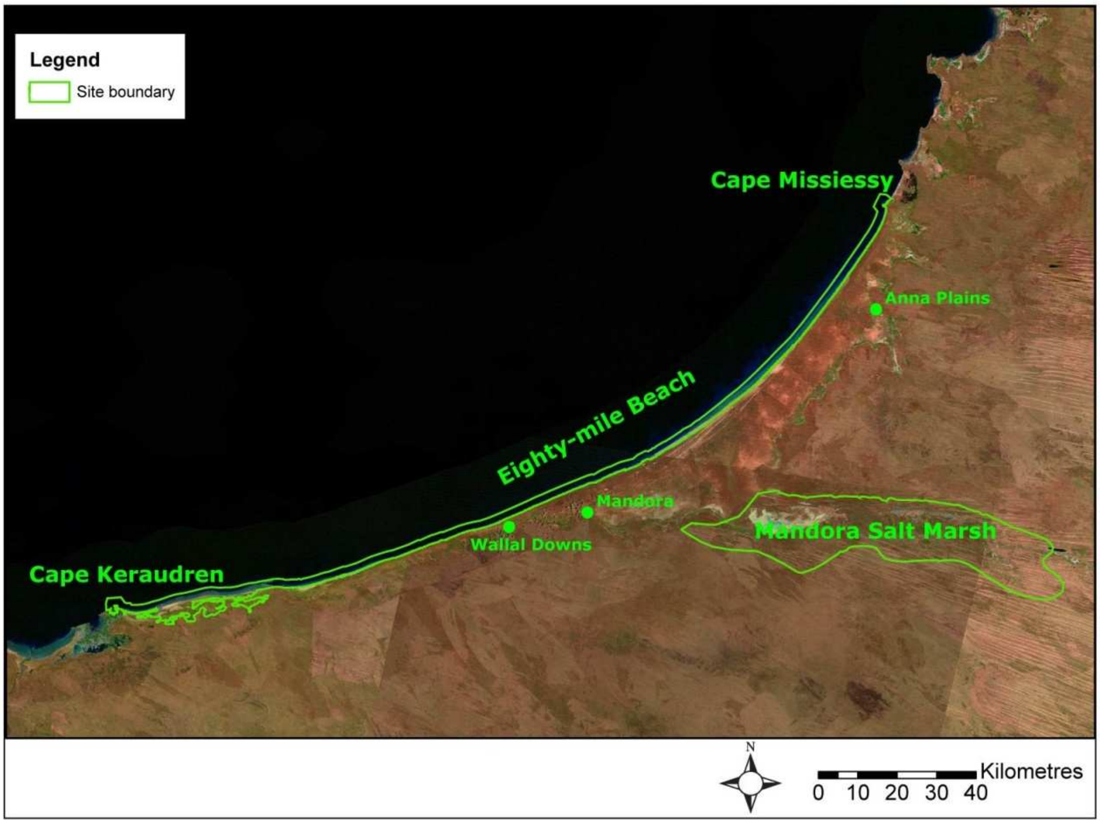

Figure E1: Location of Eighty-mile Beach Ramsar site (data supplied by DEC).

The Eighty-mile Beach Ramsar site meets the following six criteria for listing as a wetland of international importance:

Criterion 1: Eighty-mile Beach represents the greatest extent of continuous intertidal mudflat in excellent condition within the Northwest (IMCRA) bioregion. In addition, Mandora Salt Marsh contains an important and rare group of wetlands within the arid Western Plateau bioregion (Semeniuk and Semeniuk 2000). In particular the peat mound springs can be considered both bioregionally rare and outstanding examples of this wetland type in Western Australia.

Criterion 2: The site supports the Flatback Turtle (*Natator depressus*) listed as vulnerable under the EPBC Act and data deficient under the IUCN Red List.

Criterion 3: The Mandora Salt Marsh contains temporary and permanent wetlands in a predominantly arid bioregion (Western Plateau) and has been recognised as important refugia for biological diversity in arid Australia (Morton et al. 1995). The inland Grey Mangroves lining Salt Creek represent the most inland occurrence of this species (Semeniuk and Semeniuk 2000). In 1999 a suspected new species of goby (*Acentrogobius sp*. nov.) was collected from Salt Creek in Mandora Marshes (A. Storey pers. comm.). However, the specimen has yet to be officially identified and catalogued.

Criterion 4: The Eighty-mile Beach Ramsar site is considered one of the most important sites for stop-over and feeding by migratory shorebirds in Australia; second only to Roebuck Bay in the total number of migratory species for which it is considered internationally important. Furthermore, Eighty-mile Beach represents the most important site internationally (in terms of total number of individuals) for nine species of migratory shorebird in the East Asian-Australasian flyway (Bamford et al. 2008). Mandora Salt Marsh supports the critical life stage of breeding for at least 13 species of waterbird, including large numbers of Australian Pelicans and Black Swans (Birds Australia 2008). In addition, the site is significant for the breeding of at least one species of marine turtle (Flatback). This criterion was met at the date of listing and continues to be met.

Criterion 5: Eighty-mile Beach is considered to regularly support in excess of 500,000 birds (Wade and Hickey 2008). Total counts (summer) for just a 60km stretch of the 220km intertidal site are generally > 200,000 (Shorebirds 2020 unpublished data). There is a record of 2.88 million Oriental Pratincoles on the beach in February 2004 (Sitters et al. 2004).

Criterion 6: Eighty-mile Beach supports more than 1% of the flyway population (or 1% of the Australian population for resident species) of 21 waterbirds, including 17 migratory species and 4 Australian residents: Greater Sand Plover *Charadrius leschenaultii*, Oriental Plover *C. veredus*, Red-capped Plover *C. ruficapillus* (resident), Grey Plover *Pluvialis squatarola,* Bar-tailed Godwit *Limosa lapponica*, Red Knot *Calidris canutus*, Great Knot *C. tenuirostris*, Red-necked Stint *C. ruficollis*, Sanderling *C. alba,* Sharp-tailed Sandpiper *C. acuminata,* Curlew Sandpiper *C. ferruginea*, Eastern Curlew *Numenius madagascariensis*, Little Curlew *N. minutus*, Common Greenshank *Tringa nebularia*, Grey-tailed Tattler *T. brevipes,* Terek Sandpiper *T.terek,* Ruddy Turnstone *Arenaria interpres,* Pied Oystercatcher *Haematopus longirostris* (resident); Oriental Pratincole *Glareola maldivarum*, Black-winged Stilt *Himantopus himantopus* (resident) and Great Egret *Adea alba* (resident).

In addition, surveys of the entire and vast marshes system behind the coast, including Mandora Salt Marsh, revealed high numbers (over 1% levels) for several other waterbirds after cyclonic flooding in 1999-2000 (Halse et al. 2005). Substantial portions of the numbers of some of these species may have occurred within the Ramsar boundary but further analysis of the raw data is needed to identify which data apply to the Ramsar-listed (eastern) portion. Similar flooding has occurred previously, e.g. early 1980s and it is likely that these large numbers of waterbirds occur during all such flood events.

A summary of the ecological character of the Eighty-mile Beach Ramsar site is provided in Tables E1 and E2.

Table E1: Summary of the critical components and processes of the Eighty-mile Beach Ramsar site.

Component / Process	Summary Description
Climate	Semi-arid monsoonal with a prolonged dry period > 80% of rainfall in the wet season (December to March) High inter-annual variability High occurrence of tropical cyclones
The beach	
Geomorphology	Extensive intertidal mudflats comprised of fine grained sediments. Site is backed by steep dunes comprised of calcareous sand.
Hydrology	Macro-tidal regime. No significant surface water inflows. Groundwater interactions unknown (knowledge gap)
Primary production and nutrient cycling	Data deficient, but organic material deposited from ocean currents driving the system through bacterial or microphytobenthos driven primary production.
Invertebrates	Large number and diversity of invertebrates within the intertidal mudflat areas
Fish	Data deficient, but anecdotal evidence of marine fish (including sharks and rays) using inundated mudflats.
Waterbirds	Significant site for stop-over and feeding by migratory shorebirds. Regularly supports > 200,000 shorebirds during summer and > 20,000 during winter. High diversity with 97 species of waterbird recorded from the beach Regularly supports > 1% of the flyway population of 20 species
Marine Turtles	Significant breeding site for the Flatback Turtle
Mandora Salt Marsh	
Geomorphology	Wetland formation dominated by alluvial processes Wetlands were once a part of an ancient estuary Freshwater springs have been dated at 7000 years old
Hydrology	Walyarta, East Lake and the surrounding intermittently inundated paperbark thickets are inundated by rainfall and local runoff. Extensive inundation occurs following large cyclonic events Salt Creek and the Mound springs are groundwater fed systems through the Broome Sandstone Aquifer.
Water quality	Most wetlands are alkaline reflecting the influence of soils and groundwater. Salinity is variable, mound springs are fresh, Salt Creek hyper-saline and Walyarta variable with inundation. Nutrient concentrations in groundwater and groundwater fed systems are high.
Primary production and nutrient cycling	Data deficient. However evidence of boom and bust cycle at Walyarta with seasonal inundation.
Vegetation	Inland mangroves (*Avicennia marina*) lining Salt Creek are one of only two occurrences of inland mangroves in Australia. Paperbark thickets dominated by the saltwater paperbark (*Melaleuca alsophila*) extend across the site on clay soils which retain moisture longer than the surrounding landscape. Samphire (*Tecticornia spp.*) occurs around the margins of the large lakes. Freshwater aquatic vegetation occurs at Walyarta when inundated and at the mound spring sites year round.
Invertebrates	Data limited, but potentially unique species.
Waterbirds	Significant site for waterbirds and waterbird breeding, particularly during extensive inundation events. 66 waterbirds recorded Supports > 1% of the population of at least 2 species Breeding recorded for at least 24 species

Table E2: Summary of the benefits and services of the Eighty-mile Beach Ramsar site.

Category	Summary Description
Benefits and services	
Provisioning services	Freshwater- the freshwater springs at Mandora Salt Marsh provide drinking water for livestock Genetic resources - plausible, but as yet no documented uses
Regulating services	Climate regulation – plausible, but data deficient Biological control of pests – Evidence that many of the shorebirds feed on the adjacent pastoral land and that the incidence of 2.88 million Oriental Pratincole coincided with locusts in almost plague proportions, upon which the birds fed (Sitters et al. 2004)
Cultural services	Recreation and tourism – the beach portion of the site is important for recreational fishing; tourism; bird watching and shell collecting Spiritual and inspirational - spiritually significant for the Karajarri and Nyangumarta and contain a number of specific culturally significant sites; site has inspirational, aesthetic and existence values at regional, state and national levels Mandora Salt Marsh and Eighty-mile Beach have been the site of a number of significant scientific investigations (e.g. Graham 1999; Piersma et al. 2005). In addition, Eighty-mile Beach is a significant site for migratory shorebird monitoring and is currently part of the Shorebirds 2020 program.
Supporting services	As evidenced by the listing of the Eighty-mile Beach site as a wetland of international importance. The system provides a wide range of biodiversity related ecological services critical for the ecological character of the site including: • Contains exceptionally large examples of wetland types and includes rare wetland types of special scientific interest • Supports significant numbers of migratory birds • Supports waterbird breeding • Supports marine turtles

“Limits of acceptable change” is the terminology used under the Ramsar convention to set limits on how much key aspects of the ecology of the site can change without risking the ecological character. Limits of acceptable change for the Eighty-mile Beach Ramsar site have been determined based on existing data and guidelines and are summarised in Tables E3 and E4.

Table E3: Summary of Limits of acceptable change for the beach portion of the Eighty-mile Beach Ramsar site.

Component/Process	Limit of Acceptable Change
Abiotic Components and Processes	
Hydrology	Unrestricted tides along the entire length of the beach site, not impacted or modified by any artificial structure.
Primary Responses	
Primary production	Data deficient – baseline must be established before limits can be set.
Key Faunal Communities	
Invertebrates	Data deficient – baseline must be established before limits can be set.
Fish	Data deficient – baseline must be established before limits can be set.
Waterbirds	Shorebird numbers > 200,000 during summer and > 20,000 during winter in the area 0 – 60 km south of Anna Plains
	Summer counts in the area 0 – 60km south of Anna Plains: Bar-tailed Godwits > 35,000 Great Knot > 55,000 Greater Sand Plover > 23,000 Red-necked Stint > 18,000 Terek Sandpiper > 4,800
Flatback Turtles	Data deficient – baseline must be established before limits can be set.

Table E4: Summary of Limits of acceptable change for Mandora Salt Marsh within the Eighty-mile Beach Ramsar site.

Component/Process	Limit of Acceptable Change
Abiotic Components and Processes	
Hydrology	Extent and duration of inundation to be maintained, with no additional barriers to flow or extraction of floodwaters.
	Data deficient – baseline must be established before limits can be set. However a conservative limit of no increase in groundwater extractions from current levels should be established.
Nutrients	Data deficient – baseline must be established before limits can be set.
pH	Data deficient – baseline must be established before limits can be set.
Salinity	Data deficient – baseline must be established before limits can be set. Interim limit - Salinity in Salt Creek to be < 40 ppt during the wet season and < 55 ppt during the dry
	Data deficient – baseline must be established before limits can be set. Interim limit for mound springs - salinity < 6 ppt
Primary Responses	
Mangrove	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent Evidence of regeneration present (after large flood events)
Paperbark	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent of paperbark communities within the Ramsar site
Samphire	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent of samphire communities within the Ramsar site
Freshwater aquatic vegetation	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent or change in community composition of spring vegetation communities within the Ramsar site
Key Faunal Communities	
Waterbirds	Data deficient – baseline must be established before limits can be set.

By virtue of its remote location, limited diversity of adjacent land uses (pastoral and transport corridor) and limited public access, Eighty-mile Beach has fewer threats than comparable sites in southern and eastern Australia (Watkins et al. 1997; Pearson et al. 2005). However, there are still a small number of potential and actual threats that may impact on the ecological character of the Ramsar site. These are illustrated in Figure E2 and summarised in Table E5.

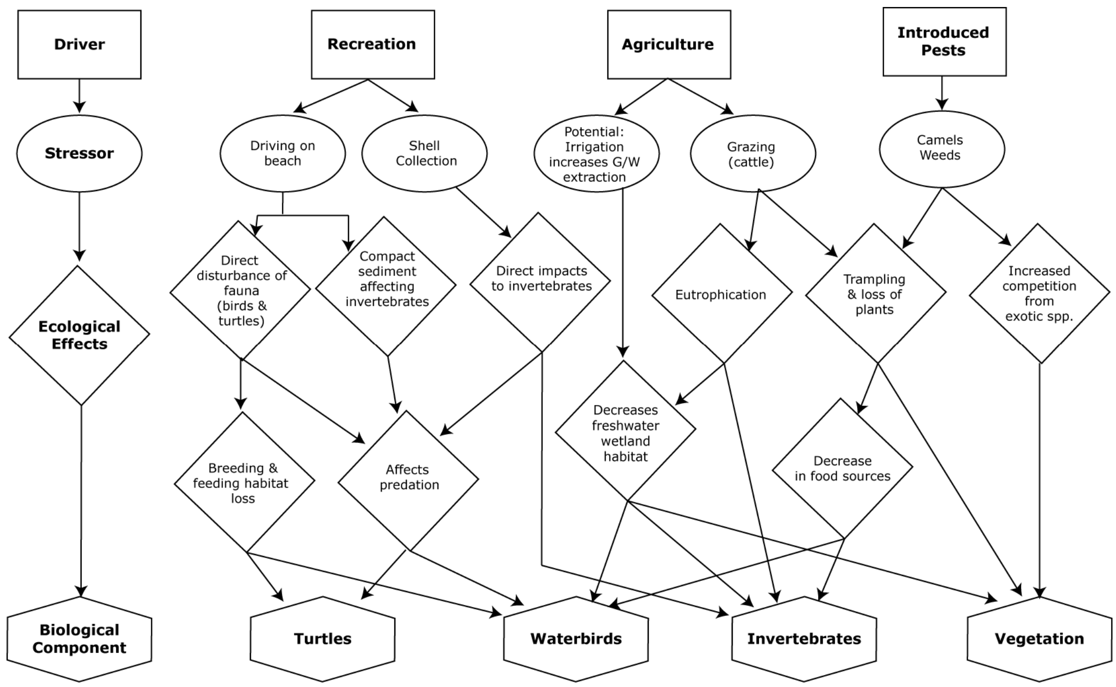

Figure E2: Stressor model of the Eighty-mile Beach Ramsar site.

Table E5: Summary of threats to the Eighty-mile Beach Ramsar site.

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or service	Likelihood	Timing of threat
Recreation – driving on the beach	• Erosion of coastal dunes • Disturbance of migratory birds • Disturbance of turtle nesting sites	Certain	Immediate – long-term
Recreation – shell collection	• Direct removal of invertebrates or decrease in habitat.	Certain	Immediate – long-term
Agriculture – cattle grazing.	• Trampling of vegetation. • Erosion of wetland shores • Increased nutrients	Certain	Immediate – medium term (until 2015)
Agriculture – extraction of groundwater for irrigation.	• Altered hydrology in groundwater dependant wetlands • Water quality impacts	Medium-low	Medium-long term
Introduced species	• Weeds displacing native vegetation • Feral predators impacting on turtles and waterbirds	Certain	Immediate – long term
Mining	• Increased water extraction leading to decreased wetland habitat (breeding and feeding habitat for waterbirds) • Off-shore mining and construction could impact on intertidal habitats	Low	Medium term
Commercial fishing	• Changes to community composition and abundance of fish communities (including sharks and rays) • Decrease in food resources for piscivorous birds	Unknown	Immediate – medium term
Climate change – increase in cyclones	• Increase in disturbance of intertidal and beach areas • Changes in inundation frequency and duration across Mandora Marshes	Medium	Long term
Climate change – sea level rise	• Changes to intertidal mudflat extent	Medium	Long term

There are a number of key knowledge gaps that limit the description of ecological character and the setting of limits of acceptable change for the Eighty-mile Beach Ramsar site. These include:

- An understanding of the hydrology of the wetlands at Mandora Salt Marsh, including the environmental water requirements of the groundwater dependant ecosystems;
- The potential groundwater connection to the intertidal mudflats at Eighty-mile Beach and the potential importance for these "freshwater" discharges to productivity at the site;
- Long-term water quality;
- Nutrient cycling and primary productivity at the site;
- Composition and extent of vegetation communities at Mandora Salt Marsh;
- Community composition and abundance of fish within the site;
- Waterbird usage, abundance and composition at Mandora Salt Marsh (current data is limited to a small number of surveys);
- Quantitative data for turtle nesting; and
- Recreational usage and impacts to ecological character.

To address these knowledge gaps and inform against the limits of acceptable change the monitoring needs for the Eighty-mile Beach Ramsar site have been documented and prioritised. Those that were identified as the highest priority are as follows:

- Water quality (Mandora Salt Marsh)
    - Nutrients, salinity, dissolved oxygen and pH
- Vegetation (entire site)
    - Extent
    - Community composition
- Waterbirds (entire site)
    - Abundance
    - Community composition
    - Breeding
- Turtles (Beach)
    - Species identification and nesting records
- Recreation use (Beach)
    - Location and number of vehicles

1. Introduction

1.1 Site details

The Eighty-mile Beach Ramsar site is located in the Shire of Broome and Shire of East Pilbara in north Western Australia. It was originally nominated as a "Wetland of International Importance" under the Ramsar Convention in 1990. Site details for this Ramsar wetland are provided in Table 1.

Table 1: Site details for the Eighty-mile Beach Ramsar site taken from the Ramsar Information Sheet (2003).

Site Name	Eighty-mile Beach, Western Australia
Location in coordinates	Latitude: 19°02' S to 20°00' S Longitude: 119°48' E to 121°32' E
General location of the site	The Eighty-mile Beach Ramsar site is located in the southern part of the Shire of Broome and extends in to Shire of East Pilbara at Cape Keraudren and parts of the Mandora Marshes. Biogeographic region: Northwest (IMCRA v4 Commonwealth of Australia 2006). River Basin: 025 Sandy Desert; Drainage Division 12: Western Plateau (Australia's River Basins 1997, GeoScience Australia) The site includes Eighty-mile Beach (220km) from Cape Missiessy to Cape Keraudren and Mandora Salt Marsh, Western Australia
Area	175,487 hectares
Date of Ramsar site designation	Designated on 7/6/1990
Ramsar/DIWA Criteria met by wetland	Ramsar criteria 1, 2, 3, 4, 5 and 6.
Management authority for the site	The site is largely unreserved. Marine areas (to 40 m above high tide mark which is the boundary of the beach portion of the Ramsar site) are under the jurisdiction of the Government of Western Australia. A portion of the Mandora Marshes portion of the site is unallocated crown land with the remainder pastoral lease (which will convert to conservation reserve following the excision of this area from pastoral lease in 2015). Parts of the site are subject to a native title claim by the Nyangumarta.
Date the ECD applies	1990
Status of Description	This represents the first ECD for the site
Date of Compilation	January 2009
Name(s) of compiler(s)	Jennifer Hale on behalf of DEC. All enquires to Michael Coote, DEC, 17 Dick Perry Ave, Technology Park, Kensington, WA 6983, Australia, (Tel: +61-8-9219-8714; Fax: +61-8-9219-8750; email: Michael.Coote@dec.wa.gov.au).
References to the Ramsar Information Sheet (RIS)	Eighty-mile Beach Ramsar site RIS compiled by the Western Australian Department of Conservation and Land Management (CALM) in 1990; most recent version 2003. Electronic version: http://www.dec.wa.gov.au/pdf/national_parks/wetlands/fact_sheets/eighty_mile_beach1.doc Updated by Jennifer Hale on behalf of DEC 2009
References to Management Plan(s)	There is no management plan for the Ramsar site. The marine areas are to be included in an interim management plan for marine parks in the Pilbara and Eighty-mile Beach regions.

1.2 Statement of purpose

The act of designating a wetland as a Ramsar site carries with it certain obligations, including managing the site to retain its 'ecological character' and to have procedures in place to detect if any threatening processes are likely to, or have altered the 'ecological character'. Thus, understanding and describing the 'ecological character' of a Ramsar site is a fundamental management tool for signatories and local site managers which should form the baseline or benchmark for management planning and action, including site monitoring to detect negative impacts.

The Ramsar Convention has defined “ecological character” and “change in ecological character” as (Ramsar 2005):

“Ecological character is the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time”

And

“…change in ecological character is the human induced adverse alteration of any ecosystem component, process and or ecosystem benefit/service.”

In order to detect change it is necessary to establish a benchmark for management and planning purposes. Ecological character descriptions (ECD) form the foundation on which a site management plan and associated monitoring and evaluation activities are based. The legal framework for ensuring the ecological character of all Australian Ramsar sites is maintained is the Environment Protection and Biodiversity Act, 1999 (the EPBC Act) (Figure 1). As mentioned above a Ramsar Information Sheet is prepared at the time of designation. However whilst there is some link between the data used for listing a site (based on the various criteria) the information in an RIS does not provide sufficient detail on the interactions between ecological components, processes and functions to constitute a comprehensive description of ecological character. In response to the short fall, the Australian and state/territory governments have developed a *National Framework and Guidance for Describing the Ecological Character of Australia’s Ramsar Wetlands. Module 2 of Australian National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia* (DEWHA 2008a).

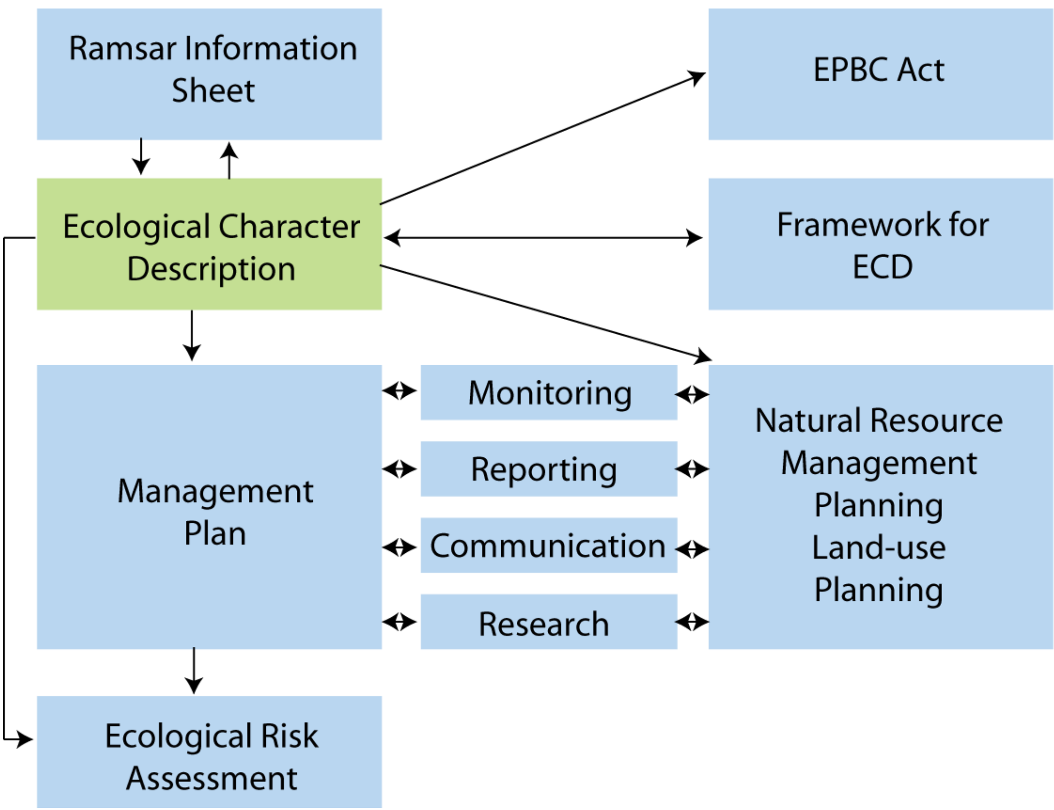

Figure 1: The ecological character description in the context of other requirements for the management of Ramsar sites (adapted from DEWHA, 2008a).

The framework emphasises the importance of describing and quantifying the ecosystem components, processes and benefits/services of the wetland and the relationship between them. It is also important that information is provided on the benchmarks or ecologically significant limits of acceptable change that would indicate when the ecological character has or is likely to change.

McGrath (2006) detailed the general aims of an ECD as follows:

1. To assist in implementing Australia's obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the *Environment Protection and Biodiversity Conservation Regulations* 2000 (Commonwealth):
    a) To describe and maintain the ecological character of declared Ramsar wetlands in Australia; and
    b) To formulate and implement planning that promotes:
        i) Conservation of the wetland; and
        ii) Wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.
2. To assist in fulfilling Australia's obligation under the Ramsar Convention to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.
3. To supplement the description of the ecological character contained in the Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and, collectively, form an official record of the ecological character of the site.
4. To assist the administration of the EPBC Act, particularly:
    a) To determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act; or
    b) To assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.
5. To assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.
6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

The objectives of the Ecological Character Description for Eighty-mile Beach are to provide a description of ecological character that:

1. Describes the critical components, processes and benefits/services of the wetlands with the Eighty-mile Beach Ramsar site at the time of Ramsar listing and the relationships between them;
2. Develops a conceptual model for Eighty-mile Beach that describes the 'ecological character' in terms of components, processes and benefits/services and the relationships between them;
3. Quantifies the limits of acceptable change for the critical components, processes and benefits/services of the wetland;
4. Provides monitoring priorities that will facilitate the detection and ability to report any significant changes in the ecological character of Eighty-mile Beach; and
5. Identifies actual or likely threats/risks to the ecological components, processes or services of the Eighty-mile Beach Ramsar site.

1.3 Relevant treaties, legislation and regulations

This section provides a brief listing of the legislation and policy that is relevant to the description of the ecological character of the Ramsar site. There is a significant amount of legislation, particularly at the state/local level, relevant to the management of the site which will be documented more fully in the management plan for the site and as such is not repeated here.

International

Ramsar convention

The Convention on wetlands, otherwise known as the Ramsar Convention, was signed in Ramsar Iran in 1971 and came into force in 1975. It provides the framework for local, regional and national actions, and international cooperation, for the conservation and wise use of wetlands. Wetlands of international importance are selected on the basis of their international significance in terms of ecology, botany, zoology, limnology and or hydrology

Migratory bird agreements and conventions

Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds, which are relevant to the Eighty-mile Beach Ramsar site. The bilateral agreements are:

JAMBA – The agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974;

CAMBA - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment 1986;

ROKAMBA - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006; and

Convention on the Conservation of Migratory Species of Wild Animals (The Bonn Convention) - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

National legislation

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act regulates actions that will have or are likely to have a significant impact on any matter of national environmental significance, which includes the ecological character of a Ramsar wetland (EPBC Act 1999 s16(1)). An action that will have or is likely to have a significant impact on a Ramsar wetland will require an environmental assessment and approval under the EPBC Act. An 'action' includes a project, a development, an undertaking or an activity or series of activities (http://www.environment.gov.au/epbc/index.html).

The EPBC Act establishes a framework for managing Ramsar wetlands, through the Australian Ramsar Management Principles (EPBC Act 1999 s335), which are set out in Schedule 6 of the Environment Protection and Biodiversity Conservation Regulations 2000. These principles are intended to promote national standards of management, planning, environmental impact assessment, community involvement, and monitoring, for all of Australia's Ramsar wetlands in a way that is consistent with Australia's obligations under the Ramsar Convention. Some matters protected under the EPBC Act are not protected under local or state/territory legislation, and as such, many migratory birds are not specifically protected under State legislation (though they are in Western Australia). Species listed under international treaties JAMBA, CAMBA and CMS have been included in the List of Migratory species under the Act. Threatened species and communities listed under the EPBC Act may also occur, or have habitat in the Ramsar site; some species listed under State legislation as threatened are not listed under the EPBC Act as threatened, usually because they are not threatened at the national (often equivalent to whole-of-population) level. The Regulations also cover matters relevant to the preparation of management plans, environmental assessment of actions that may affect the site, and the community consultation process.

Australian Heritage Council Act 2003
The Australian Heritage Council Act establishes the Australian Heritage Council, which advises the Australian Government on heritage list nominations under the EPBC Act, and also gives the Australian Heritage Council responsibility to maintain the Register of the National Estate. Eighty-mile Beach and Mandora Marshes have been placed on the Register for National Estate. Under the EPBC Act the Minister must consider information in the Register of the National Estate in making decisions under the Act.

Western Australia state policy and legislation
Wildlife Conservation Act 1950
This Act provides for the protection of wildlife and all fauna in Western Australia is protected under section 14 of the Wildlife Conservation Act 1950. The Act establishes licensing frameworks for the taking and possession of protected fauna and also establishes offences and penalties for interactions with fauna.

Conservation and Land Management Act 1984
This Act is administered by the State Department of Environment and Conservation (DEC) and applies to public lands. It sets the framework for the creation and management of marine and terrestrial parks, reserves and management areas in Western Australia, and deals with the protection of flora and fauna within reserve systems.

Aboriginal Heritage Act 1972
There are several important Aboriginal heritage sites within the Eighty-mile Beach Ramsar site, which are protected under this act.

Fisheries Resource Management Act 1995
The Fisheries Resource Management Act 1995 establishes a regulatory framework for managing commercial fishing in WA and has a primary objective: 'to conserve, develop and share the fish resources of the State for the benefit of present and future generations'. The Act provides stipulations for specific fishing equipment and also covers aquaculture industries. It is administered by Fisheries Western Australia.

Environmental Protection Act 1986
The Environmental Protection (Clearing of Native Vegetation) Regulations 2004 under the Act prohibit clearing of native vegetation, unless a clearing permit is granted by the Department of Environment and Conservation or the clearing is for an exempt purpose. The exemptions allow low impact day-to-day activities involving clearing to be undertaken in accordance with the regulations. People who wish to clear native vegetation are required to obtain a permit if an exemption does not apply. Ramsar wetlands and the area within 50 metres of their boundary are identified as environmentally sensitive areas. The clearing exemptions of the Act do not apply in environmentally sensitive areas

Rights in Water and Irrigation Act 1914
The Rights in Water Irrigation Act 1914 and the Rights in Water and Irrigation Amendment Bill 1999 provide for the management of water resources in the state. There are provisions for sustainable use and development to meet the needs of current and future users as well as for the protection of ecosystems and the environment in which water resources are situated. Amendments to the Act, which came into operation on 10 January 2001, establish a licence trading system of water rights in Western Australia.

1.4 Method

The method used to develop the ecological character description for the Eighty-mile Beach Ramsar site is based on the twelve-step approach provided in the *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands* (DEWHA 2008a) illustrated in Figure 2. A more detailed description of each of the steps and outputs required is provided in the source document.

1. Introduction to the description
Site details, purpose of the description, relevant legislation

2. Describe the site
Site location, climate, maps and images, tenure, criteria and wetland types

3. Identify and describe the critical components, processes, benefits and services
3.1 Identify all possible components, processes, benefits and services
3.2 Identify the critical components, processes benefits and services responsible for determining the ecological character of the site
3.3 Describe each of the critical components, processes, benefits & services

4. Develop a conceptual model of the wetland
Depict the critical components & processes of the wetland and their interactions

5. Set limits of acceptable change (LAC)
Determine LAC for critical components, processes and services

6. Identify threats to the ecological character of the site
Identify the actual or likely threats to the site

7. Describe changes to ecological character
Describe changes to the ecological character since the time of listing
Include information on the current condition of the site

8. Summarise knowledge gaps
Use information from Steps 3 - 7 to identify knowledge gaps

9. Identify site monitoring needs
Use information from Steps 3 - 8 to identify monitoring needs

10. Identify communication and education messages
Identify any communication & education messages highlighted during the development process

11. Compile the description of ecological character

12. Prepare or update the Ramsar Information Sheet
Submit as a companion document to the ecological character description

Figure 2: Twelve step process for developing an ECD (adapted from DEWHA 2008a).

This ECD was developed primarily through a desktop assessment and is based on existing data and information. Although a series of visits to the site were undertaken, no new data were collected. A technical expert group and a stakeholder advisory group were formed to provide input and comment on the ECD. Details of members of each of these and more details of the method are provided in Appendix A.

2. General Description of the Eighty-mile Beach Ramsar Site

2.1 Location

The Eighty-mile Beach Ramsar site is located in north Western Australia. The site comprises two separate areas: 220km of beach and associated intertidal mudflats from Cape Missiessy to Cape Keraudren; and Mandora Salt Marsh 40km to the east. Note that for the purposes of this ECD the coastal portion of the site is referred to as “the beach” and the inland portion “Mandora Salt Marsh”; the term “Eighty-mile Beach” refers to the entire Ramsar site.

The beach and Mandora Salt Marsh are separated by the North Highway. Three pastoral stations lie within close proximity to the site; Anna Plains, Mandora and Wallal (Figure 3). The northernmost extent of the site is 142 km south of Broome and the southernmost extent 150 km north of Port Hedland. The majority of the site lies within the Kimberley region and the Shire of Broome. However, the southern 40km of coastline is within the Pilbara region and the Shire of East Pilbara (Figure 4).

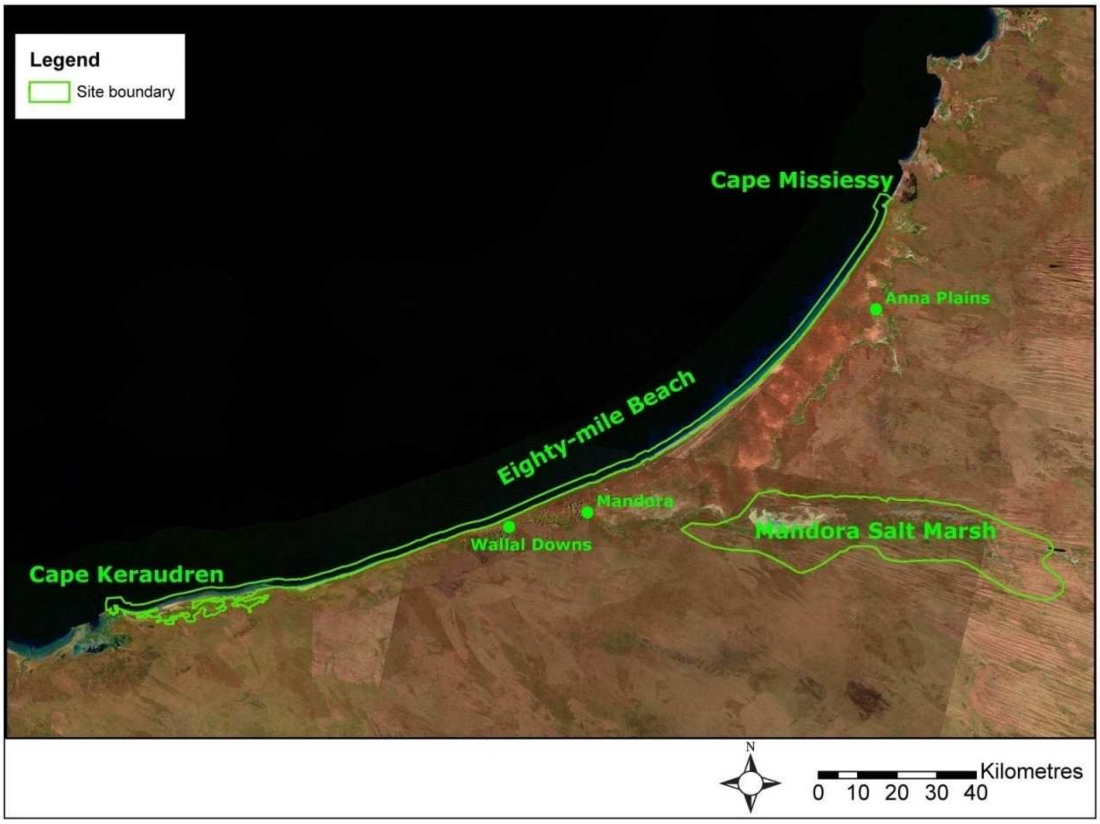

Figure 3: Location of Eighty-mile Beach Ramsar Site (data supplied by DEC).

The coastal section lies within the Dampierland bioregion, while Mandora Salt Marsh is within the Great Sandy Desert bioregion. The bioregions are both considered “rangelands” and contain large areas of relatively undisturbed ecosystems. Dampierland, however, is considerably less arid than the Great Sandy Desert. Dampierland is considered to have a semi-arid to tropical monsoonal climate and comprises extensive plains, ranges and spectacular gorges. The Great Sandy Desert bioregion has an arid tropical climate and is characterised by extensive red sandplains, dunefields and remnant rocky outcrops (DEWHA 2008b). Under the new bioregionalisation for aquatic ecosystems in Australia the site is within Drainage Division 12 (Western Plateau).

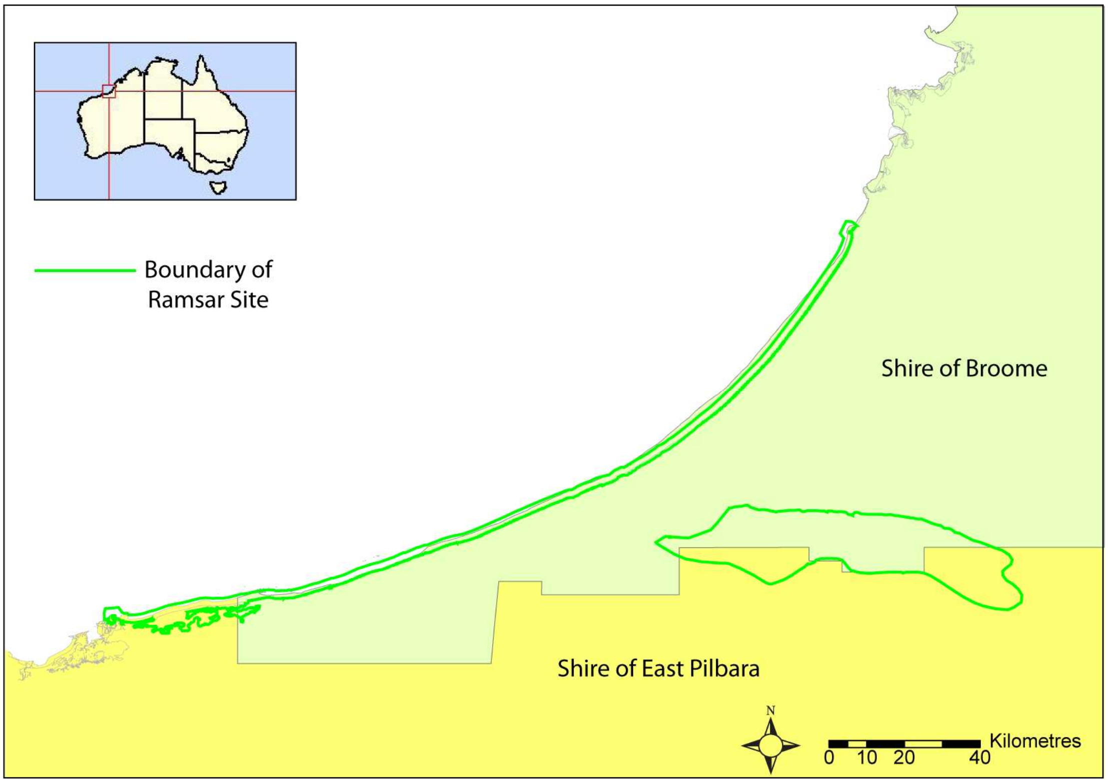

Figure 4: Location of the Eighty-mile beach Ramsar site and local government authorities.

2.2 Land tenure

The beach section of the Eighty-mile Beach Ramsar site lies within unallocated crown land, as does a portion of the Mandora Salt Marsh. The majority of the saltmarshes and the surrounding area is pastoral lease. There are four large pastoral leaseholds of relevance to the Ramsar site: Anna Plains, Mandora, Wallal and Pardoo. These leases occupy the land from 40m above high tide mark along the coast. Anna Plains station also covers the majority of the Mandora Salt Marsh site.

All pastoral leases in Western Australia issued under the now repealed Land Act 1933 expire on 30 June 2015. Under the Land Administration Amendment Act 2000, there is an opportunity for areas to be excluded from lease renewals for "public purposes". One such purpose is conservation (Department of Planning and Infrastructure 2008a). The Department of Conservation and Environment has held discussions with the four lease holders associated with the Eighty-mile Beach Ramsar site. Agreements have been reached for land adjacent to the Ramsar site along the coast to be excised from the Anna Plains, Mandora and Wallal pastoral leases. Additionally, Anna Plains has agreed to the exclusion of the Mandora Salt Marsh and this area will be managed for conservation purposes from 2015 (Figure 5).

In addition to the pastoral leases, there are mining tenements and exploration permits over much of the site and surrounding land (Figure 6 and see section 5 below).

The area covering a large portion of the Ramsar site including the southern sections of the beach and all of the Mandora Salt Marsh is subject to a native title claim by the Nyangumarta. This is currently before the Native Title Tribunal, with a decision expected by March 2009 (Office of Native Title 2008).

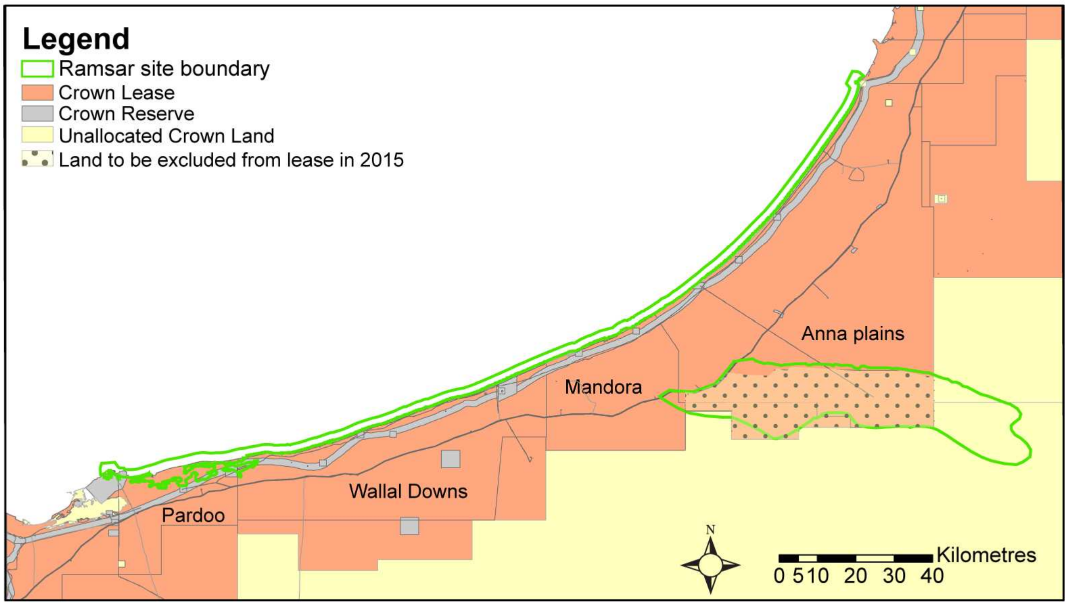

Figure 5: Land tenure within and surrounding the Eighty-mile Beach Ramsar site, including the area covered by the 2015 excision (data supplied by DEC).

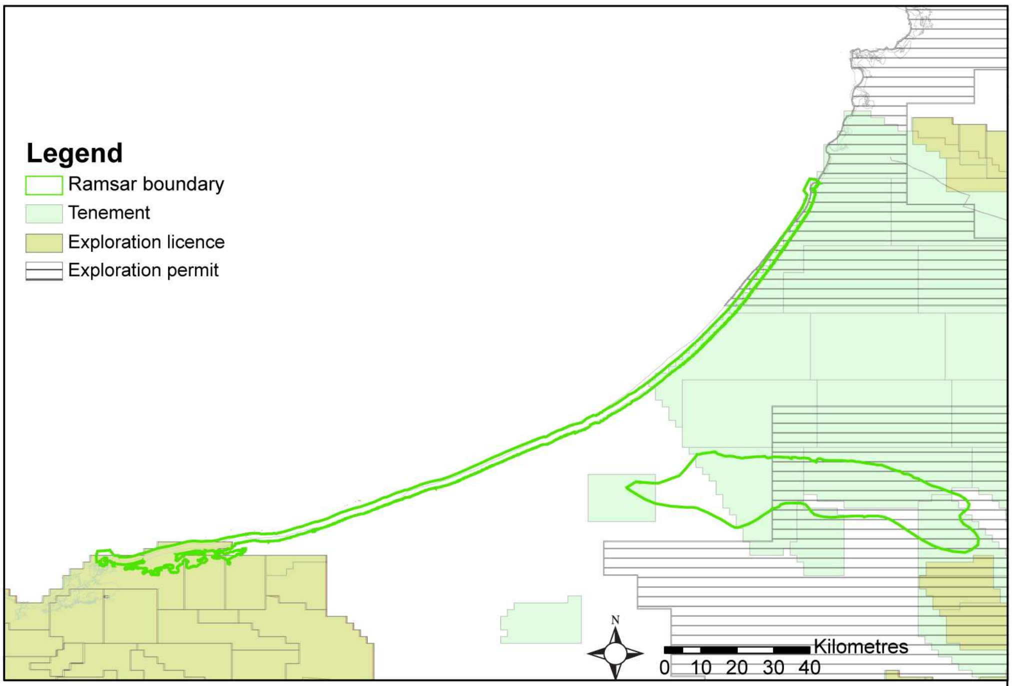

Figure 6: Mining tenements and exploration permits in the Eighty-mile Beach Ramsar site and surrounding area (data supplied by DEC).

2.3 Climate

Eighty-mile Beach lies in the dry tropics of northern Australia. The climate is semi arid, monsoonal with a prolonged dry season and is highly variable both inter-annually (between years) and intra-annually (within a year). The three aspects of climate that most directly affect wetland ecology are rainfall (both local and in the catchment), temperature and relative humidity as these all fundamentally affect wetland hydrology and the water budget.

Rainfall falls almost exclusively in the wet season (November to April) with highest monthly average rainfall in January and February (80 – 100mm). However, there is considerable variability in rainfall as evidenced by the 10th and 90th percentiles, which range from < 1mm per month to > 200 mm per month (Figure 7). The majority of the rainfall occurs during cyclonic events, resulting in large rain events over relatively short periods of time. The highest daily rainfall on record is > 280 mm recorded in March 2000 (Bureau of Meteorology 2008).Annual average rainfall at Mandora is very low, in the order of 470 mm per year. However, there is high inter-annual variation with annual rainfalls ranging from < 150mm to > 1000mm in the 40 years of records from this site (Figure 8).

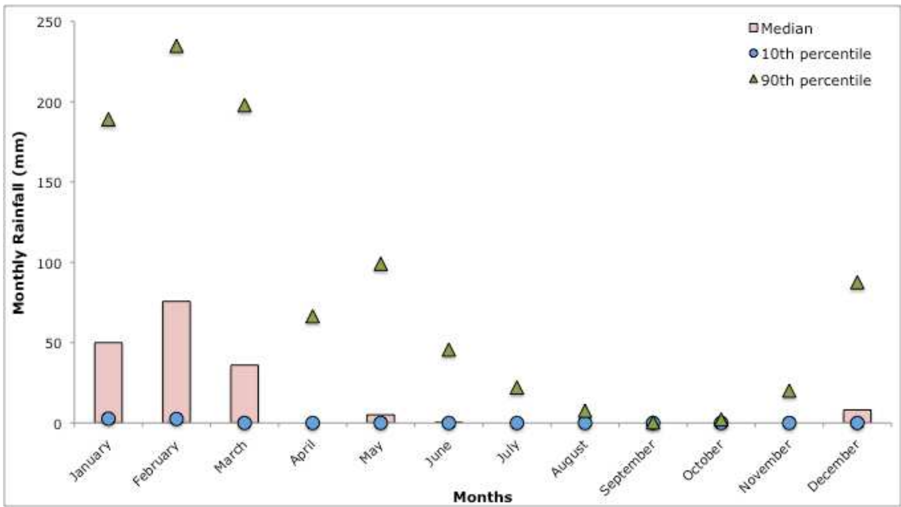

Figure 7: Median (10th and 90th percentile) monthly rainfall at Mandora (1913 – 2008; Bureau of Meteorology).

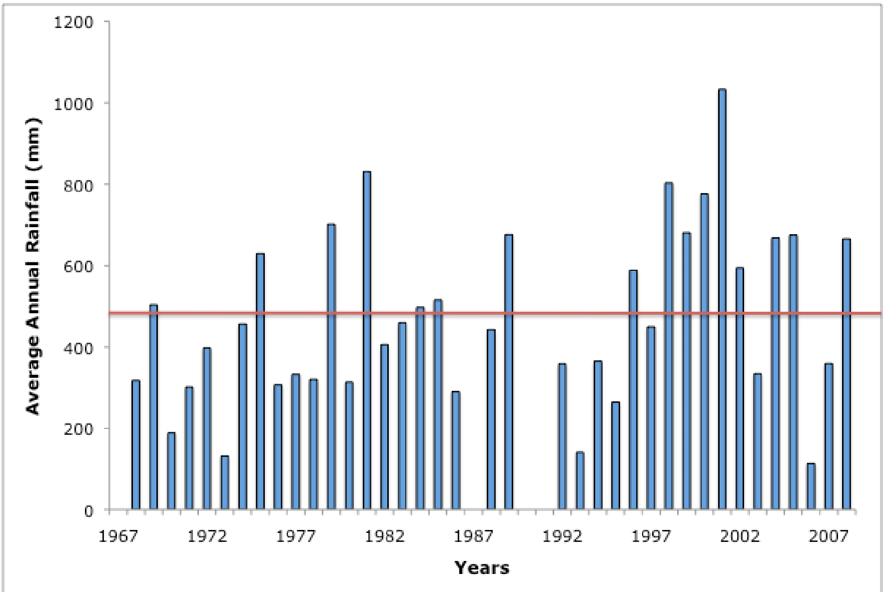

Figure 8: Average annual rainfall at Mandora (1967 – 2007; Bureau of Meteorology). Note horizontal line shows long term average.

Temperatures range from warm to hot year round, with average wet season maximum temperatures around 36 °C and average minimum temperatures between 22 and 25 °C. During the dry season average maximum temperatures are slightly cooler (29 – 35 °C). June and July are the coolest months with average maximum temperatures around 29 °C and average minimum temperatures of approximately 12 - 14 °C (Figure 9).

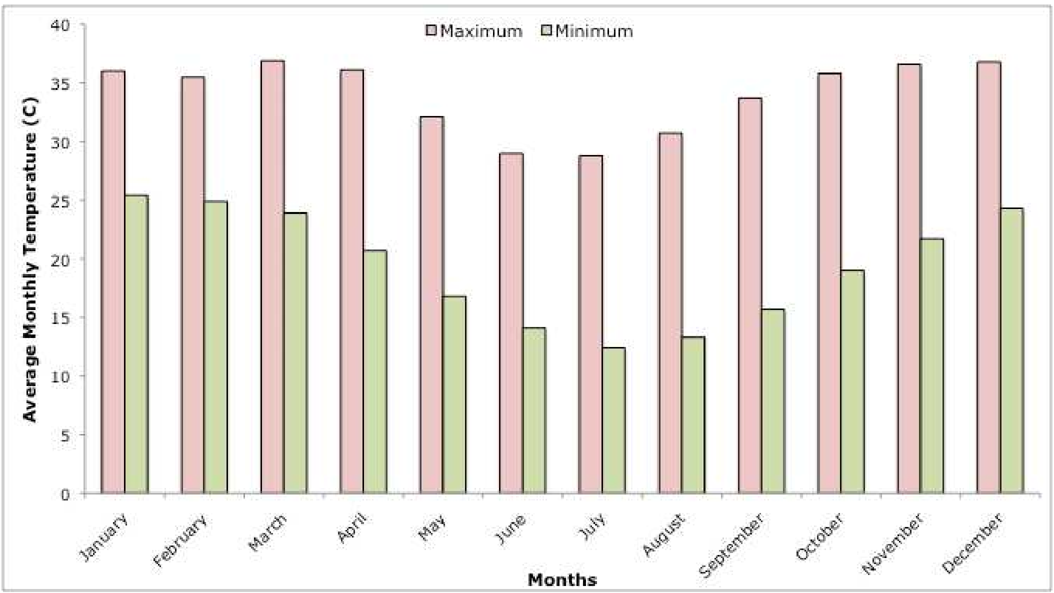

Figure 9: Average monthly maximum and minimum temperatures at Mandora (1969 – 2008; Bureau of Meteorology).

Relative humidity ranges from 50 – 65% in the wet season to 30 – 40% in the dry months. This, combined with the high temperatures produces evaporation that, on average greatly exceeds rainfall (Figure 10).

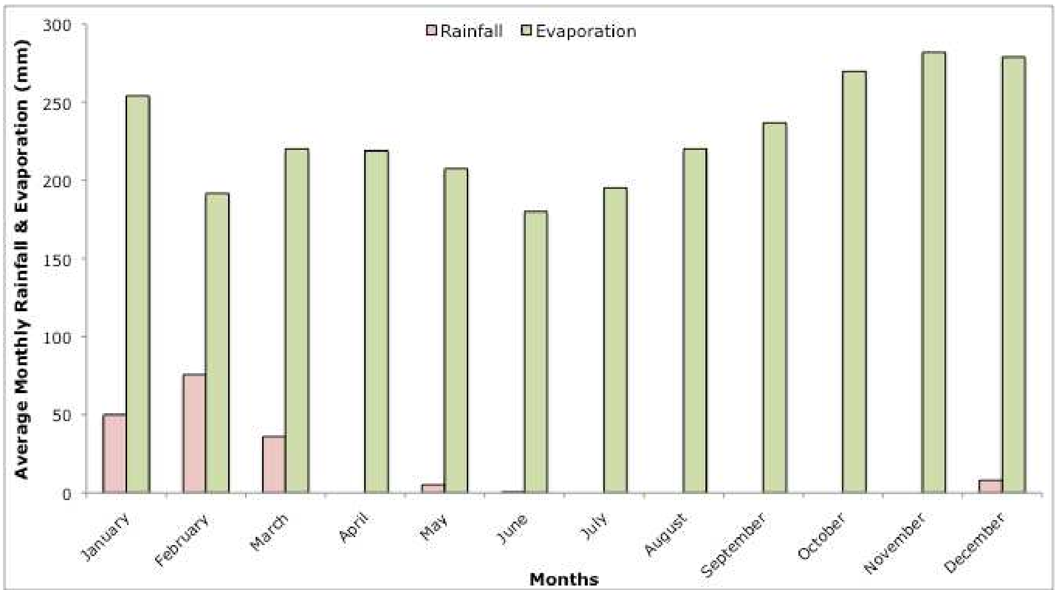

Figure 10: Average monthly rainfall (Mandora) and evaporation (Broome) (1913 – 2008; Bureau of Meteorology).

Eighty-mile Beach lies within the area of highest occurrence of tropical cyclones in Australia (Figure 11). Graham (1999) reported that over a 40 year period over 21 cyclones crossed the coast in the vicinity of Eighty-mile beach). Cyclones typically occur during the wet season and bring high winds and torrential rainfall. This can have dramatic effects on the ecology of the site. For example, Pearson et al. (2005) reported that tropical cyclone Vance (March 1999) resulted in the loss of part of the beach near Anna Plains. It has been suggested that high winds resulted in the removal of mature Sesbania trees and temporary replacement with Typha at Saunders Springs (Graham 1999).

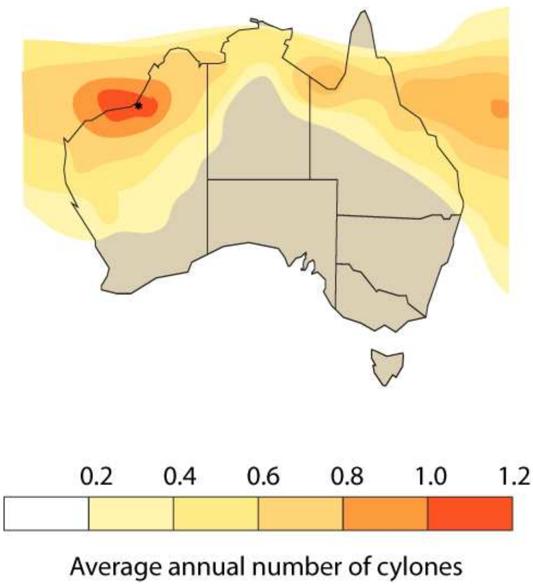

Figure 11: Average annual number of cyclones in Australia (adapted from the Bureau of meteorology, 2008).

2.4 Wetland types

The wetlands within the Eighty-mile Beach Ramsar site have not been mapped, or formally inventoried. However, it is evident from satellite imagery and other information sources that there are a number of wetland types present. Classification of aquatic ecosystems is a difficult task. Clear boundaries are not easy to define or delineate and at a landscape scale the diversity in aquatic ecosystems is part of a continuum, rather than a series of discrete units (Hale and Butcher 2008a). The application of the Ramsar wetland classification system to the wetlands in the Eighty-mile Beach site is not straight forward and in many cases multiple types occur over quite small spatial scales (in the order of tens of metres). What are presented here are dominant wetland types, and where multiple classifications could be applied to the same area, both are included.

In general, a total of eight major wetland types are present within the Eighty-mile Beach Ramsar site:

- *E - Sand, shingle or pebble shores*; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.
- *G - Intertidal mud, sand or salt flats*
- *I - Intertidal forested wetlands*; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests.
- *R - Seasonal/intermittent saline/brackish/alkaline lakes and flats*.
- *Sp - Permanent saline/brackish/alkaline marshes/pools.*
- *Xf - Freshwater, tree-dominated wetlands*; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.
- *Xp - Forested peatlands*; peat swamp forests.

Intertidal mudflats (Type G) and Sand, shingle or pebble shores (Type E)

The 220km of coastline within the Ramsar site consists of extensive intertidal mudflats. These range in width from 1 to 4 km (Honkoop et al. 2006) and are comprised of fine silt / clay sediments. Along the landward edge of these fine sediments is a sand beach, much of which is also intertidal in nature.

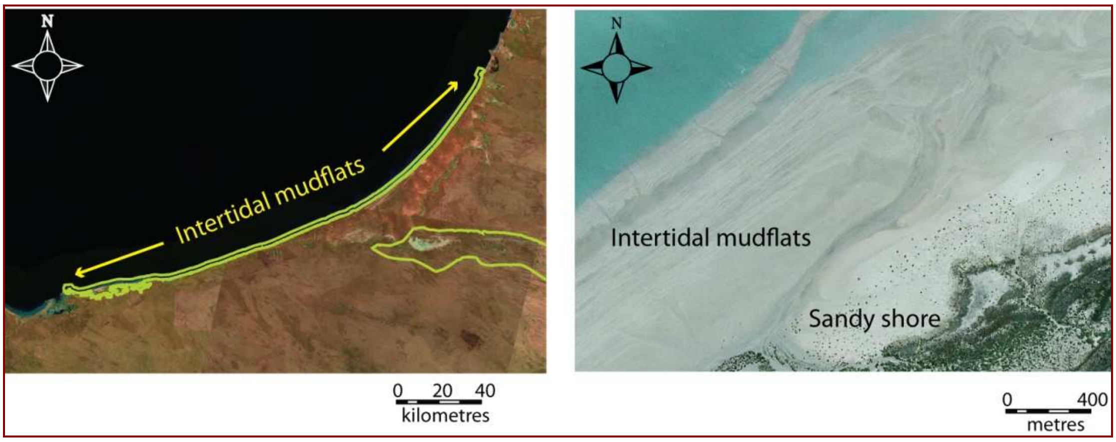

Figure 12: General location (left) and aerial view (right) of the intertidal mudflat wetland type at Eighty-mile Beach. Sandy shores occupy the landward edge of the intertidal zone.

Intertidal forested wetlands (Type I)

There are small patches of Grey Mangrove lining two tidal creeks along the coastal section of the Ramsar site. These are the only areas of mangrove on the coast within the site and they total approximately 100 hectares in area (Johnstone 1990).

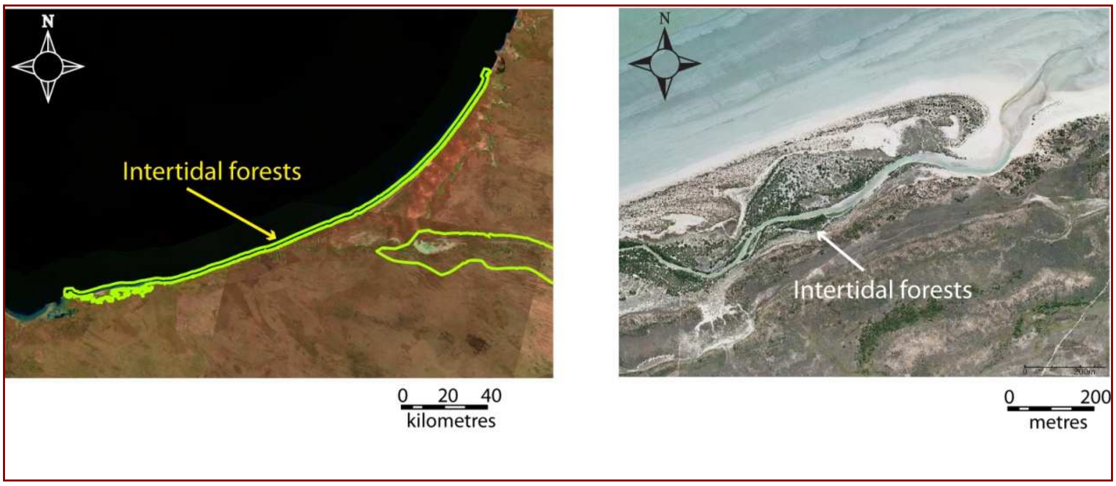

Figure 13: General location (left) and aerial view (right) of the intertidal forest wetland type at Eighty-mile Beach.

Seasonal/intermittent saline/brackish/alkaline lakes and flats (R) and Permanent saline/brackish/alkaline marshes/pools (Sp)

Mandora Salt Marsh contains two large seasonal / intermittent wetlands, Walyarta and East Lake. These wetlands are seasonally inundated, predominantly by direct precipitation and local runoff following heavy rainfall. When full, they are fresh, but alkaline and as water evaporates salts concentrate until eventually only a dry saltpan remains (Graham 1999). The area immediately surrounding these is dominated by saltmarsh and is included within this wetland type. Between the two lakes is Salt Creek, a permanent water body that does not easily fit into the wetland classification system. This wetland is ground water fed and flows from east to west into Walyarta after heavy rain. However, during other times, Salt Creek exists as a series of isolated pools, with water "disappearing into the sands to the east of Walyarta". It is thought that it may be connected to the coast via an aquifer (Graham 1999).

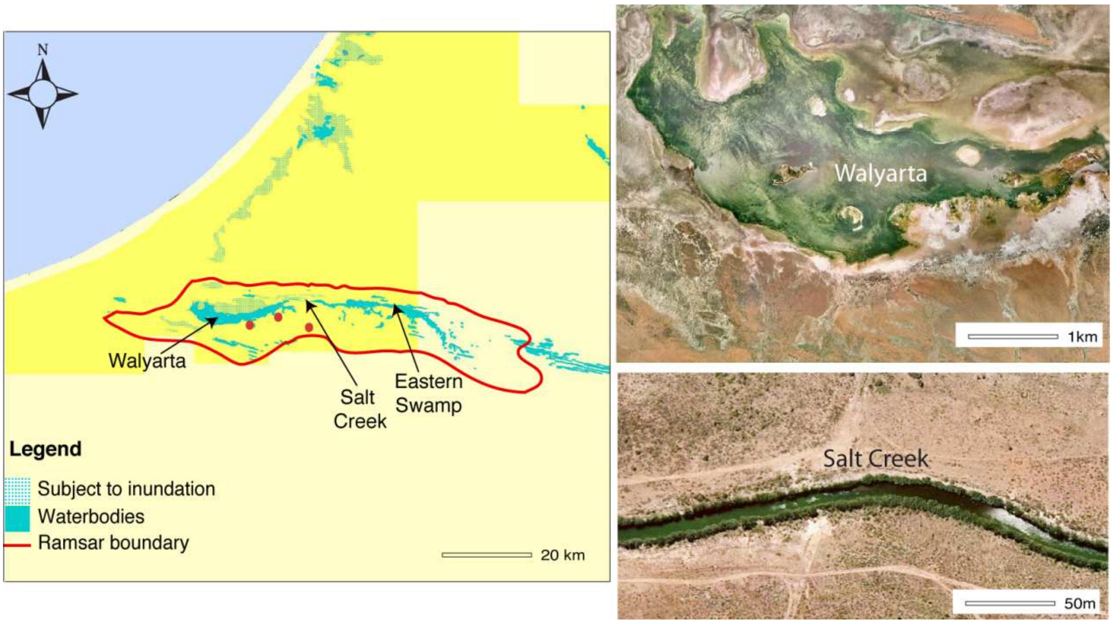

Figure 14: General location (left) and aerial views (right) of wetland types R and S.

Freshwater, tree-dominated wetlands (Xf)

To the south and north of Walyarta and east lake (but more extensive in the south) of the lakes within the Mandora Salt Marsh site are areas of clay soil that retain surface water for longer than the surrounding landscape (Graham 1999). These support stands and thickets of Saltwater Paperbark (*Melaleuca alsophilia*) and could be considered temporary, freshwater, tree-dominated wetlands.

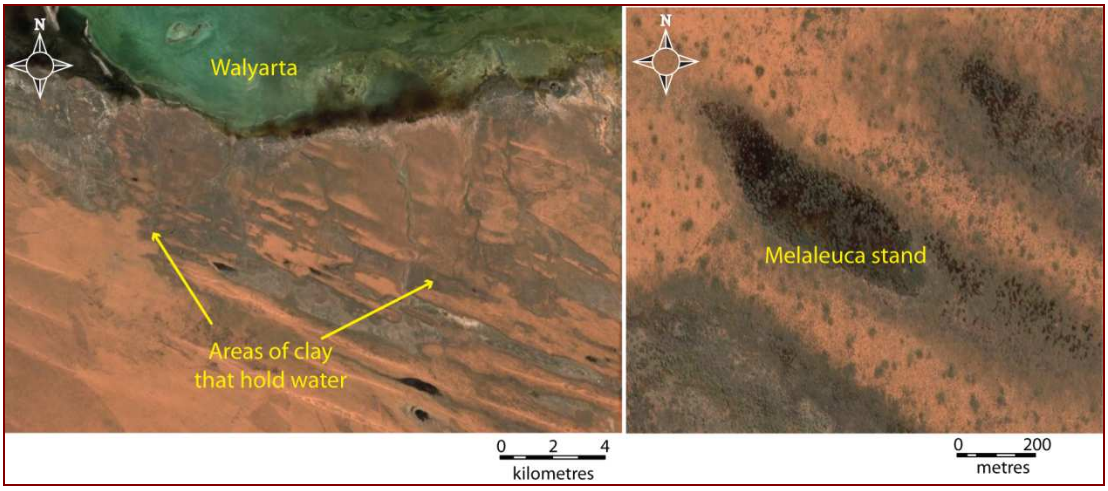

Figure 15: Aerial views of the freshwater tree dominated wetlands at Mandora Salt Marsh. The image on the left shows the areas of clay soil (grey) that hold water for longer and support Paperbark communities.

Freshwater springs (Y) and Forested peatlands (Xp)

To the south of Walyarta are a number of freshwater mound springs, including Eil Eil (formally known as Mandora Spring), Saunders and Fern Springs. These are mostly classical raised peat bogs consisting of a central mound of saturated peat 2 – 3 m in elevation. The springs vary in size from approximately 0.1ha to several hectares. The mound is typically surrounded by an inundated moat, which may contain aquatic or emergent vegetation. There are both freshwater and saline springs, which support paperbarks and mangroves respectively.

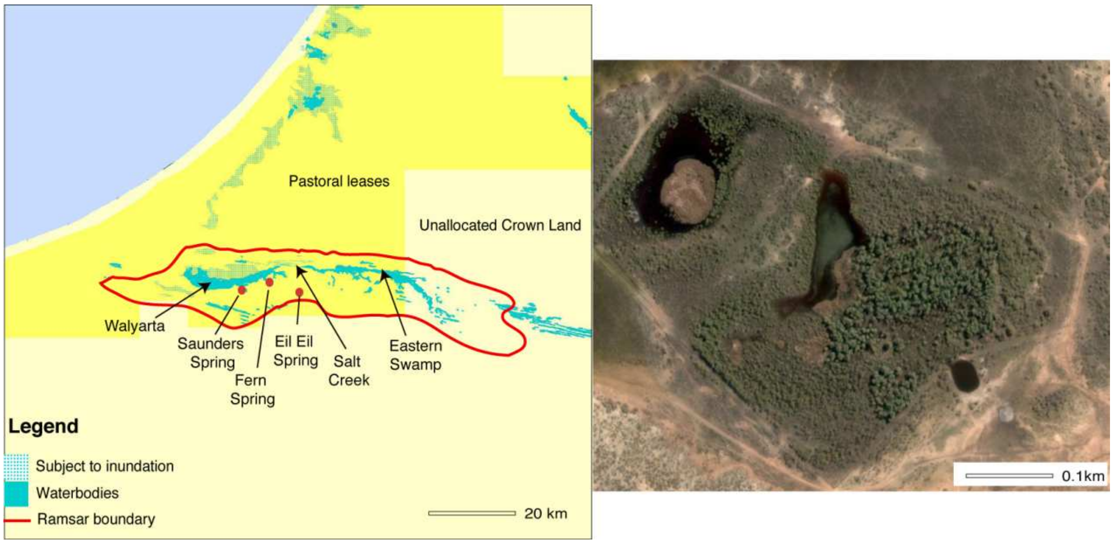

Figure 16: General location (left) and aerial view (right) of freshwater springs (wetland types Y and Xp) at Mandora Salt Marsh. The example shown (right) is Saunders Spring, which is a typical peat mound spring.

2.5 Ramsar criteria

2.5.1 Criteria under which the site was designated (1990)

At the time that Eighty-mile Beach was first nominated as a Wetland of International Importance, there were eleven criteria against which a wetland site could qualify (Table 2). At this time, Eighty-mile Beach was considered to meet four of these criteria as follows (Ramsar Information Sheet, 2003):

Criterion 1a: The site includes an outstanding example of a major beach with associated inter-tidal flats and coastal floodplain, located in the arid tropics; a good example of a classical raised peat bog located in the arid tropics; and contains the most inland occurrences of mangroves in Western Australia.

Criterion 2c: The vulnerable Greater Bilby (*Macrotis lagotis*) occurs within the Mandora Salt Marsh, and the vulnerable Flatback Turtle (*Natator depressus*) regularly nest at scattered locations along Eighty-mile Beach.

Criterion 3a: It is estimated that more than 500,000 shorebirds use Eighty-mile Beach as a migration terminus each year and over 336,000 shorebirds were counted on Eighty-mile Beach in November 1982.

Criterion 3c: Eighty-mile Beach supports more than 1% of the flyway population (or 1% of the Australian population for resident species) of 18 shorebirds (17 waders and 1 tern), including 15 migratory species and 3 Australian residents.

Table 2: Criteria for Identifying Wetlands of International Importance as at listing date, 1990. Criteria for which Eighty-mile Beach has been listed are highlighted in green.

Basis	Number	Description
Criteria for representative or unique wetlands	1a	it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region
	1b	it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region
	1c	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
	1d	it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.
General Criteria based on plants and animals	2a	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
	2b	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
	2c	it is of special value as the habitat of plants or animals at a critical stage of their biological cycle
	2d	it is of special value for one or more endemic plant or animal species or communities.
Specific criteria based on waterfowl	3a	it regularly supports 20,000 waterfowl
	3b	it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity
	3c	where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl

2.5.2 Assessment based on current information and Ramsar criteria

There have been a number of refinements and revisions of the Ramsar criteria since 1990. They have been re-numbered and in 1996, an additional two criteria (criteria seven and eight) were adopted by the Ramsar Convention in Brisbane and a ninth criterion was added at the 9th Ramsar Conference in Uganda in 2005. In addition, there has been a revision of population estimates for waterbirds (Wetlands International 2006; Bamford et al. 2008), which influences the application of criterion six; and additional data have been collected for the site.

Therefore, a revision and update of the Ramsar Information Sheet has been undertaken as a part of this ecological character description, which includes an assessment of the Eighty-mile Beach Ramsar site against the current nine Ramsar criteria (Table 3). In deciding if the site qualifies under criterion six (regularly supports 1% of the individuals in a population of one species of waterbird), an approach consistent with the Ramsar Convention has been adopted (see Text Box 1).

Table 3: Criteria for Identifying Wetlands of International Importance (adopted by the 7th (1999) and 9th (2005) Meetings of the Conference of the Contracting Parties). Criteria for which Eighty-mile Beach qualifies are highlighted in green.

Number	Basis	Description
Group A. Sites containing representative, rare or unique wetland types		
Criterion 1		A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Group B. Sites of international importance for conserving biological diversity		
Criterion 2	Species and ecological communities	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3	Species and ecological communities	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4	Species and ecological communities	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.
Criterion 5	Waterbirds	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6	Waterbirds	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
Criterion 7	Fish	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8	Fish	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.
Criterion 9	Other taxa	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

The Ramsar Guidelines http://ramsar.org/key_guide_list2006_e.htm#E state (Glossary):
regularly (Criteria 5 & 6) - as in supports regularly - a wetland regularly supports a population of a given size if:
i) the requisite number of birds is known to have occurred in two thirds of the seasons for which adequate data are available, the total number of seasons being not less than three; or
ii) the mean of the maxima of those seasons in which the site is internationally important, taken over at least five years, amounts to the required level (means based on three or four years may be quoted in provisional assessments only).
In establishing long-term 'use' of a site by birds, natural variability in population levels should be considered especially in relation to the ecological needs of the populations present. Thus in some situations (e.g., sites of importance as drought or cold weather refuges or temporary wetlands in semi-arid or arid areas - which may be quite variable in extent between years), the simple arithmetical average number of birds using a site over several years may not adequately reflect the true ecological importance of the site. In these instances, a site may be of crucial importance at certain times ('ecological bottlenecks'), but hold lesser numbers at other times. In such situations, there is a need for interpretation of data from an appropriate time period in order to ensure that the importance of sites is accurately assessed.

In some instances, however, for species occurring in very remote areas or which are particularly rare, or where there are particular constraints on national capacity to undertake surveys, areas may be considered suitable on the basis of fewer counts. For some countries or sites where there is very little information, single counts can help establish the relative importance of the site for a species.

The International Waterbird Census data collated by Wetlands International is the key reference source.

Text Box 1: Application of the Ramsar definition of "regularly" to criteria.

An assessment against each of the criteria for the Eighty-mile Beach Ramsar site is as follows:

Criterion 1: Eighty-mile Beach represents the greatest extent of continuous intertidal mudflat in excellent condition within the Northwest (IMCRA) bioregion[1]. In addition, Mandora Salt Marsh contains an important and rare group of wetlands within the arid Western Plateau bioregion (Semeniuk and Semeniuk 2000). In particular the peat mound springs can be considered both bioregionally rare and outstanding examples of this wetland type in Western Australia. This criterion was met at designation in 1990 and continues to be met at present.

Criterion 2: In the Australian context, it is recommended that this criterion should only be applied with respect to nationally threatened species/communities, listed under the EPBC Act 1999 or the International Union for Conservation of Nature (IUCN) red list. There are five threatened species that have been recorded within the boundary of the Eighty-mile Beach Ramsar site, one mammal, two waterbirds and two marine turtles[2]:

- Greater Bilby (*Macrotis lagotis*), listed as vulnerable under the EPBC Act and IUCN Red List. It has been recorded at Mandora Salt Marsh (Graham 1999).

- Nordmann's Greenshank (*Tringa guttifer*) listed as endangered under the IUCN Red List. Single individual recorded once at Eighty-mile Beach in November 2005 (Birds Australia Rarities Committee 2005)

- Australian Painted Snipe (*Rostratula australis*) listed as vulnerable under the EPBC Act. Single individual recorded once at Mandora Salt Marsh in 1999 (Birds Australia 2008)

[1] The original assessment against this criterion in 1990 mentioned the adjacent coastal floodplain. However, this is located outside the boundary of the Ramsar site and has not been included here.
[2] The Dugong (*Dugong dugon*) has been recorded off the coast adjacent to Eighty-mile Beach, but there is not suitable habitat within the Ramsar site boundaries.

- Flatback Turtle (*Natator depressus*) listed as vulnerable under the EPBC Act and data deficient under the IUCN Red List. Recorded nesting at Eighty-mile Beach (Spotila 2004)

- Green Turtle (*Chelonia mydas*) listed as vulnerable under the EPBC Act and data deficient under the IUCN Red List. Recorded foraging (Pendoley 2005) and potentially nesting (Pendoley 1997) at Eighty-mile Beach.

Central to the application of this criterion are the words “a wetland” and “supports”. Guidance from Ramsar (Ramsar 2005) in applying the criteria indicates that the wetland must provide habitat for the species concerned. In the case of the Greater Bilby, this is unlikely to be true. This marsupial is an arid zone specialist that feeds on seeds of desert plants and insects such as termites and ants (Gibson 2005). It obtains all the moisture it requires from its diet and does not drink water. It has been recorded in the terrestrial areas surrounding the wetlands and within the boundary of the Ramsar site. However, the wetland does not provide habitat for this species in the form of food or other resources. Therefore, it cannot be said to contribute to the Ramsar site meeting this criterion.

Similarly, the observation of single birds on one occasion, as is the case with Nordmann’s Greenshank and the Australian Painted Snipe, does not provide sufficient evidence to support this criterion. In both cases there is a possibility that the individuals may have been vagrants. Without further evidence, these two waterbird species cannot be said to contribute to the Ramsar site meeting this criterion.

In the case of the marine turtles, this criterion is certainly met for the Flatback Turtle, for which the site is significant nesting habitat (DEWHA 2008c). The case for the Green Turtle is less certain. While they have been recorded in the site, Eighty-mile Beach has not been identified as significant habitat for this species (DEWHA 2008c). This criterion was met at designation in 1990 and continues to be met at present.

Criterion 3: Although the Eighty-mile Beach Ramsar site was not originally nominated under this criterion, an argument can be made that the site is important for maintaining the biological diversity of a bioregion. The Mandora Salt Marsh contains temporary and permanent wetlands in a predominantly arid bioregion (Western Plateau) and has been recognised as important refugia for biological diversity in arid Australia (Morton et al. 1995). The inland Grey Mangroves (*Avicennia marina*) lining Salt Creek represent the most inland occurrence of this species (Semeniuk and Semeniuk 2000) and one of the only two inland occurrences in the Western Plateau. In 1999 a suspected new species of goby (*Acentrogobius sp*. nov.) was collected from Salt Creek in Mandora Marshes (A. Storey pers. comm.). The specimen has yet to be officially identified and catalogued. It is likely that this criterion was met at the time of listing and continues to be met.

Criterion 4: The Eighty-mile Beach Ramsar site is considered one of the most important sites for stop-over and feeding by migratory shorebirds in Australia; second only to Roebuck Bay in the total number of migratory species for which it is considered internationally important. Furthermore, Eighty-mile Beach represents the most important site internationally (in terms of total number of individuals) for nine species of migratory shorebird in the East Asian-Australasian flyway (Bamford et al. 2008). Mandora Salt Marsh supports the critical life stage of breeding for at least 13 species of waterbird, including large numbers of Australian Pelicans and Black Swans (Birds Australia 2008). In addition, the site is significant for the breeding of at least one species of marine turtle (Flatback). This criterion was met at the date of listing and continues to be met.

Criterion 5: Eighty-mile Beach is considered to regularly support in excess of 500,000 birds (Wade and Hickey 2008). Total counts (summer) for just a 60km stretch of the 220km intertidal site are generally greater than 200,000 (Shorebirds 2020 unpublished data). There is a record of 2.88 million Oriental Pratincoles on the beach in February 2004 (Sitters et al. 2004). This criterion was met at the date of listing and continues to be met.

Criterion 6: This criterion is applied to the international population estimates as provided by Wetlands International. For international migratory species, the appropriate population is the East Asian-Australasian Flyway and for Australian resident species there are some with national distributions for which the Australian population estimates are applied and others with regionally distinct populations (see Wetlands International 2006).

Eighty-mile Beach supports more than 1% of the flyway population (or 1% of the Australian population for resident species) of 21 waterbirds, including 17 migratory species and 4 Australian residents: Greater Sand Plover *Charadrius leschenaultii*, Oriental Plover *C. veredus*, Red-capped Plover *C. ruficapillus* (resident), Grey Plover *Pluvialis squatarola,* Bar-tailed Godwit *Limosa lapponica*, Red Knot *Calidris canutus*, Great Knot *C. tenuirostris*, Red-necked Stint *C. ruficollis*, Sanderling *C. alba,* Sharp-tailed Sandpiper *C. acuminata,* Curlew Sandpiper *C. ferruginea*, Eastern Curlew *Numenius madagascariensis*, Little Curlew *N. minutus*, Common Greenshank *Tringa nebularia*, Grey-tailed Tattler *T. brevipes,* Terek Sandpiper *T.terek,* Ruddy Turnstone *Arenaria interpres,* Pied Oystercatcher *Haematopus longirostris* (resident); Oriental Pratincole *Glareola maldivarum*, Black-winged Stilt *Himantopus himantopus* (resident) and Great Egret *Adea alba* (resident). This criterion was met at the date of listing and continues to be met.

In addition, surveys of the entire and vast marshes system behind the coast, including Mandora Salt Marsh, revealed high numbers (over 1% levels) for several other waterbirds after cyclonic flooding in 1999-2000 (Halse et al. 2005). Substantial portions of the numbers of some of these species may have occurred within the Ramsar boundary but further analysis of the raw data is needed to identify which data apply to the Ramsar-listed (eastern) portion. Similar flooding has occurred previously, e.g. early 1980s and it is likely that these large numbers of waterbirds occur during all such flood events.

Criteria 7 and 8: Although there are records of fish from the Eighty-mile Beach Ramsar site both from along the beach (Piersma et al. 2005) and at Mandora Salt Marsh (Graham 1999), these are not considered sufficient to meet these criteria. The diversity of fish species is not high, nor have rare or threatened species been recorded within the site. There is anecdotal evidence of endemic fish species occurring in Salt Creek (Storey unpublished) however this is unconfirmed and remains a significant knowledge gap. There is insufficient information at this time to apply these criteria.

Criterion 9: The application of this criterion relies on estimates of the total population of non-bird species. In the case of the Eighty-mile Beach Ramsar site this would require estimates of frogs, turtles and / or invertebrates. This criterion cannot be assessed based on current information.

2.6 Overview of the site

Eighty-mile Beach is a large (220km) linear sand coast. The boundary of the Ramsar site along the beach is defined by the tide, extending from Mean Low Water (MLW) to 40 m above Mean High Water (MHW). The intertidal zone is comprised of a large expanse of intertidal mudflats (up to 4km wide at the lowest tides (Honkoop et al. 2006) and a narrow strip at the landward edge of coarser quartz sands. The site is bounded by coastal dunes to the east. The discontinuous linear floodplain immediately inland of the frontal sand dunes, are predominantly outside the Ramsar boundary.

The primary beach dunes are stabilised by Beach Spinifex (*Spinifex longifolius*) and Green Birdflower (*Crotalaria cunninghamii*) (Burbidge 1944, Craig 1983). Secondary parallel, calcareous dune ridges and swales commonly feature scattered Dune Wattle (*Acacia bivenosa*) (McKenzie 1985). Important grasses include *Whiteochloa airoides* and the local endemic Grey Soft Spinifex (*Triodia epactia*), a resinous hummock-forming species (Jacobs 1992). There are two minor mangrove stands, both occupying about 50 ha in small tidal creeks near Mandora Station. The stands are dominated by Grey Mangrove to 4-6 m height with a few Yellow Mangrove (*Ceriops tagal*) present. Samphire communities also occur in the vicinity (Johnstone 1990).

The intertidal zone supports an abundance of macroinvertebrates, which provide food for very large numbers of shorebirds. To date over 100 species of birds have been recorded at the beach, including 97 species of waterbird and 42 species of migratory shorebird. The site is considered one of the most important in Australia for numbers of shorebirds supported (Bamford et al. 2008). The beach is also an important nesting site for a Flatback Turtles (Chapman in prep.).

The areas adjacent to the beach (but predominantly outside the site boundary) are also ecologically important. The Coastal plains in the southern portion of Anna Plains Station are a stronghold for Australian Bustard (*Ardeotis australis*)and support high densities of Red Kangaroo (*Macropus rufus*). The western part of Walla Station is notable for dense populations of Euro (*Macropus robustus*) (RIS 2003). This area of coastal floodplain is periodically inundated during large cyclonic events, becoming continuous with Mandora Salt Marsh. During these times, the area supports large numbers of waterbirds and significant waterbird breeding.

The second part of the Ramsar site is Mandora Salt Marsh, located 40 km inland of the beach. This comprises of a series of floodplain depressions within a linear dune system (Semeniuk and Semeniuk 2000). The site comprises two large depressional wetlands and a series of small mound springs. Surrounding the wetlands are expanses of arid zone plains on red soils (Graham 1999).

To date, a total of 269 species of vascular plants, from 55 families, have been collected from the Mandora Salt Marsh. This includes 37 species from the family Poaceae, and nine introduced weeds (Willing and Handasyde 1999). The most inland occurrences of mangroves in Western Australia, Grey Mangrove*,* occur on the site (Beard 1967). The stands commence from an island in Walyarta (30 km inland) and occur along the length of Salt Creek, terminating with an isolated stand about 52 km inland of Eighty-mile Beach (RIS 2003).

Twenty-two species of mammal, including the nationally threatened Greater Bilby have been recorded at Mandora Salt Marsh (Graham 1999). Forty-nine species of reptiles, six species of amphibian and 110 species of bird have been recorded at Mandora Salt Marsh (Graham 1999; Birds Australia 2008). In addition, although there is limited data on the species present at the site, a survey at the Salt Marsh in 1999 resulted in the discovery of a new species of Bush Tomato (*Solanum oligandrum*) and two previously undescribed species of Dragon (*Diporiphora spp*.) (Willing and Handasyde 1999).

Although the beach portion of the site is primarily unallocated crown land, public access is limited. The area immediately inland is pastoral lease and there are few public roads that connect the northern highway with the coast. The major access point is at the Eighty-mile

Beach Caravan Park approximately120 km south of Cape Missiessy. Here tourists can enter the beach and intertidal areas and, as driving is permitted on the beach itself; travel some distance to the north or south. The site is a significant tourist destination with beach fishing, 4-wheel driving and shell collecting the dominant activities.

The waters adjacent to the beach are important for commercial fishing. Although there is a permanent closure for finfish trawling, there is gill-netting of Threadfin Salmon and trap-fishing of demersal fish (e.g. Red Emperor and Gold-banded Snapper). The latter of these may occur within the boundaries of the Ramsar site in inshore areas (Fisheries WA 2006). In addition, the coastal waters adjacent to the Ramsar site are important for the collection of pearl oysters (*Pinctada maxima*) and there are a number of aquaculture facilities for this species near the northern boundary of the site (Fisheries WA 2006).

Mandora Salt Marsh is predominantly on leasehold land and has been subject to cattle grazing for many years. The wetlands within the Ramsar site, particularly the permanent freshwater springs, provide a valuable water source for cattle. However, the Mandora Marshes will be excluded from lease renewal in 2015 and managed for conservation proposes from 2025.

The wetlands within the Ramsar site are significant to at least three local indigenous language groups, the Karajarri in the north, the Nyangumarta in the south and the Ngarla in the southern end of Eighty-mile Beach. Traditional owners have a strong affinity with the inland wetlands which are important sources of freshwater in the arid landscape. The wetlands feature strongly in traditional stories and history.

3. Critical Components and Processes

3.1 Identifying critical components and processes

The basis of an ECD is the identification, description and where possible, quantification of the critical components and processes of the site. Wetlands are complex ecological systems and the complete list of physical, chemical and biological components and processes for even the simplest of wetlands would be extensive and difficult to conceptualise. It is not possible, or in fact desirable, to identify and characterise every organism and all the associated abiotic attributes that are affected by, or cause effect to, that organism to describe the ecological character of a system. This would result in volumes of data and theory but bring us no closer to understanding the system and how to best manage it. What is required is to identify the key components, the initial state of the systems, and the basic rules that link the key components and cause changes in state (Holland 1998). Thus, we need to identify and characterise the key or critical components and processes that determine the character of the site. These are the aspects of the ecology of the wetland, which, if they were to be significantly altered, would result in a significant change in the system.

DEWHA (2008) suggest the minimum components, processes, benefits and services, which should be included in an ECD are those:

- that are important determinants of the sites unique character;
- that are important for supporting the Ramsar or DIWA criteria under which the site was listed (or in this case nominated);
- for which change is reasonably likely to occur over short to medium time scales (<100 years); and
- that will cause significant negative consequences if change occurs.

Climate (as described in section 2.3 above) and geomorphology are accepted as the fundamental drivers of wetland ecology (Mitsch and Gosselink, 2000). Together with the hydrological regime they influence all other aspects of wetland ecology. Therefore, climate, geomorphology and hydrology can be considered critical components of all wetland systems. Additional components and processes that can be considered critical to maintaining ecological character are likely to vary depending on the wetland; its position in the landscape and the benefits and services it provides.

The linkages between the reasons the site was listed and the components and processes within the Eighty-mile Beach Ramsar site are provided in (**Table 4**). This identifies not only the critical components and processes that are directly responsible for meeting each of the criteria, but also the components and processes that are important in supporting these.

It is difficult to separate components (physical, chemical and biological parts) and processes (reactions and changes). For example, aspects of hydrology such as rainfall or depth to groundwater may be considered as components, while other aspects of hydrology such as flow and tidal regime could be considered processes. Similarly the species composition of birds at a site may be considered a component, but feeding and breeding are processes. In the context of this ECD a separation of the ecology of wetlands into nouns (components) and verbs (processes) is an artificial boundary and does not add clarity to the description. As such components and processes are considered together. The interactions between components and processes, the functions that they perform and the benefits and services that result are considered in detail in the proceeding section (3.2).

Table 4: Relationship between the Ramsar criteria met and critical components and processes in the Eighty-mile Beach Ramsar site

Ramsar Criteria	Direct Components & Processes	Supporting Biotic Components & Processes	Supporting Abiotic Components & Processes
1. *Contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region*	Extent and diversity of wetland types; particularly: intertidal mudflats, intermittent brackish wetlands and mound springs	Vegetation communities (mangroves, paperbarks and aquatic vegetation)	Climate Hydrology (surface and groundwater flows; tides) Geomorphology (including geology and soils)
2. *Supports vulnerable, endangered, or critically endangered species or threatened ecological communities.*	Flatback Turtles	Invertebrates	Hydrology (tides) Geomorphology (including soils)
3. *Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region*	Mound springs, Inland Mangroves	Primary productivity and nutrient cycling	Climate Hydrology (groundwater) Geomorphology Water quality (salinity)
4. *Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions*	Waterbirds (breeding and migration) Marine turtles (breeding)	Habitat extent and distribution (mangroves, mudflats, aquatic vegetation) Primary productivity Invertebrates Predation	Climate Hydrology (surface and groundwater flows; tides) Geomorphology (including geology and soils) Water quality (salinity)
5. *Regularly supports 20,000 or more waterbirds*	Waterbirds	Habitat extent and distribution (mangroves, mudflats, aquatic vegetation) Primary productivity Invertebrates Predation	Climate Hydrology (surface and groundwater flows; tides) Geomorphology (including geology and soils)
6. *Regularly supports > 1% of the population of one or more species of waterbird*	Bar-tailed Godwit Black-winged Stilt Broad-billed Sandpiper Common Greenshank Curlew Sandpiper Eastern Curlew Great Knot Greater Sand Plover Grey Plover Grey-tailed Tattler Little Curlew Oriental Plover Oriental Pratincole Pied Oystercatcher Red Knot Red-capped Plover Red-necked Stint Ruddy Turnstone Sanderling Sharp-tailed Sandpiper Terek Sandpiper Great Egret	Habitat extent and distribution (mudflats) Primary productivity Invertebrates Predation	Climate Hydrology (tides and groundwater) Geomorphology (including geology and soils)

The Eighty-mile Beach Ramsar site is comprised of two distinct and separate areas: the Eighty-mile Beach itself (coastal) and the inland Mandora Salt Marsh. These areas are very different in terms of wetland types and ecological character. As such the description of critical components, processes, benefits and services has been separated for each of these sections.

Critical components and processes for the Eighty-mile Beach Ramsar site have been identified based on the application of the DEWHA criteria listed above (including the reasons for the site listing contained in **Table 4**) as:

- **The Beach**
  - Hydrology (tides);
  - Geomorphology (including soils);
  - Primary production;
  - Invertebrates;
  - Fish;
  - Waterbirds; and
  - Marine turtles.

- **Mandora Salt Marsh**
  - Hydrology (surface and groundwater);
  - Geomorphology (including soils);
  - Water quality (salinity, pH and nutrients);
  - Phytoplankton and primary production;
  - Vegetation (mangroves, paperbark, samphire and aquatic flora);
  - Invertebrates; and
  - Waterbirds.

The attributes and characteristics of each of these critical components and processes are described below. Where possible, quantitative information has been included. However, as with many ecological character descriptions, there are significant knowledge gaps (see section 8).

3.2 The Beach (Eighty-mile Beach coastal strip)

The critical components and processes of the beach portion of the Eighty-mile Beach Ramsar site are summarised in Table 5 and detailed in section 3.2.1 to 3.2.6 below.

Table 5: Summary of critical components and processes from the beach section of the Eighty-mile Beach Ramsar site.

Component / Process	Direct Components & Processes
Geomorphology	Extensive intertidal mudflats comprised of fine grained sediments. Site is backed by steep dunes comprised of calcareous sand. Small number of tidal creeks dissect the beach (but not the mudflats) in southern section.
Hydrology	Macro-tidal regime. No significant surface water inflows. Groundwater interactions unknown (knowledge gap)
Primary production and nutrient cycling	Data deficient, but organic material deposited from ocean currents driving the system through bacterial or microphytobenthos driven primary production.
Invertebrates	Large number and diversity of invertebrates within the intertidal mudflat areas
Fish	Data deficient, but anecdotal evidence of marine fish (including sharks and rays) using inundated mudflats.
Waterbirds	Significant site for stop-over and feeding by migratory shorebirds. Regularly supports > 200,000 shorebirds during summer and > 20,000 during winter. High diversity with 97 species of waterbird recorded from the beach Regularly supports > 1% of the flyway population of 20 species
Marine Turtles	Significant breeding site for the Flatback Turtle

3.2.1 Geomorphology, geology and soils

The Eighty-mile Beach Ramsar site lies within the Canning Basin and is comprised of predominantly Quaternary age sediments (Geoscience Australia 2008). The region is of low relief, with a gentle slope from east to west. A stylised cross section showing the geology of both portions of the Ramsar site is provided in Figure 17.

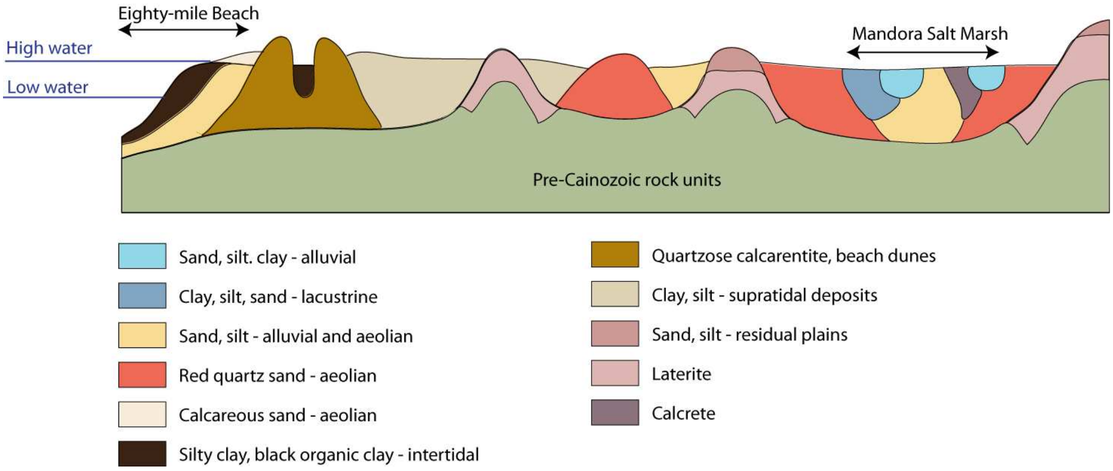

Figure 17: Diagrammatic representation of the geology in the vicinity of the Ramsar site. Note that this is not to scale and the vertical slope in particular is much exaggerated (adapted from Geosciences Australia 2008).

The beach contains black organic sediments in the intertidal zone in a wide flat expanse. The width of the intertidal mudflats averages approximately 2.6 km but is greater in the north of the site than the south (Pearson et al. 2005). These sediments are of marine origin. The south flowing Leeuwin Current carries carbonate rich sediments to the shoreline where the loss of current velocity causes the sediments to settle out, forming the intertidal mudflats (Pearson et al. 2005). The mudflats are predominantly fine silts and clays with a grain size < 63 µm. However, in the upper intertidal areas, this grades into coarser sandy material (Honkoop et al. 2006).

At the eastern extent of the mudflats, there is a steep incline with a step (0.5m) marking the edge of the intertidal zone (Honkoop et al. 2006). The step is formed by the combined action of incoming tide and backwash colliding with the aeolian deposited coarse sand of the dunes (Honkoop et al. 2006). The sediments above this “step” are comprised of coarse calcareous sand and this strip of white sandy beach is approximately 100m wide. The beach is bordered to the east by dunes comprised of quartz sand (Geoscience Australia 2008). Of note are the lack of silica based sands and the dominance of calcareous sediments of marine shell origin (Pearson et al. 2005).

There are a small number of tidal creeks that dissect the beach within the Ramsar site, along the southern sections. The most significant of these is the paleo-channel of Salt Creek, which contains the only coastal mangrove community in the Ramsar site. Pearson et al. (2005) speculated on the differences between the northern and southern parts of the beach, suggesting that the extensive mudflats in the north had a dampening effect on wave action leading to a lower energy environment and increased deposition of fine materials. Conversely, the decreased extent of mudflats at the southern end of the beach results in a sandier substrate within the intertidal zone. This increases the wave energy, decreasing deposition. This increased wave energy in the south may also contribute to the increased dissection of the dunes and tidal creek systems.

3.2.2 Hydrology

Eighty-mile Beach is located in a region subject to macro-tides however there is no tide gauge located within the site and this remains a significant knowledge gap given the importance of tidal regime on intertidal mudflat ecology. The tidal regime at Broome (Figure 18) provides an indication of daily tidal range. Despite the magnitude of the tide the tidal regime has been described as gentle ranging from an average of 6m to as much as 8m during Spring tides. There are no anthropogenic structures that impact on tidal flows across the site.

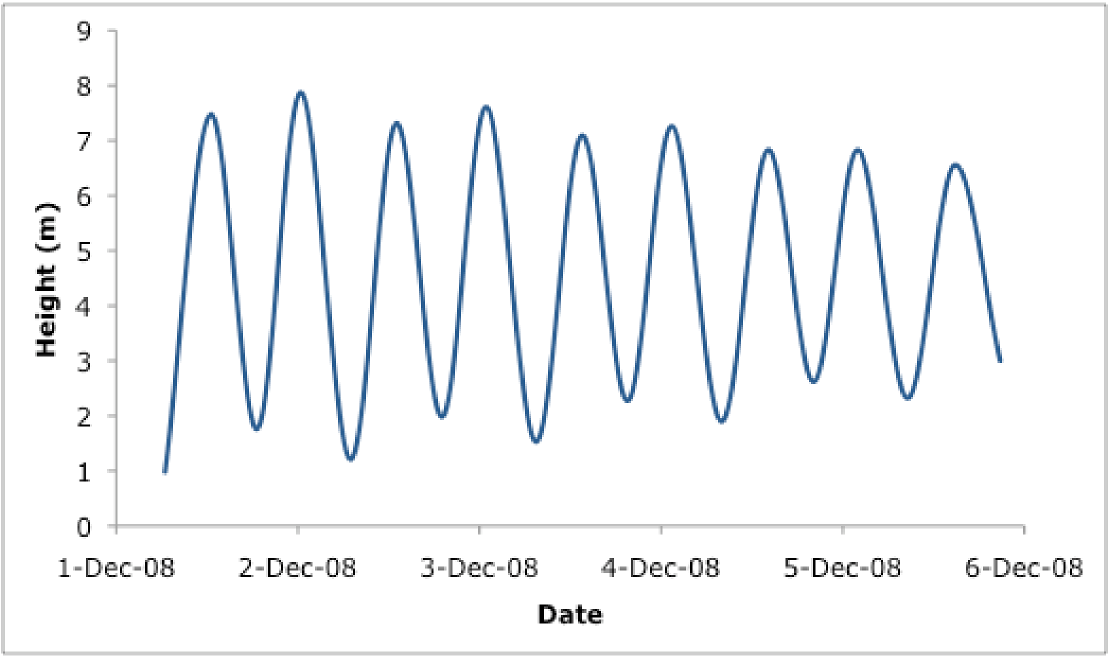

Figure 18: Tidal cycle at Broome (closest gauging point to Eighty-mile Beach). Data from Department of Planning and Infrastructure 2008b)

3.2.3 Primary productivity and nutrient cycling

Primary productivity and nutrient cycling are undoubtedly critical processes to the ecological character of Eighty-mile Beach. However, very little is known about these processes within the site and this remains a significant knowledge gap. Studies elsewhere suggest that microorganisms drive primary production and nutrient cycling in intertidal systems (Decho 2000). Organic matter carried to the system by ocean currents is deposited in the intertidal zone. Heterotrophic bacteria play a crucial role in remineralising organic carbon, nitrogen and other nutrients. Microphytobenthos (bottom dwelling algae comprised predominantly of diatoms and dinoflagellates in tropical systems) drives primary productivity in these unvegetated habitats (MacIntyre et al. 1996). While these generalities are probably true for the intertidal mudflats at Eighty-mile Beach there is no data to characterise or quantify these processes.

3.2.4 Invertebrates

The fauna of marine soft sediment systems are often broken into a number of groupings based on rough size categories, habitat preference and also feeding modes. In marine soft sediment systems fauna can be described as:

- Microfauna - microscopic organisms such as protozoa and rotifers,
- Meiofauna - a loose grouping of organisms which typically can pass through a 1 mm mesh net but are retained by a 45 µm sieve (although this can vary).
- Macrofauna- those organisms greater than 1 mm.

Infauna is a term used to describe aquatic organisms that live within the sediment rather than on its surface and can include members of all three size fractions.

There is no specific data for micro and meiofauna at Eighty-mile Beach. Meiofauna occupy the interstitial spaces of the sediment and are often the most diverse component of the marine benthos (Dittman 2007). Meiofauna graze on bacteria and microalgae and prey on other species and immature stages of some of the macrofauna.

The macrozoobenthos of Eighty-mile Beach contains over 200 taxa (Lavaleye et al. 2005). However, due to the uncertainty of the accurateness of identifications at the species level the data were grouped into higher taxonomic levels and are presented in Appendix C. The most abundant taxa collected included a brittle star *Amphiura tenuis* (Amphiuridae), the bivalve mollusc *Siliqua pulchella* (Culteliidae), polychaete worms (Oweniidae), mud shrimp (Coropiidae, Amphipoda), and sandhoppers (Oedicerotidae, Amphipoda).

3.2.5 Fish

Although fish are undoubtedly an important component in the Eighty-mile Beach ecosystem, there is no published information (in the grey or scientific literature) on fish species or fish usage of the site. This remains a significant knowledge gap for this ECD.

It is likely that a range of tropical fish utilise the inundated mudflats during high tide cycles. Detritivores such as Mullet (*Mugil cephalus*) are important components of intertidal mudflat ecosystems. They feed on the surface of sediment ingesting benthic algae, bacteria and small invertebrates and contribute significantly to secondary production.

There is anecdotal evidence that elasmobranches such as stingrays feed in the inundated intertidal mudflats on a range of larger invertebrates such as brittle stars, crabs and molluscs. In addition there are also observations of sharks, sawfish and other large predators feeding on fish and other prey within the mudflats at high tide.

3.2.6 Waterbirds

Eighty-mile Beach is considered one of the most significant sites in Australia for migratory shorebirds (DEWHA 2008c). The beach supports a high number and diversity of shorebirds and is an important stop-over and feeding site.

<u>Diversity and abundance</u>
Eighty-mile Beach supports high diversity and abundance of wetland birds. A total of 97 wetland bird species have been recorded within the beach portion of the Ramsar site (Table 6). This includes 42 species that are listed under international migratory agreements CAMBA (38), JAMBA (38) and ROKAMBA (32) as well as an additional 22 Australian species that are listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC). In addition, there is a single record for Nordmann's Greenshank (*Tringa guttifer*) from the beach, which is listed as endangered under the IUCN Red List (Appendix D).

Eighty-mile Beach is renowned for large numbers of shorebirds and the beach is one of the most important sites for migratory shorebirds in the East Asian-Australasian Flyway (Bamford et al. 2008). Its location makes Eighty-mile Beach a primary staging area for many migratory shorebirds on their way to and from Alaska and eastern Siberia (Wade and Hickey 2008). Although many birds may then move further on their journey, many others remain at the site for the non-breeding period. Due to the great length of the beach, total counts from this site are limited to three records of shorebird numbers:

- October 1998 – 465,890 waders (Minton et al. 2003a)
- November 2001 – 472,418 waders (Minton et al. 2003b)
- February 2004 – 2,880,000 Oriental Pratincoles (Sitters et al. 2004)

Table 6: Number of waterbird species recorded at the Beach portion of the Eighty-mile Beach Ramsar site.

Bird group	Typical feeding requirements	Number of species
Ducks and allies	Shallow or deeper open water foragers Vegetarian (e.g. Black Swan) or omnivorous with diet including leaves, seeds and invertebrates	7
Grebes	Deeper open waters feeding mainly on fish	2
Pelicans, Cormorants, Darters	Deeper open waters feeding mainly on fish	3
Heron, Ibis, Spoonbills	Shallow water or mudflats Feeding mainly on animals (fish and invertebrates)	12
Hawks, Eagles	Shallow or deeper open water on fish and occasionally waterbirds and carrion	3
Crakes, Rails, Water Hens, Coots	Coots in open water; others in shallow water within cover of dense emergent vegetation such as sedge. Some species vegetarian, others mainly take invertebrates, some are omnivores	8
Shorebirds	Shallow water, bare mud and salt marsh Feeding mainly on animals (invertebrates and some fish)	41
Gulls, Terns	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats.	11
Total		97

There are counts for portions of the beach spanning a number of years and all are in excess of 20,000 birds. Summer counts from a sub-site 10 – 60km south of Anna Plains, are consistently> 200,000 birds and winter > 20,000 birds (D. Rogers unpublished data). The most extensive quantitative data set for the site is for a 20km stretch of beach (10 – 30km south of Anna Plains). Counts from this section indicate > 20,000 waders during every summer from 2002 to 2008 (Figure 19). It should be noted that not only is this data from a small area within the site, it includes only shorebirds and does not include terns or other waterbirds. In addition, despite the regular occurrence of counts, variability is still very high (standard deviation > 20% of the mean). Variability is a combination of the actual numbers of birds present at the beach and counting conditions with tide and daytime temperatures playing a significant role in counting results (D. Rogers pers. comm.).

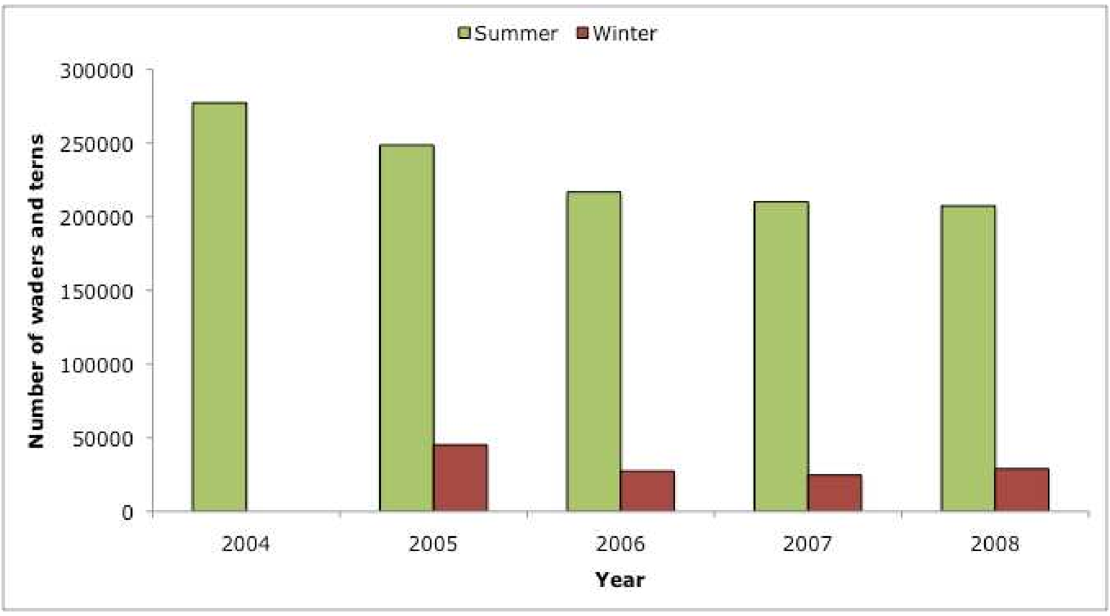

Figure 19: Numbers of waders along a 20km site at Eighty-mile Beach from which consistent counts are available (data from AWSG - Rogers unpublished; Skewes 2003, 2004 and 2005).

It is important to note that the site is significant in terms of total waterbird numbers, not only during the summer (non-breeding season), but also during winter. There are populations of both resident birds that are present at the site year round as well as immature migratory birds that remain in Australia for up to three years(e.g. Great Knot, Bar-tailed Godwit, Eastern Curlew).

The beach is also significant for the role it plays in supporting individual waterbird species. Maximum counts for 20 bird species exceed the 1% population thresholds (Wetland International 2006; Table 7). In addition, Eighty-mile Beach is considered the most significant site (in terms of numbers of birds) in the South-East Asian Flyway for nine international migratory species (Bamford et al. 2008); Bar-tailed Godwit; Terek Sandpiper, Grey-tailed Tattler, Great Knot, Red Knot, Curlew Sandpiper; Greater Sand Plover, Oriental Plover and Oriental Pratincole.

Migratory shorebirds have been observed along the entire length of the beach. However, data from the 2001 survey was used to plot the distribution of shorebirds (Figure 20). Although this represents the data from a single count only, anecdotal evidence suggests that the area south of Anna Plains contains the highest density of birds (D. Rogers pers. comm.).

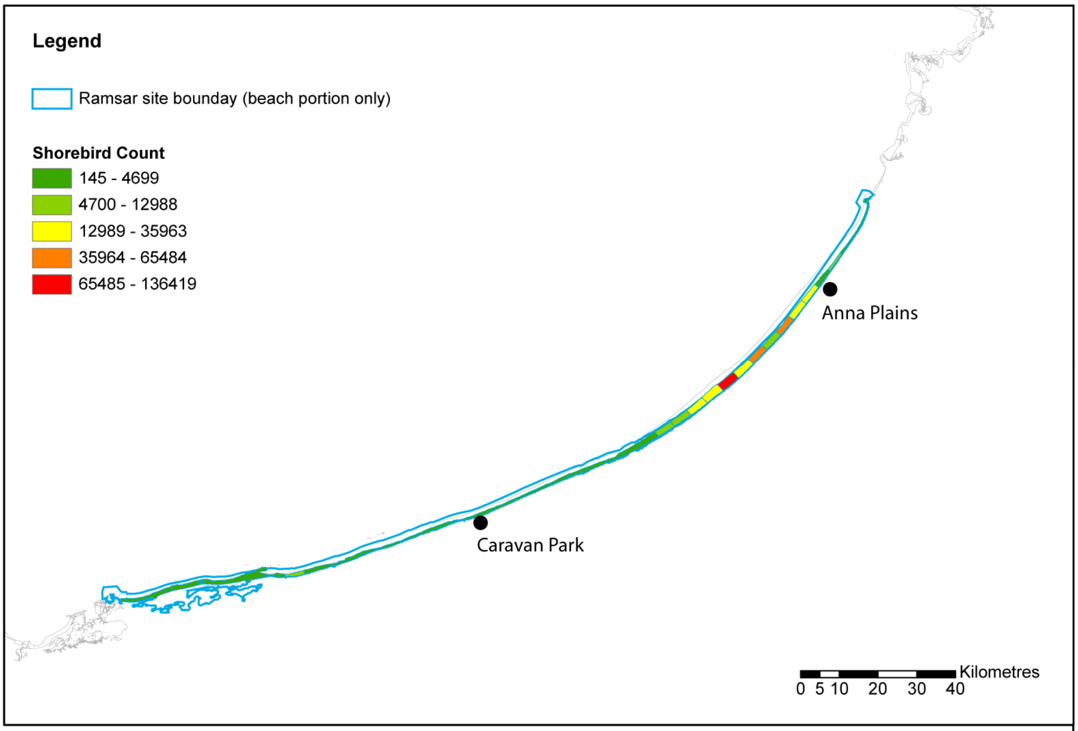

Figure 20: Distribution of shorebirds along Eighty-mile Beach during 2001 (data: AWSG unpublished).

Data from the beach portion of the Ramsar site provides strong evidence to support the claim that Eighty-mile Beach "regularly" supports > 1% of the population of most of the species listed in Table 6. This is despite the fact that regular count data are limited to a small portion of the beach; hence the site almost certainly holds larger proportions of most if not all of such species. Some examples of the variability in counts for wading species is provided in Figure 21 which illustrates that the 1% population thresholds are regularly met even when the count is for a 20km stretch of the 220km long beach.

Table 7: Species at Eighty-mile Beach with maximum counts exceeding 1% population levels (Wetlands International 2006).

Species	Count	Date	% of Pop.	Migratory species?	Source
Bar-tailed Godwit	110,209	Oct 1998	34	Yes	Minton et al. 2003b
Broad-billed Sandpiper	314	Dec 2006	1	Yes	AWSG unpublished
Common Greenshank	3,880	Dec 2006	6	Yes	AWSG unpublished
Curlew Sandpiper	60,000	Unknown	33	Yes	Bamford et al. 2008
Eastern Curlew	709	Oct 1998	2	Yes	Minton et al. 2003b
Great Knot	169,044	Nov 2001	45	Yes	Minton et al. 2003b
Greater Sand Plover	64,584	Nov 2001	59	Yes	Minton et al. 2003b
Grey Plover	1,585	Nov 2001	1	Yes	Minton et al. 2003b
Grey-tailed Tattler	14,647	Nov 2001	29	Yes	Minton et al. 2003b
Little Curlew	3,691	Nov-2004	2	Yes	AWSG unpublished
Oriental Plover	57,619	Oct 1998	82	Yes	Minton et al. 2003b
Oriental Pratincole	2,880,000	Feb 2004	100	Yes	Sitters et al. 2004
Pied Oystercatcher	653	Oct 1998	6	No	Minton et al. 2003a
Red Knot	80,700	Unknown	37	Yes	Bamford et al. 2008
Red-capped Plover	11,453	June 2005	12	No	AWSG unpublished
Red-necked Stint	60,000	Unknown	18	Yes	Bamford et al. 2008
Ruddy Turnstone	3,480	Oct 1998	10	Yes	Minton et al. 2003b
Sanderling	3,219	Nov 2001	15	Yes	Minton et al. 2003b
Sharp-tailed Sandpiper	25,000	Unknown	16	Yes	Bamford et al. 2008
Terek Sandpiper	9,820	Nov 2001	16	Yes	Minton et al. 2003b

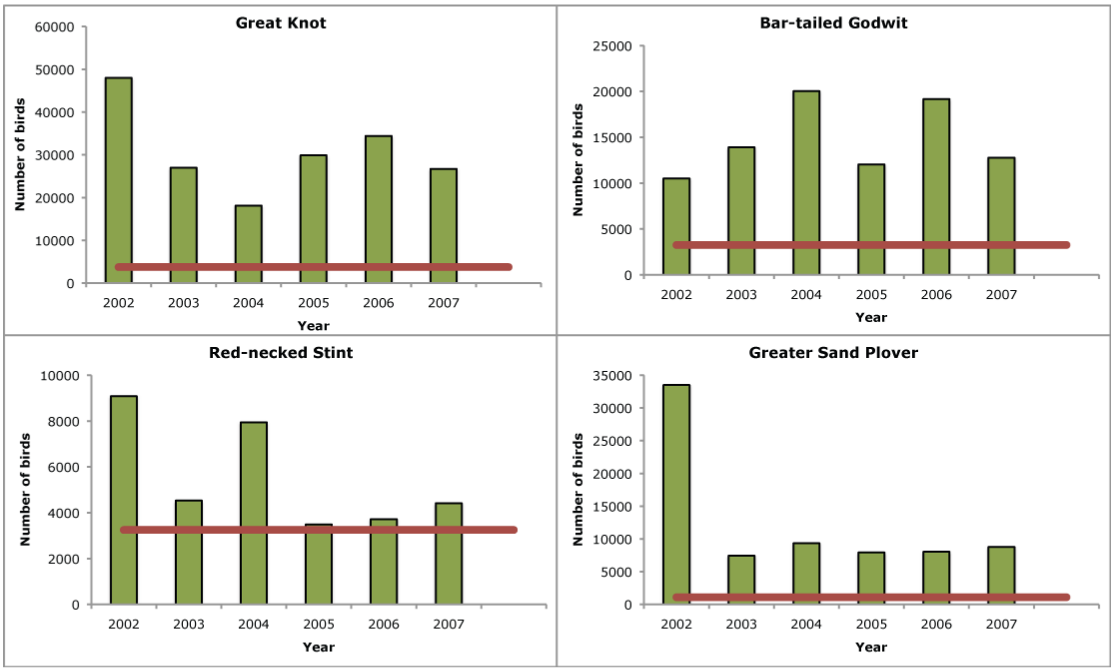

Figure 21: Example of variability in counts and evidence for "regularly" supports > 1% of the population of wetland birds. Counts are from a 20km stretch of Eighty-mile Beach (10 – 30km south of Anna Plains). Red line indicates 1% population threshold (Wetlands International 2006). Data sourced from AWSG – Rogers unpublished and Skewes 2003, 2004 and 2005.

3.2.6 Marine turtles

The Beach portion of the Eighty-mile Beach Ramsar site is considered an important rookery for the threatened Flatback Turtle[3] (*Natator depressus*) (DEWHA 2008c; Spotila 2004; Pendoley 1997). It is estimated that many hundreds of females nest in the sandy, low energy beaches during December and January (Pendoley 2005; Spotila 2004). Comprehensive, quantitative data on numbers and locations is not available, however, the DEC marine turtle database suggests that the areas near Mandora station and the Eighty-mile Beach Caravan Park have the highest density of nesting sites (Figure 22). This is supported by recent survey data from November 2008 where 331 nests and 54 false tracks were recorded in just a 6 km stretch of beach adjacent to the access track from the Caravan Park (DEC 2009). Whether this is a reflection of the true distribution of nesting sites or indicative of survey effort and distribution is not known.

Unlike other marine turtle species, Flatback Turtle hatchlings are not pelagic and remain within 10 – 100km of their natal beaches feeding in low energy, shallow environments on benthic invertebrates (DEC 2008). Therefore, it is possible that Eighty-mile Beach also provides some foraging habitat for this species.

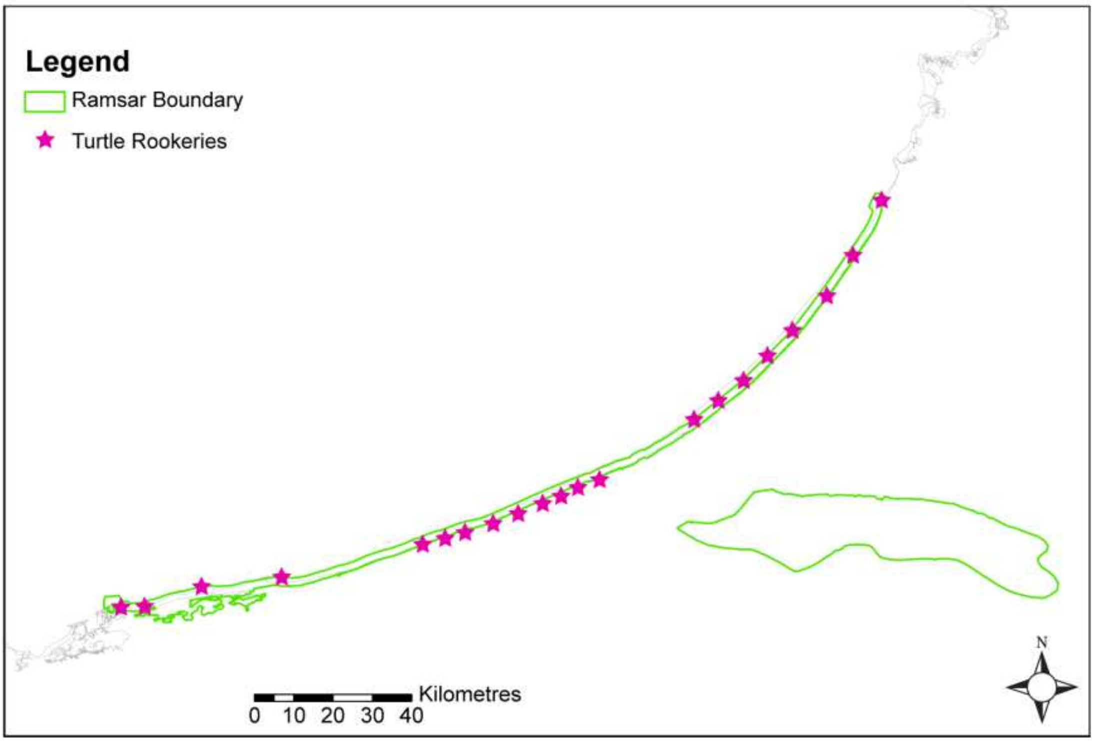

Figure 22: Locations of marine turtle rookeries within the Eighty-Mile Beach Ramsar site (data: B. Prince, DEC marine turtle database).

[3] Although there is anecdotal evidence of the Green Turtle also nesting at the site, there are no confirmed records.

3.3 Mandora Salt Marsh

The critical components and processes of the Mandora Salt Marsh portion of the Eighty-mile Beach Ramsar site are summarised in Table 8 and detailed in section 3.3.1 to 3.3.6 below.

Table 8: Summary of critical components and processes from the Mandora Salt Marsh section of the Eighty-mile Beach Ramsar site.

Component / Process	Direct Components & Processes
Geomorphology	Wetland formation dominated by alluvial processes Wetlands were once a part of an ancient estuary Freshwater springs have been dated at 7000 years old
Hydrology	Walyarta, East Lake and the surrounding intermittently inundated paperbark thickets are inundated by rainfall and local runoff. Extensive inundation occurs following large cyclonic events Salt Creek and the Mound springs are groundwater fed systems through the Broome Sandstone Aquifer.
Water quality	Most wetlands are alkaline reflecting the influence of soils and groundwater. Salinity is variable, mound springs are fresh, Salt Creek hyper-saline and Walyarta variable with inundation. Nutrient concentrations in groundwater and groundwater fed systems are high.
Primary production and nutrient cycling	Data deficient. However evidence of boom and bust cycle at Walyarta with seasonal inundation.
Vegetation	Inland mangroves (*Avicennia marina*) line Salt Creek are one of only two occurrences of inland mangroves in Australia. Paperbark thickets dominated by the saltwater paperbark (*Melaleuca alsophila*) extend across the site on clay soils which retain moisture longer than the surrounding landscape. Samphire (*Tecticornia spp.*) occurs around the margins of the large lakes. Freshwater aquatic vegetation occurs at Walyarta when inundated and at the mound spring sites year round.
Invertebrates	Data limited, but potentially unique species.
Waterbirds	Significant site for waterbirds and waterbird breeding, particularly during extensive inundation events. 66 waterbirds recorded Supports > 1% of the population of at least 2 species Breeding recorded for at least 24 species

3.3.1 Geomorphology, geology and soils

The geology of Mandora Salt Marsh reflects alluvial and inland water processes. The floor of the two large wetlands comprises of sand, silt and clay of alluvial origin. The areas to the south of these wetlands that retain water and support paperbark communities are comprised of clay. There are pockets of peat soils (in the mound springs) and the entire wetland area is surrounded by red quartz sand (Geoscience Australia 2008). Soil samples collected from the wetlands indicated that the majority of the site is covered by clay with a salt crust (Graham 1999).

The wetlands of the Mandora Salt Marsh are of estuarine origin and were once part of a large drainage system known as the Wallal Palaeoriver (Storey unpublished). Carbon dating of peat sediments in Eil Eil spring (Wyrwoll et al. 1986) suggest the wetlands formed approximately 7,000 years ago and have been geographically isolated since this time.

Semeniuk and Semeniuk (2000) applied a geomorphic classification to the wetlands at Mandora Salt Marsh and described three geomorphic types within the system:

1. A straight chain of playas (intermittently flooded basins) located in the swales between linear dunes (Walyarta and East Lake);

2. Damplands - seasonally waterlogged basins (mostly to the south of the large lakes); and
3. Peat mounds – self emergent peaty wetlands (mound springs).

3.3.2 Hydrology

Surface water

The hydrology of Mandora Salt Marsh is not well understood and has not been quantified. Walyarta, East Lake and the Melaleuca wetlands are filled predominantly from rainfall and run-off during the wet season in January – March. Walyarta probably fills seasonally to a depth of < 0.5 m (Storey unpublished), East Lake to a lower depth, and although seasonal flooding of the Melaleuca stands does not occur, the clay soils are likely to be seasonally waterlogged.

Episodically, cyclonic events result in more extensive rainfall and inundation has been known to extend beyond the Ramsar site boundary and west across the Northern Highway. Such incidents were recorded in 1942, 1980, 1982, 1997, 1999 and 2000 and have been linked to yearly rainfall > 800mm (Halse 2005). In 2000 flooding was almost continuous from Anna Plains to Wallal. During these events, the depth of water in Walyarta may exceed 2m (Graham 1999).

The extent and depth of inundation affects the duration of surface water, and this also has not been quantified. However, in the majority of years Walyarta and East Lake are either dry or after partial inundation they dry back to bare clay beds.

Groundwater

Groundwater is a significant component of the hydrology of the Eighty-mile Beach Ramsar site and to Mandora Salt Marshes in particular. The site lies within the La Grange Groundwater Management Area and the Broome Sandstone aquifer is the most relevant of the groundwater systems to the ecological character of the wetlands. The hydrological connections and the ecological water requirements of the wetlands have yet to be determined. Whilst ecological water requirements information is not yet known, the Department of Water manages the site's water through the La Grange Plan and the water licensing system (Department of Water 2008).

What is known is that the mound springs are probably the expression of upwelling from deep within the Broome Sandstone aquifer through fractures in the rock (Semeniuk and Semeniuk 2000). This results in the permanent surface water in these springs despite the low rainfall and high evaporation experienced in the area.

Salt Creek is also fed from groundwater and has areas of permanent standing water. This system, however, is not connected to the springs. The groundwater aquifer that feeds Salt Creek is shallow and the exposure to the air concentrates the salinity. In addition, it is thought that it may be re-charged from marine sources, contributing to the salinity (Semeniuk and Semeniuk 2000; Graham 1999).

3.3.3 Water quality

Unlike the beach portion of the Ramsar site, where macro-tides exchange large volumes of water twice daily, thereby minimising any potential water quality changes; water quality, is a significant component of the ecological character of the wetlands at Mandora Salt Marsh. There is, however, limited information with quantitative data restricted to a single sampling event in October 1999 (Graham 1999). As this sampling followed the extensive flooding event in early 1999 it is difficult to determine if the results are typical of the site and it would be expected that water quality during drier years may be substantially different.

Results from the 1999 sampling indicated the following (Storey unpublished):

Walyarta

Only a limited set of variables was measured at a single site in Walyarta. The water was brackish to saline (salinity = 27 parts per thousand, ppt) and alkaline (pH = 8.8). Daytime water temperature was high (34 °C) and despite the high temperature (which reduces the amount of oxygen that can be held in solution) the water was supersaturated with oxygen (dissolved oxygen = 108 % saturation). This is indicative of high primary productivity within the water column.

Salt Creek
Two sites were sampled in Salt Creek, a full set of variables was measured at the spring feeding the creek and a reduced set of variables in a pool of standing water within the creek). Water was saline to hyper saline. The salinity of the spring was 38.5 ppt and the pool salinity much higher at > 60 ppt, probably reflecting concentration effects as water evaporates. Water was alkaline (pH 8.4 – 7.8) with a high sulphate concentration (7320 mg/L). Water temperatures in the middle of the day were high (34 – 35 °C) and dissolved oxygen concentrations super saturated (> 200 % saturation). Nitrogen concentrations were very high with total nitrogen of 2800 µg/L. Approximately half the nitrogen was in dissolved inorganic form, mostly as nitrate-nitrite.

Mound Springs
A full set of water quality variables was measured at seven mound springs (Table 9). Although the results were variable, some patterns can be seen in the data.

Table 9: Water quality data from seven mound springs at Mandora Salt Marsh. October 1999 (Storey unpublished).

Site	Temp ℃	pH	DO %	Sal. ppt	TN µg/L	NO_x µg/L	NH_4 µg/L	TP µg/L	PO_4 µg/L
Eil Eil	29	7.6	49	1.4	2700	<20	140	150	60
Fern	26	7.5	86	5.8	1400	30	20	210	210
Linear	21	8.4	100	0.6	5200	150	<20	20	20
Little Eil Eil	25	7.5	31	1.2	2000	40	310	490	270
Melaleuca	36	9.6	>200	4.7	17000	60	140	2000	40
Saunders	36	9.2	>200	1.3	5200	110	20	710	10
Top	19	8.3	106	0.5	5400	50	20	580	40

The majority of the springs were fresh, with the exception of Fern and Melaleuca, which could be considered brackish. Storey (unpublished) indicated that these two sites were lower in the landscape and closer to Lake Walyarta. All sites were alkaline, but the pH at Saunders and Melaleuca springs was higher than other sites (> 9). These two sites were also characterised by higher water temperatures and greater dissolved oxygen concentrations than the other springs sampled. Nutrient concentrations were variable across the springs. Total nitrogen ranged from a low of 1400 µg/L at Fern spring to a high of 17000 µg/L at Melaleuca spring. However, at all sites little of the total nitrogen was in available form with the proportion of dissolved inorganic nitrogen (nitrate-nitrite and ammonium) < 20%. The total phosphorus concentration was also higher at Melaleuca (2000 µg/L) that other spring sites. However, the proportion of bioavailable orthophosphate was highly variable ranging from 100% at Fern spring to < 10% at a number of sites.

Groundwater
Water quality was assessed at two groundwater bores within the Mandora Salt Marsh, to the north of Walyarta. Water was fresh to brackish (salinity = 1.3 to 1.5 ppt) and neutral (pH = 7.1). Total nitrogen concentrations were high (13000 – 16000 µg/L) with almost all nitrogen occurring as nitrate-nitrite.

3.3.4 Primary productivity and nutrient cycling

There is a lack of data on primary productivity and nutrient cycling at Mandora Salt Marsh. Graham (1999) noted that following extended inundation, algal growth at Walyarta was prolific and would represent a significant biomass. Observations of algal and cyanobacterial blooms were also made at Salt Creek. Elevated nutrient and dissolved oxygen concentrations at Melaleuca and Saunders springs (Storey unpublished data) indicate that water column primary production, possibly of phytoplankton was high during October 1999. However, little else is known about these processes at the site.

3.3.5 Vegetation

Although a large number of plant species (178) have been recorded at Mandora Salt Marsh (Appendix B), there are four groups of vegetation that could be considered critical components of the ecological character of the Eighty-mile Beach Ramsar site:

- Mangroves
- Paperbark thickets
- Samphire
- Freshwater aquatic vegetation

Information on the extent, community composition and condition of each of these communities is sparse and limited to a small number of field investigations. What is known of the characteristics of each of these communities is summarised below.

Mangroves

The presence of Grey Mangroves at Salt Creek in Mandora Salt Marsh was documented by Beard in 1967. He suggested that the formation was a relict stand from a time when sea levels were higher and the Marsh was a mangrove-lined estuary (Graham 1999). The mangroves line both sides of Salt Creek in a mono-specific stand with trees to 5m high. Grey mangroves also occur at other locations within the Ramsar boundary including linear stands parallel to the southern shore of Walyarta and at the Stockyard Springs to the east (Graham 1999). The stands at Salt Creek are seemingly even aged, however at other locations, more complex age structure occurs. In spring 1999, large numbers of germinating seedlings of Grey Mangrove were recorded within the Ramsar site and extending as far west as the Great Northern Highway.

Paperbark thickets

Low Paperback thickets dominated by *Melaleuca alsophila* (formerly described as *M. acacioides*) cover much of the clay soils to the south and east of Walyarta within the Ramsar boundary. They occur in areas that become seasonally waterlogged and occasionally inundated (Graham 1999).

Samphire

The shores of Lake Walyarta and much of the area surrounding East Lake are covered in samphire dominated by *Tecticornia* spp. (formerly *Halosarcia*). These areas are seasonally waterlogged / inundated and grade into salt tolerant grasslands of *Sporobolus* sp. (Graham 1999).

Freshwater aquatic vegetation

When flooded, Walyarta contains a mix of submerged aquatic species including Ribbon Weed (*Vallisneria spiralis*) and the freshwater macro-algae Chara sp. (Graham 1999). It is likely however, that these types of freshwater species only occur following significant, inundation such as that which occurred during 1999 and 2000. At other times, when the lake only partially fills, salinity may remain too high for these freshwater aquatic species. The characteristics of this wetland in this regard remain a knowledge gap.

The freshwater mound springs contain a complex mosaic of vegetation associations, which are illustrated by the example of Saunders Spring, for which a recent survey has been conducted (DEC in prep.). DEC (in prep.) described three broad vegetation communities within the spring (Figure 23):

1. A tall stand of paperbark (*Melaleuca leucadendra*) and Dragon Tree (*Sesbania formosa*) occurs on top of the peat mound and stands out in the landscape. With trees up to 20 m in height, it towers above the surrounding low paperbark thickets. Under this is a dense ground cover of the mangrove fern (*Acrostichum speciosum*).
2. Growing in the moat surrounding the peat mound is Cumbingi (*Typha domingensis*)
3. Outside the moat, the vegetation is more terrestrial with dense *Acacia ampliceps* shrubland grading into salt marsh. However, patches of sedges (*Eleocharis sp.*) occur on wetter soils.

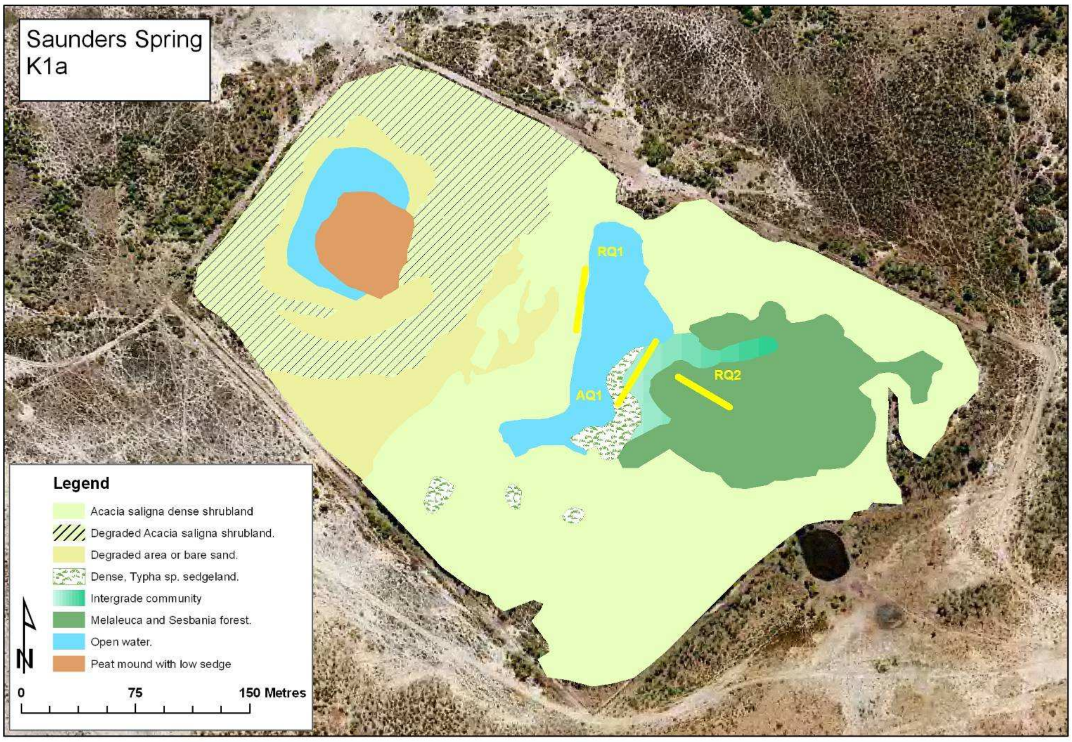

Figure 23: Broad vegetation communities at Saunders Spring (from DEC in prep.).

3.3.6 Invertebrates

Macro and micro-invertebrates were collected from surface and groundwater samples from a number of sites during a one-off survey in 1999 (Storey et al. 1999). Pore water samples from cores made in the peat were collected at four springs. Overall at least 133 taxa were collected with insects accounting for 74% of the taxa, of which Coleoptera (beetles) made up 24% (Storey unpublished). Salt Creek supported the fewest numbers of invertebrates with 15 taxa, with most sites averaging 30 taxa. There was a high proportion of taxa recorded from only 1 or 2 sites (74%). The groundwater samples had few taxa, as was expected, but supported a few species which could have possible stygofaunal origins (Storey unpublished).

The fauna of the pore water were depauperate, but contained species not found in the surface water of the parent springs. Community composition reflected salinity gradients observed at the wetlands, with fewer species being recorded in the higher saline environments. Approximately 30% of the recorded taxa were restricted to the freshwater springs.

Aquatic invertebrate fauna of artesian springs are often characterised by relictual species and locally endemic species (Storey unpublished). However only one truly endemic species was recorded a gastropod *Assiminea* sp. This genus is considered marine and the presence of a ‘new’ species may relate to the wetlands having once been an estuary, with their subsequent isolation at the start of the Holocene leading to genetic and morphological divergence (Storey unpublished).

Seasonal and inter-annual variation in species composition and a comprehensive assessment of species diversity is not available and remains a knowledge gap. However, the rarity of the aquatic habitat in the bioregion would suggest that this site is significant for aquatic invertebrate regional diversity. Storey (unpublished) compared species richness to a number of other one-off surveys of arid system wetlands stating that the fauna of Mandora Salt Marsh was rich, but not ‘outstanding’, recording fewer taxa than most other studies. The endemicity of the fauna was also low compared to other systems, both in Western Australia and elsewhere in Australia, for most groups (rotifer, cladocerans, copepods, ostracods, oligochaetes, water mites, and insects). For example the rotifers collected at the wetland, in which Australia has approximately 15% endemicity, had an estimated 10% endemicity with only two novel species being recorded. Sample size and limited collections may have led to this result (Storey unpublished).

3.3.7 Birds

Mandora Salt Marsh is considered a significant site for wetland birds, particularly in years of significant inundation (Halse et al. 2005).

Diversity and abundance
Mandora Salt Marsh supports a diversity and abundance of waterbirds. A total of 66 species of wetland bird have been recorded within the Ramsar site boundary at Mandora Salt Marsh (Table 10). This includes 20 species that are listed under international migratory agreements CAMBA (17), JAMBA (18) and ROKAMBA (15) as well as an additional 24 Australian species that are listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC). In addition, there is a single record for the Australian Painted Snipe (*Rostratula australis*) from Mandora Salt Marsh, which is listed as vulnerable under national threatened species legislation (EPBC) (Appendix D).

It should be noted that because waterbirds are highly mobile, some with continental or international ranges of occurrence, and because many are secretive or easily overlooked within dense aggregations, lists of species recorded at a particular site are rarely complete and tend to increase over time. This is particularly true for the Mandora Salt Marsh portion of the Ramsar site, where published bird records are limited to two intense surveys (Graham 1999 and Halse et al. 2005) both related to episodic floods. It is likely that this species list provided below will increase with further monitoring and improved records.

There are records of large numbers of birds at Mandora Salt Marsh, although surveys are more limited than for the beach portion of the Ramsar site. Surveys in 1997 and 1999 recorded > 20,000 waterbirds within the Ramsar boundary at Mandora Salt Marsh (Graham 1999). Following the extensive inundation of the area in 1999 and 2000 very large numbers of waterbirds were recorded from aerial surveys 480,000 – 490,000 (Halse et al. 2005) although the area surveyed included larger areas of inundated land outside the Ramsar boundary.

Table 10: Number of wetland birds recorded at Mandora Salt Marsh.

Bird group	Typical feeding requirements	Number of species
Ducks and allies	Shallow or deeper open water foragers Vegetarian (e.g. Black Swan) or omnivorous with diet including leaves, seeds and invertebrates	10
Grebes	Deeper open waters feeding mainly on fish	2
Pelicans, Cormorants, Darters	Deeper open waters feeding mainly on fish	4
Heron, Ibis, Spoonbills	Shallow water or mudflats Feeding mainly on animals (fish and invertebrates)	11
Hawks, Eagles	Shallow or deeper open water on fish and occasionally waterbirds and carrion	2
Crakes, Rails, Water Hens, Coots	Coots in open water; others in shallow water within cover of dense emergent vegetation such as sedge. Some species vegetarian, others mainly take invertebrates, some are omnivores	8
Shorebirds	Shallow water, bare mud and salt marsh Feeding mainly on animals (invertebrates and some fish)	23
Gulls, Terns	Terns, over open water feeding on fish; gulls, opportunistic feeders over a wide range of habitats.	5
Other wetland birds	Clamorous Reed Warbler	1
Total		66

The site is also significant for the role it plays in supporting individual waterbird species. Maximum counts for two Australian waterbird species exceed the 1% population thresholds (Wetland International 2006):

- Black-winged Stilt - 10,000 birds recorded in June 1997 (Graham 1999); and
- Eastern Great Egret – 1,200 birds recorded in October 1997 (Graham 1999).

During the exceptional 1999 and 2000 floods of the coastal plains and marshes, estimated total numbers of waterbirds for the entire inundated area (over 150 km long by 100 km wide) indicated that > 1% of the population of a further 11 species was exceeded (Table 11). This included an estimated 73% of the Australian population of Black-winged Stilts and 27 % of the population of Whiskered Terns. However, these counts include extensive inundated land outside the Ramsar site boundary. Nevertheless, this indicates that the site is important for wetland birds, especially during these large inundation events and that the surrounding landscape is a significant habitat for birds during these times (Halse et al. 2005)and further surveys may clarify portions of these numbers supported by the Ramsar site.

Table 11: Maximum counts of wetland birds that exceeded the 1% population thresholds (Wetlands International 2006) at Mandora Salt Marsh and surrounding inundated land 1999 – 2000 (Halse et al. 2005).

Species	Count	% of Population
Plumed-Whistling Duck	14,070	1.4
Australasian Shoveler	621	5.2
Hardhead	98,750	9.9
Little Egret	4690	4.7
Glossy Ibis	26,140	2.6
Straw-necked Ibis	48,630	4.9
Brolga	3620	3.6
Eurasian Coot	43,290	4.3
Black-winged Stilt	219,520	73.2
Banded Stilt	2670	1.3
Red-necked Avocet	3740	3.4
Whiskered Tern	27,360	27.4

<u>Breeding</u>
The Eighty-mile Beach Ramsar site, and Mandora Marshes in particular, are significant regionally for wetland bird breeding, though on an infrequent basis. Although data is limited, a total of 27 species of wetland bird have been recorded breeding within or adjacent to the site (Appendix C). This list includes 13 species recorded breeding during 1999 within the boundary of the Ramsar site (Graham 1999) as well as a further 14 species that were recorded by Halse et al. (2005) from the Mandora Salt Marsh and surrounding inundated area in 1999 and 2000.

Halse et al. (2005) indicated that the total system (which includes Mandora Salt Marsh and the surrounding area) was regionally significant for breeding of a number of wetland bird species during 1999 and 2000 (Table 12). Numbers of breeding efforts by several species, notably Black-winged Stilt, Whiskered Tern and Hoary-headed Grebe, over the entire inundated marshes system in these years, are assumed to be especially high and would represent major contributions to the Australian populations of these species. Further analyses of data or survey effort are needed to clarify the specific contribution of the Ramsar site to these numbers but it would in each case be substantial.

It was estimated that 70% of the Black Swans present bred during these floods, constituting a regionally significant breeding event. Halse et al. (2005) commented that although only small numbers of ducks were observed breeding, this was likely to be related to their cryptic nature, rather than an actual reflection of breeding. Further, they indicated that it was likely that the marsh supported significant breeding of Pink-eared Ducks, Hardheads, Grey Teal, Plumed Whistling Ducks and Pacific Black Ducks.

Table 12: Breeding of wetland birds in Mandora Salt Marsh 1999 – 2000 (Halse et al. 2005)

Species	Aug 1999	June 2000	Aug 2000
Plumed Whistling Duck		41	140 (estimated 48% of adults bred)
Black Swan	53	475	
Pacific Black Duck		Many	
Grey Teal	4	Many	
Pink-eared Duck		1	
Hardhead	2	2	
Australasian Grebe		1	
Hoary-headed Grebe		104	Estimated 1000s of nests
Darter	5		
Australian Pelican	210	2050	50
White-faced Heron	1		
Little Egret		20	200 nests
White-necked Heron	1	10	
Intermediate Egret		150	
Great Egret		40	
Unidentified egrets		10	10
Nankeen Night Heron		100	100
Straw-necked Ibis	10	260	4000 juveniles seen
Eurasian Coot		60	3
Black-winged Stilt	1	3500	Most adults thought to have bred
Red-necked Avocet		1	
Red-capped Plover		1	
Black-fronted Dotterel	1		
Red-kneed Dotterel		20	
Masked Lapwing		12	
Gull-billed Tern	15	1750	Most adults thought to have bred
Whiskered Tern		1000s	Nests throughout Marsh and most adults thought to have bred

4 Critical ecosystem benefits and services

4.1 Overview of benefits and services

Ecosystem benefits and services are defined under the Millennium Ecosystem Assessment definition of ecosystem services as "the benefits that people receive from ecosystems (Ramsar Convention 2005, Resolution IX.1 Annex A). This includes benefits that directly affect people such as the provision of food or water resources as well as indirect ecological benefits.

The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) defines four main categories of ecosystem services:

1. **Provisioning services -** the products obtained from the ecosystem such as food, fuel and fresh water;
2. **Regulating services** – the benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation;
3. **Cultural services** – the benefits people obtain through spiritual enrichment, recreation, education and aesthetics; and
4. **Supporting services** – the services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time.

The ecosystem benefits and services of the Eighty-mile Beach Ramsar site are outlined in Table 13.

Table 13: Ecosystem services and benefits provided by the Eighty-mile Beach Ramsar site.

Category	Description
Provisioning services	
Fresh water	The freshwater springs at Mandora Salt Marsh provide drinking water for livestock
Genetic resources	Plausible, but as yet no documented uses
Regulating services	
Biological control of pests and diseases	Evidence that many of the shorebirds feed on the adjacent pastoral land and that the incidence of 2.88 million Oriental Pratincole coincided with locusts in almost plague proportions, upon which the birds fed (Sitters et al. 2004)
Climate regulation	Data deficient – plausible but not documented.
Cultural services	
Recreation and tourism	Eighty-mile Beach (near Wallal Station) is a tourist attraction with people engaging in fishing, 4WD and shell collecting
	Although permission has to be obtained to enter Mandora Salt Marsh it is popular for passive recreation and bird watching
Spiritual and inspirational	The wetlands and beach areas are spiritually significant for the Karajarri and Nyangumarta and contain a number of specific culturally significant sites.
	The site has inspirational, aesthetic and existence values at regional, state and national levels.
Scientific and educational	Mandora Salt Marsh and Eighty-mile Beach have been the site of a number of significant scientific investigations (e.g. Graham 1999; Piersma et al. 2005). In addition, Eighty-mile Beach is a significant site for migratory shorebird monitoring and is currently part of the Shorebirds 2020 program.
Supporting services	
Biodiversity	As evidenced by the listing of the Eighty-mile Beach Ramsar site as a wetland of international importance. The system provides a wide range of biodiversity related ecological services critical for the ecological character of the site including: • Containing a diversity of wetland types • Supporting significant numbers of migratory shorebirds • Supporting significant wetland bird breeding • Supporting Flatback Turtle breeding
Nutrient cycling	Nutrient cycling – data deficient
	Carbon sequestration – data deficient but plausible

4.2 Identifying critical ecosystem services and benefits

The critical ecologically based ecosystem services and benefits of a Ramsar site have been identified based on the same criteria provided by DEWHA (2008) used for selecting critical components and processes (see section 3.1 above). The relationship between these critical ecosystem services, reasons for listing as a wetland of international importance and the components and processes that support them is provided in Table 14. The descriptions of these identified critical ecological services integrate the components and processes that contribute to the wetland providing the services. Conceptually, it is the components and processes and the interactions between them that characterise each of the critical ecological services. Each of the identified critical ecological services is described below.

Table 14: Critical ecosystem services, the Ramsar criteria they contribute to and the components and processes responsible for creating them.

Critical Ecosystem Service	Ramsar Criteria	Components & Processes Creating the Service
Contains exceptionally large examples of wetland types and includes rare wetland types of special scientific interest	*1. Contains a representative, rare or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region* 3. *Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region*	The interactions between hydrology and geomorphology that provide a physical template for diverse vegetation and physical wetland habitats.
Supports significant numbers of migratory birds	4. *Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions* 5. *Regularly supports 20,000 or more waterbirds* 6. *Regularly supports > 1% of the population of one or more species of waterbird*	Wetland habitats Primary productivity Predation
Supports waterbird breeding	4. *Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions* 5. *Regularly supports 20,000 or more waterbirds*	Wetland habitats Climate and hydrology Primary productivity Predation
Supports marine turtles	*2. Supports vulnerable, endangered, or critically endangered species or threatened ecological communities.* 4. *Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions*	Geomorphology (soils) Hydrology Predation
Supports tourism	*Not applicable*	Wetland habitats (beach); Invertebrates (shell collecting)
Provides significant indigenous cultural values.	*Not applicable*	Climate and hydrology (water source) Wetland habitats

4.3 Contains large wetland types and includes rare wetlands of special scientific interest

As described in section 2.3, the Eighty-mile Beach Ramsar site contains a range of wetland types, some of which can be considered significant in a bioregional context. The major wetland habitats that are considered critical to the ecological character of the site are:

- Intertidal mudflats;
- Inland mangroves;
- Inland temporary wetland systems; and
- Mound springs

This diversity of habitat is brought about by the interactions between geomorphology, hydrology, water quality and vegetation (Figure 24). The critical components and processes and the interactions between them that result in these wetland habitats is described below.

Intertidal Mudflats (Ramsar wetland type G)
A combination of the low relief topography and the high tidal regime at Eighty-mile Beach provides an extensive intertidal zone. The interaction between the tide and the fine sediments acts in a cyclic way to maintain the habitat, with the soft sediments decreasing the energy of incoming waves and resulting in a low energy depositional environment where fine sediments accumulate (Honkoop et al. 2006).

The system has few terrestrial carbon inputs, with minimal mangrove areas and no major surface water flows. The fine sediments carried on ocean currents contain organic matter, which is the building block of productivity in this system. Little is known about primary production in this system and the extent that the system is driven by benthic primary producers that exist on the mudflats remains a knowledge gap.

Secondary production in soft sediment intertidal habitats is also driven by microorganisms, with sedimentary bacteria being consumed by the meio and macrofauna. Microphytobenthos produce extracellular polymeric substances which coat and bind sediments and enter the food chain by either being directly consumed by herbivorous fish, epibenthic (surface dwelling) fauna or by infauna (Dittman 2007 and references therein).

Species interactions including herbivory and predation are complex and population dynamics of both consumers and producers can be affected by each other. Ecological processes in marine systems where consumers influence population dynamics of their prey and communities in which they occur are well documented for herbivory, particularly on coral reefs (Connell and Vanderklift 2007), but less so for predation and competition in soft sediment systems. Predation is believed to potentially influence communities in some places and time, but the degree of influence is not well understood, nor does it have as large or clear consequences as herbivory (Connell and Vanderklift 2007). This is evidenced at Eighty-mile Beach where studies of shorebird density versus prey densities provided inconclusive results (Rogers et al. 2005).

Predation of the benthic fauna of the intertidal mudflats is undertaken by invertebrates, shorebirds, and other vertebrates. Available data provides an approximation of the predatory taxa. However, as the macrofauna data are reported at family level resolution, the precise breakdown of functional feeding groups is not possible as many families of invertebrate exhibit multiple feeding modes. Dittman (2007) reports that there is a prevalence of surface deposit feeders in tropical mudflats, and whilst deposit feeding was common among the invertebrate macrofauna at Eighty-mile Beach, predators were also a significant component (approximately 20 %) (see **Table 15**). However, data from Eighty-mile Beach is consistent with Dittman (2007) in terms of species abundance with deposit or suspension feeders accounting for > 50% of individuals collected in the 1999 survey (based on data in Lavaleye et al. 2005).

Table 15: Functional feeding group of invertebrate families from the macrofauna of Eighty-mile Beach.

Feeding group at family level of taxonomic resolution	Description	macrofauna spp. (%)
Suspension feeders	Feeds by filtering suspended particulate organic matter from water (also called filter feeders).	15
Deposit feeders	Feeds on the detritus that accumulates on/in the sediment (also called detritus feeders). Can be surface and subsurface deposit feeders.	19
Suspension and deposit feeders	As above	2
Predators	An organism that lives by preying on other organisms. Parasitic groups have been included here.	20
Predators and scavengers	Feed on live and dead animal material.	5
Scavengers	Feed on dead organic material	1
Omnivores	Feed on plants and animals	1
Multiple groups within a single family		2
Unassigned		10

The relative importance of fish predation at Eighty-mile Beach is not known as no data has been collected on the fish fauna. However, it can be assumed that fish are an important component of the food chain both as prey to piscivorous birds and predators of invertebrates. Bird size can affect prey intake rate and feeding rate with larger birds being able to take larger prey and potentially forage and capture more prey faster. Whilst the intake of shorebirds increases with prey abundance, the response is not linear as above certain prey densities the intake rate reaches an asymptote as the time taken to find, handle and consume prey limits the intake rate (Rogers et al. 2007). The fact that there are large numbers of shorebirds supported at Eighty-mile Beach indicates that a significant amount of the potential feeding area supports prey densities adequate for successful foraging (Rogers et al. 2007).

Marine turtles may also play a role in the food chain at Eighty-mile Beach as Flatback turtles are carnivorous and specialists at feeding in soft sediments and shallow waters. However, feeding within the Ramsar site of these marine reptiles would be limited to high tide and it is likely that significant feeding grounds are further off-shore in deeper waters.

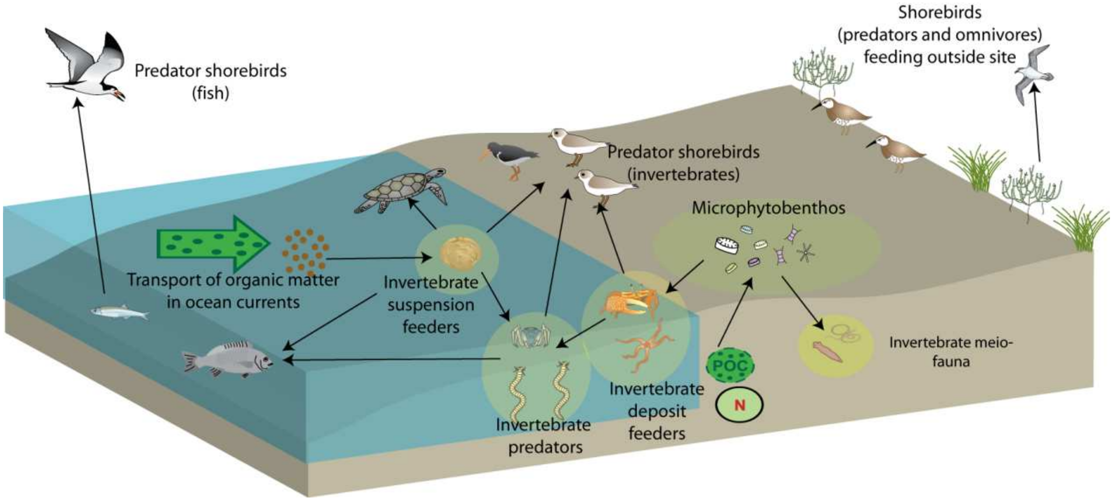

Figure 24: Indicative food web for the beach portion for the Eighty-mile Beach Ramsar site.

<u>Inland Mangroves (Ramsar wetland type I)</u>

The inland mangroves of Mandora Salt Marsh are unique and represent one of only two such systems in Australia, the other being at Lake Macleod (Johnstone 1990). The mangroves are comprised of a single species (Grey Mangrove) and are most likely a relic from a time when the site was part of an estuary (Semeniuk and Semeniuk 2000). The major stand lines Salt Creek. The permanence of this ground water fed system is essential for survival of the mangrove community. Another important factor is seasonal flooding of the system. Over the course of the dry season, salts concentrate in Salt Creek making it hypersaline (Storey et al. 1999). Without freshwater inflows during the wet season, which lower the salinity in the system, it is likely that the mangroves would not be able to tolerate the conditions (Semeniuk and Semeniuk 2000). In addition, regeneration of these mangroves and recruitment of seedlings has been observed at the site following large scale flooding (Willing and Handasyde 1999). Although this is not proof of a causative connection between flooding and mangrove recruitment it is a possibility.

Inland Temporary Wetland Systems (Ramsar types S, Xf)
Mandora Salt Marsh contains a variety of temporary wetland systems some which may experience seasonal inundation (e.g. Walyarta) and others which may be inundated less frequently (e.g. Paperbark thickets). It is thought that direct precipitation and surface water flow are the main hydrological source for these systems (Graham 1999; Semeniuk and Semeniuk 2000). As such, climate and the water holding clay soils are the components that are the most critical to providing these wetland habitats.

The topography of the land, together with soil type provides a mosaic of water regimes with different depths and durations of inundation. Water regime is the single biggest determinant of wetland vegetation, with different groups of species having different morphological adaptations to patterns of inundation. Most commonly, it is a plants ability to adapt to low oxygen in the soil following inundation that determines its optimum water regime. Brock and Cassanova (1997) classified plants into functional groups based on water regime and adaption to flooding and these have been applied to the vegetation types at the temporary wetland systems of Mandora Salt Marsh (Figure 25).

The freshwater macroalgae (*Chara sp.*) observed at Lake Walyarta (Graham 1999) can be considered a submerged plant, adapted to a life under water and no vegetated terrestrial stage. Ribbon Weed (*Vallisneria spiralis*) is an amphibious responder, elongating stems and leaves to maintain contact with the surface to enable oxygen exchange. Little is known about physiological changes in salt marsh species in response to inundation (Colmer and Flowers 2008). However, given that there were a number of dead samphire plants present following the receding flood in 1999 (Willing and Handasyde 1999) it is likely that they are amphibious tolerators, capable of surviving short periods of inundation.

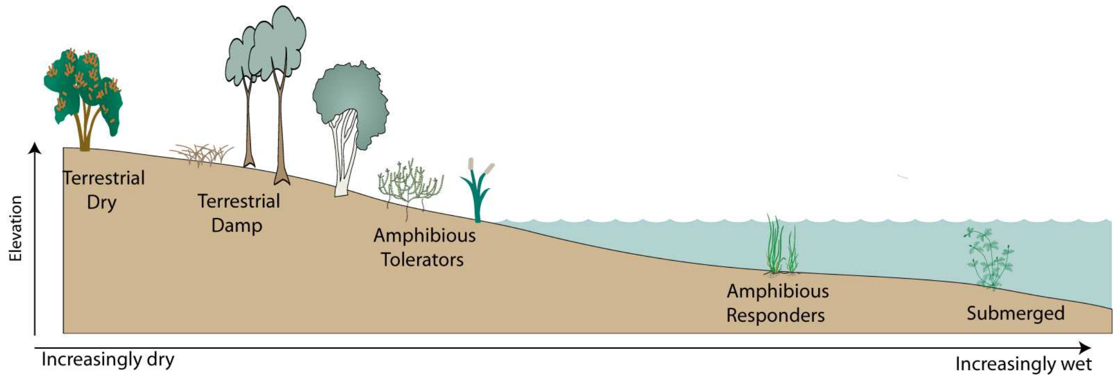

Figure 25: Functional plant types (from Brock and Cassanova 1997).

Freshwater Mound Springs (Ramsar types Y and Xp)
The interactions of geomorphology and groundwater results in the expression of freshwater springs within the Mandora Salt Marsh. These have been described as typical peat based mound springs, formed by the movement of water through cracks in the Broome Sandstone aquifer (Semeniuk and Semeniuk 2000). They are characterised by a thick (3 – 4 m) mound of peat accumulated over geological time scales, surrounded by a moat of freshwater. The peat bed is topped by a forest of *Melaleuca sp.* up to 20m in height along with emergent reeds *Schoenoplectus formosa, Schoenoplectus litoralis, Typha domingensis* and

Acrostichum speciosum. Riparian vegetation surrounding the moat is a dense shrubland dominated by *Acacia saligna* (DEC in prep.).

The permanence of these freshwater wetlands makes them extremely important to biodiversity in the arid environment. They provide habitat for aquatic flora and fauna year round and a source of drinking water for terrestrial animals. They are reliant on good quality, alkaline groundwater to maintain their ecological character and continue to support biodiversity within the site.

4.4 Supports significant numbers of migratory birds

As previously stated, Eighty-mile Beach is one of the most significant sites (in terms of waterbird numbers) for migratory shorebirds in Australia and in fact in the East Asian-Australasian Flyway (DEWHA 2008c). Birds in the East Asian-Australasian Flyway migrate from breeding grounds in NE Asia and Alaska to non-breeding grounds in Australia and New Zealand, covering the journey of 10,000 km twice in a single year (Figure 26).

The lifecycle of adult international migratory shorebirds involves (Bamford et al. 2008):

- Breeding in May to August (northern hemisphere);
- Southward migration to the southern hemisphere (August to November);
- Feeding and foraging in the southern hemisphere (August to April);
- Northward migration to breeding grounds (March to May).

During both northward and southward migration, birds may stop at areas on route to rest and feed. These stopovers are referred to as “staging” areas and are important for the bird’s survival. In addition, birds on their first southward migration have not yet reached breeding maturity and may remain in Australia over a number of southern winters depending on the species.

Figure 26: East Asian-Australasian Flyway (adapted from Bamford et al. 2008).

The Eighty-mile Beach Ramsar site supports migratory shorebirds during a number of stages of this lifecycle. The site is a significant staging area, particularly on southward migration routes, with large numbers of birds stoping to rest and feed here before moving further inland or south within Australia (Bamford et al. 2008). Many birds, however, upon arrival at Eighty-mile Beach will spend the non-breeding season at this site feeding and gaining energy reserves for the long journey back to breeding grounds in the north. Some of these species will feed almost exclusively within the intertidal zones and shallow waters. Others, such as the Oriental Pratincole, use the beach areas for roosting, but feed on adjacent inland areas. Finally, some juvenile birds remain at Eighty-mile Beach over the entire year, as evidenced by relatively high winter counts of migratory shorebirds on the site (D. Rogers unpublished data).

The feeding and foraging requirements for a number of migratory shorebirds supported by the Eighty-mile Beach Ramsar site have been described (Table 16).

Table 16: Habitat requirements of a number of migratory shorebirds at Eighty-mile Beach (information from BirdLife International, 2008 unless otherwise specified).

Shorebird	Breeding Area	Feeding, foraging and other habitat requirements
Bar-tailed Godwit	Northern Russia	Mudflat and intertidal zone forager. In intertidal areas the diet consists of annelids, bivalves and crustaceans, although it will also take cranefly larvae and earthworms on grasslands and occasionally small fish. Longest known non-stop flight (> 11,000 km) recorded for this species.
Broad-billed Sandpiper	Russia, Siberia	Intertidal mudflats and saltmarshes. Diet consists of marine nereid worms, small bivalves and snails, crustaceans, adult and larval insects (e.g. beetles, flies, grasshoppers, ants), as well as the seeds of aquatic plants.
Common Greenshank	Arctic circle, Siberia	Wide variety of inland and sheltered coastal wetlands – mudflats and saltmarshes. Predominantly carnivorous, diet consisting of insects and their larvae (especially beetles), crustaceans, annelids, molluscs, amphibians, small fish and occasionally rodents.
Great Knot	Northern Siberia	Coastal habitats, intertidal mudflats and sandflats. Diet consists of bivalves up to 36 mm long as well as gastropods, crustaceans (e.g. crabs and shrimps), annelid worms and echinoderms (e.g. sea cucumbers).
Greater Sand Plover	China, Mongolia, Siberia	Coastal wetlands, intertidal mudflats or sandflats. Diet contains mainly marine invertebrates such as molluscs (snails), worms and crustaceans (such as shrimps and crabs).
Grey Plover	Arctic tundras, Siberia	Coastal, intertidal mudflats, sandflats. Diet consists of marine polychaete worms, molluscs and crustaceans (e.g. crabs, sand shrimps), occasionally also taking insects (e.g. grasshoppers and beetles) or earthworms from inland areas.
Grey-tailed Tattler	Siberia	Sheltered coasts with intertidal mudflats. Described as a visual hunter of small active invertebrates in intertidal mud. Diet consists of crustaceans and other invertebrates.
Little Curlew	Siberia	Forages in dryland environments such as plains and saltmarsh. May use Eighty-mile Beach as a staging area or roosting site, feeding on nearby plains. Diet consists predominantly of adult and larval insects (e.g. grasshoppers, crickets, weevils, beetles, caterpillars, ants and termites) and spiders as well as vegetable matter including seeds.
Oriental Plover	China, Mongolia, Russia	Forages in dryland environments such as plains and saltmarsh. May use Eighty-mile Beach as a staging area or roosting site, feeding on nearby plains on insects.
Oriental Pratincole	China, India	Open country often near water, grassy flats and mudflats but primarily an aerial feeder. At Eighty-mile Beach it's occurrence in large numbers has been linked to large numbers of terrestrial insects on nearby plains. Feeding in dryland areas and roosting in the Ramsar site during the heat of the day (Sitters et al. 2004).
Red-necked Stint	Northern Siberia,	Mostly coastal sheltered inlets and estuaries with intertidal mudflats foraging on microbenthic invertebrates
Ruddy Turnstone	Northern Siberia	Intertidal areas and at Eighty-mile Beach within the intertidal zone. Diet consists of insects, crustaceans, molluscs (especially mussels), annelids, echinoderms, small fish, carrion and birds eggs.
Terek Sandpiper	Russia	Intertidal coastal, - mainly saline mudflats. Diet consists of consisting of a variety of insects, small molluscs, crustaceans (including crabs), spiders and annelid worms
Whimbrel	Siberia	Intertidal coastal mudflats, river deltas and mangroves, occasionally sandy beaches. Diet consists of crustaceans (e.g. crabs), molluscs, large polychaete worms and occasionally fish, reptiles or young birds.

The important components and processes that support migratory shorebirds at Eighty-mile Beach include invertebrates and species interactions (see 3.1.11 above).

4.5 Supports waterbird breeding

Twenty-six species of waterbird have been recorded breeding within the Eighty-mile Beach Ramsar site, mostly at Mandora Salt Marsh. The species recorded breeding at the site utilise a range of different habitats within the system (Table 17). The significant and large scale breeding recorded at the site has been initiated by large flood events, such as those that occurred in 1999 and 2000. It is thought that temporary arid zone wetlands are important at a continental scale for bird breeding (Halse et al. 2005). Although there are not statistically significant links between food resources supplied following inundation and water bird numbers, ecological theory suggests that this is part of the relationship between flooding and waterbird breeding.

Table 17: Requirements of waterbirds recorded breeding in the Eighty-mile Beach Ramsar site (adapted from Jaensch 2002; Marchant et al 1994).

Species	Breeding habitat and behaviour
Ducks and allies	
Black Swan	Nest mound built in open water, on an island, or in swamp vegetation. Requires minimum water depth of 30 – 50 cm until cygnets are independent. First flight 20 – 25 weeks.
Grey Teal	Commonly nest in a tree hollow or on the ground or in swamp vegetation. Ducklings leave the nest soon after hatching by dropping to the ground/water. First flight at approximately 8 weeks.
Hardhead	Nest well hidden in inundated dense vegetation (shrubs or reeds/ sedges). Ducklings leave nest at hatching, close association with parents until fledged.
Pacific Black Duck	Commonly nest in a tree hollow or on the ground or in swamp vegetation. Ducklings leave the nest soon after hatching by dropping to the ground. First flight at approximately 8 weeks.
Pink-eared Duck	Opportunistic breeder utilising a range of vegetation over water, including tree hollows stumps, shrubs. Commonly using old nests of other waterbirds. Ducklings leave the nest soon after hatching by dropping to the ground/water.
Plumed Whistling Duck	In tall grasslands, in or near vegetation cover, typically at the end of the wet season.
Wandering Whistling Duck	Nest in scrape in tall grasslands or shrubland on dry ground, typically at the end of the wet season.
Grebes	
Australasian Grebe	Nests in deep open water building a nest of floating aquatic vegetation Dispersed breeding pairs. Young leave nest soon after hatching, but are dependent on adults for approximately 8 weeks.
Hoary-headed Grebe	Nest on floating mound of aquatic vegetation anchored to emergent vegetation Young leave the nest soon after hatching, but have a close association with parents for some time after.
Pelicans, Cormorants and Darters	
Australian Pelican	Colonial breeder with nests usually on islands with little or no vegetation Adults can obtain food for their dependent young locally or from distant wetlands. Young leave nests to form crèche at about 3 – 4 weeks. First flight at 3 months.
Darter	Nests in horizontal branches and forks of trees (Eucalyptus, Melaleuca, Barringtonia, Guttapercha) in or over water. Breeds as dispersed pairs or in small colonies. Requires water to remain until nestlings are independent. Hatchlings leave nest after 4 weeks, first flight at approximately 8 weeks.
Herons, Ibis, Egrets and Spoonbills	
Great Egret	Nests high in a tree (freshwater swamp or mangrove) above standing water in the wet season. Invariably nests in colonies, often with other colonial species. Young fledge in approximately 5 weeks
Intermediate Egret	Nests high (up to 15 m) in a tree above standing water. Invariably nests in colonies, often with other colonial species, both in mangroves and wooded swamps
Nankeen Night Heron	Nests in a tree or shrub standing in water, often in loose association with other herons and egrets. Young fledge in 6 – 7 weeks.

Species	Breeding habitat and behaviour
Straw necked Ibis	Commonly breed in mixed colonies with other ibis, egrets and herons, Nest in shrubs over water, sometimes on islands. Fledge 4 weeks after hatching, fed for two weeks by parents after leaving nest.
White-faced Heron	Nests in tree forks and horizontal branches, not necessarily in a wetland. Little information on nesting period or fledging.
White-necked Heron	Nests in trees on near horizontal branches over water First flight 6 – 8 weeks after hatching.
Cranes, Crakes and Rails	
Eurasian Coot	Nests in or over water in vegetation (shrubs, trees, sedges) building a supported nest at the water line or a partly floating mound. Dispersed pairs or loose clusters. Young leave nest soon after hatching, but are dependent on adults for approximately 5 weeks.
Shore birds	
Black-fronted Dotterel	Nests in a scrape on the ground close to water. Young leave nest within a few days and first flight at 3 to 4 weeks
Black-winged Stilt	Nest made in a small mound in salt marsh or swamp, or in a scrape in the substrate of an island or spit. Young leave nest within 1 day and self-feed close to parents.
Masked Lapwing	Nest in short grass or bare ground. Not necessarily linked to inundation (other than as food source).
Red-capped Plover	Nests in scrape made in sand or mud Young leave nest within one day and self fed, require vegetation for cover
Red-kneed Dotterel	Nest in scrape in mud on an island, ridge or other elevated position, often in dense shrub such as samphire.
Red-necked Avocet	Nest in scrape in mud on an island, ridge or other elevated position.
Gulls and Terns	
Gull-billed Tern	Nest in a range of habitats including on top of inundated samphire and on low bare islets. Young may leave nest at 2 – 3 days old, but dependent on parents for 3 months.
Whiskered Tern	Floating nests on inundated temporary wetland systems, often over grass, sedge, ribbon weed or samphire. Young may leave the nest at a few days and fledge in only 8 – 14 days.

A conceptual model showing the relationships between components and processes that support these large waterbird breeding episodes is provided in Figure 27 and described below:

Cyclonic conditions result in increased rainfall and wide scale flooding on the clay soils. Inundation of the wetlands and surrounding soils mobilises organic carbon, nitrogen and phosphorus from vegetated debris into a dissolved mineralised form ready for uptake by bacteria and phytoplankton and the system enters a highly productive “boom” phase. High phytoplankton productivity provides food for a high abundance and diversity of macroinvertebrates, which in turn provides plentiful food for fish and waterbirds.

Inundation of the wetlands provides a diversity of habitats with different water depths and vegetation cover. Deeper water areas such as that at Walyarta provide habitat for submerged plants (e.g. Ribbon weed and Chara), whose diversity and abundance is at its highest during or following these floods. It also provides feeding habitat for deep water feeding guilds of birds such as Pelicans and Darters (see Appendix D). Areas surrounding the deeper lakes and spring are inundated to a shallower depth (e,g, Samphire and Paperbark communities). This provides shelter and/or nesting sites for waterbirds such as egrets, Gull-billed Terns and Black-winged Stilts. Shallow inundated bare areas provide habitat for wading species (both resident and migratory), which arrive to feed in the rich substrates of the floodwaters.

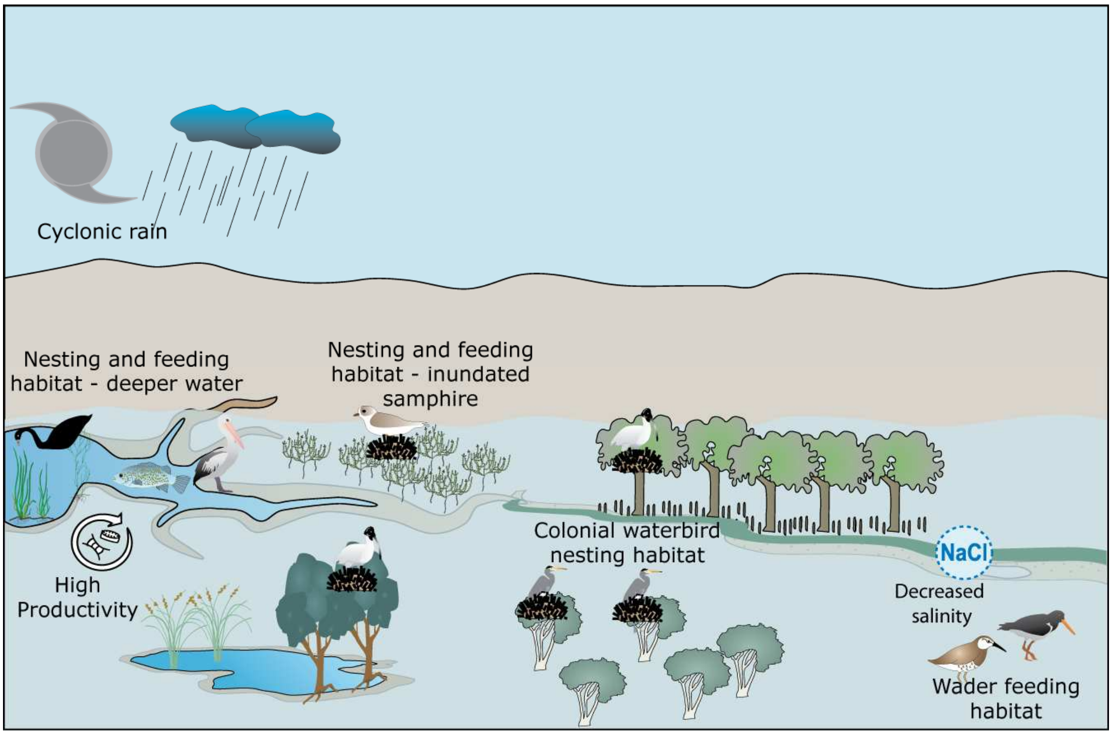

Figure 27: Conceptual model illustrating waterbird breeding habitats during flooding of Mandora Marshes.

4.6 Supports marine turtles

Eighty-mile Beach provides significant nesting (and potentially foraging habitat) for the Flatback Turtle (*Natator depressus*), which is listed as vulnerable under the EPBC Act (Spotila 2004). In addition, there is anecdotal evidence of Green Turtle (*Chelonia mydas*) occurring at the site (Pendoley 1997 and 2005).

Unlike other marine turtles, which have a global distribution, Flatback Turtles are endemic to the Australian-New Guinea continental shelf (DEWHA 2008c). Also, dissimilar to other marine turtles, which have a pelagic open ocean phase, juveniles and adult Flatback Turtles spend all of their lives in shallow (10 – 20m) turbid waters (Walker and Parmenter 2000). Their lifecycle is simple (Figure 28) following mating; females come ashore to nest in sandy beaches. The requirements of nesting beaches (although not fully understood) have been characterised by (Mortimer 1979):

- Accessibility from the sea;
- Sufficient elevation to prevent inundation of nests by tide;
- Substrate must facilitate gas exchange; and
- Sediment must be moist enough to prevent collapse of the egg chamber during construction.

In addition, it is thought that Flatback Turtles prefer low energy coastal environments for nesting (Pendoley 2005). At Eighty-mile Beach, due to the high tide levels and the predominance of fine sediments at lower tidal elevation, suitable nesting sites are along the sandy strip to the landward edge of the intertidal zone.

Flatback Turtles are carnivorous in all phases of their lifecycle. They feed in shallow, turbid waters on jellyfish and soft-bodied benthic invertebrates such as sea cucumbers, crustaceans, molluscs and sea-pens (Limpus 2004). This prey is readily available within the Ramsar site. However, despite their preference for shallow, inshore waters, they are still known to migrate great distances between feeding and breeding grounds (DEWHA 2008c).

As such it is likely that Eighty-mile Beach supports these animals for a portion of their lifecycle only.

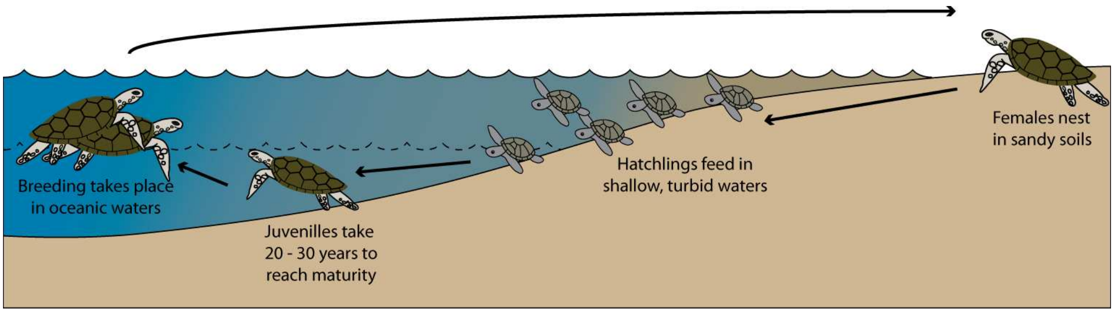

Figure 28: Lifecycle of the Flatback Turtle (adapted from Lanyon et al. 1989).

4.7 Supports tourism

Eighty-mile Beach and Mandora Marshes are both listed on the Register of the National Estate (IDs 18107 and 19827, respectively) for their natural and cultural values.

Recreation and Tourism

Eighty-mile Beach is a popular tourist destination for those travelling by road between Port Hedland and Broome. There is limited public access to the beach and no public access to Mandora Salt Marsh (although permission can be sought from pastoral station owners). The main public access to the beach is at the Eighty-mile Beach Caravan Park, which is located adjacent to the Wallal pastoral station. There is also access to the very southern edge of the site at Cape Keradruen.

Vehicles are able to access the beach adjacent to the caravan park and four-wheel driving and motorcycle riding on the beach is a popular activity. Other major recreational activities on the beach include fishing and shell collecting.

Historical sites

The Talgarno military base, immediately east of Anna Plains homestead, was significant in the post-Second World War period for the monitoring and recovery of British Blue Streak rockets, test-fired from Woomera in South Australia. A large gravel airstrip, artesian bores and a few concrete blockhouses remain (Watkins et al. 1997).

An identified shipwreck of a wooden vessel lies within the boundaries of the Ramsar site. It is not protected, but may be a historical interest (Western Australian Shipwreck Database).

4.8 Provides significant indigenous cultural values

There are at least three indigenous language groups with connections to the land contained with the Eighty-mile Beach Ramsar site the Karajarri in the north, the Nyangumarta in the south and the Ngrala who have been associated with the southern end of the beach portion of the site. A native title claim has been lodged by the Nyangumarta for 39,931 km^2, which includes Mandora Salt Marsh and a large portion of Eighty-mile Beach. The matter is before the tribunal and a decision is expected by March 2009 (Office of Native Title 2008).

Indigenous communities have a classification system for water sources that separates “top waters” (i.e. surface water) from “bottom waters” (ground water). Some of the types of water sources contained within the Eighty-mile Beach Ramsar site are described in Table 18. There are traditional stories and beliefs associated with the wetlands in the region that highlight their importance in indigenous culture.

Table 18: Indigenous terminology for water sources and wetlands in the region of the Ramsar site (Yu, 1999).

Name	Description
lirri	Soaks, in which water is dug up for drinking. Some soaks are permanent; others dry up in laja, the hot time.
jila	Permanent water sources. In some cases jila have visible surface water, for example at Pikarangu (Joanna Springs), but many require digging, which is done in a prescribed way, to access the water. A jila may be marked only by a small depression in the ground. There may be scrubby ti-tree vegetation surrounding the water source. Jila are important as rain making centres, occupied by pulany, (powerful snakes, of destructive potential who must be approached with respect and care, to avoid angering them). There are prescribed ways in which these jila should be approached, and dug out, particularly when rain making ceremonies are held.
pajalpi	The ecosystem surrounding springs. These are permanent water sources and are found on the fringes of mudflats along the coast, or inland areas
wawajangka	Fresh water seepages found in mudflats in the intertidal zone and only accessible at low tides.
pirapi	Claypans filled by rainwater and usually dry up either after the rain or as the hot time approaches. They provide water for short periods of time after rains.

Yu (1999) summarised the importance of groundwater and wetlands for the traditional owners as follows:

- Wetlands and water sources were occupation sites and as a consequence there are a large number of artefacts within close proximity including: middens, *pinka* (large baler shells) used to scoop and carry water for drinking, *wiluru* (like an oil stone) used for sharpening spear heads, axes, and flakes, and *kurtanyanu* and *jungari* (grinding stones).

- All water sites are named places (e.g. Walyarta is the indigenous name for the large western lake at Mandora Salt Marsh). There are strong cultural ties and mythological narratives associated with wetlands. For example, most of the permanent water sources are inhabited by powerful water snakes, who have the powers to produce rain, regenerate or damage the country and take people's lives. These permanent water sources are called *ngapa kunangkul* (living water).

- There is a range of personal connections between traditional owners and wetlands / water sources. Many of the senior members of the communities were born and grew up around these wetlands and so there are historical events associated with them.

5. Threats to Ecological Character

Wetlands are complex systems and an understanding of components and processes and the interactions or linkages between them is necessary to describe ecological character. Similarly threats to ecological character need to be described not just in terms of their potential effects, but the interactions between them. One mechanism for exploring these relationships is the use of stressor models (Gross 2003). The use of stressor models in ecological character descriptions has been suggested by a number of authors to describe ecological character (Phillips and Muller, 2006; Phillips et al. 2005; Hale and Butcher 2008) and to aid in the determination of limits of acceptable change (Davis and Brock 2008).

Stressors are defined as (Barrett et al. 1976):

"*physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level*"

In evaluating threats it is useful (in terms of management) to separate the driver or threatening activity from the stressor. In this manner, the causes of impacts to natural assets are made clear, which provides clarity for the management of natural resources by focussing management actions on tangible threatening activities. For example, increased nutrients may be identified as a threat for wetlands in the Mandora Salt Marsh. However, management actions cannot be targeted at increased nutrients without some understanding of why the increase is taking place. By identifying the threatening activities that could contribute to increased nutrients (e.g. cattle grazing) management actions can be targeted at these threatening activities and reduce the impact to the wetland.

By virtue of its remote location, limited diversity of adjacent land uses(pastoral and transport corridor) and limited public access, Eighty-mile Beach has fewer threats than comparable sites in southern and eastern Australia (Watkins et al. 1997; Pearson et al. 2005). However, there are still a small number of potential and actual threats that may impact on the ecological character of the Ramsar site. The stressor model (Figure 29) illustrates the major drivers (threatening activities) stressors and resulting effects in the Eighty-mile Beach Ramsar site. A description of each of these drivers is provided below, together with a brief description of more minor threats to the system.

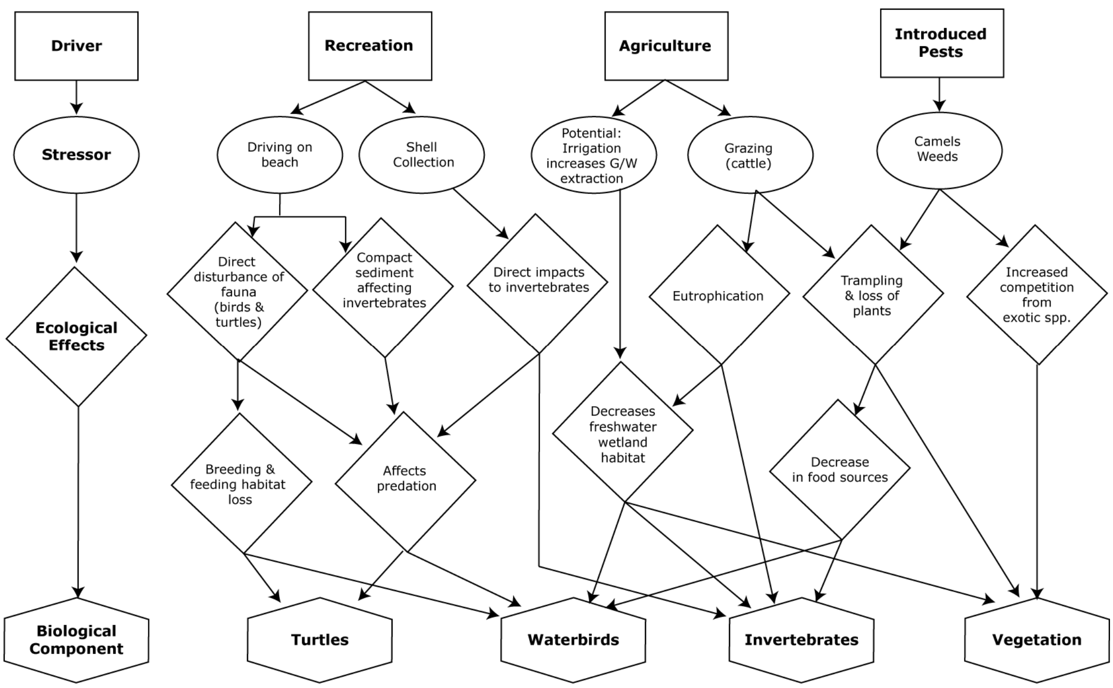

Figure 29: Stressor model of the Eighty-mile Beach Ramsar site (after Gross 2003 and Davis and Brock 2008).

5.1 Recreation

As mentioned in section 3.2 above, recreation within the Eighty-mile Beach Ramsar site is predominantly limited to the area adjacent to the Caravan Park near Wallal Downs pastoral station. However, from this access point, vehicles (4WD and motorcycles) can access the beach and travel some distance north and south. Although the impacts of this activity have not been quantified, there is anecdotal evidence of impacts to coastal sand dunes, migratory shorebirds, turtles and benthic intertidal fauna (Watkins et al. 1997).

Migratory shorebirds travel over 10,000 km from breeding grounds in the northern hemisphere to non-breeding sites in the southern hemisphere, and return north each year. It has been found that disturbance of birds when feeding or roosting may result in a significant loss of energy. This may even compromise their ability to build up enough reserves to complete the return journey to breeding grounds (DEW 2005). Driving along the beach, particularly during high tide, when roosting sites are limited, results in significant disturbance to migratory shorebirds along Eighty-mile Beach (Pearson et al. 2005) and may also impact turtle nesting sites (Chapman in prep.).

Recreational fishing is a popular activity along the beach portion of the Ramsar site. However, the impact of this on fish populations is not known. In addition, Eighty-mile Beach is renowned for the large shells prized by both recreational and commercial shell collectors. These are largely absent from the area with high numbers of tourists (Pearson et al. 2005). Collection of these shells not only results in the (perhaps inadvertent) removal of resident fauna from the site, but also reduces habitat for remaining fauna.

5.2 Agriculture

The grazing in adjacent lands to the beach portion of Eighty-mile Beach is not seen to cause any significant impacts to the site (Watkins et al. 1997). However, a large portion of the Mandora Salt Marsh site is within the Anna Plains Station lease and in 1999, access by cattle was considered to be causing detrimental impacts to the wetlands (Graham 1999). Although some wetlands have been fenced and alternative water supplies provided for cattle (DEC in prep.) others are still accessible by stock. Given the arid zone environment, stock tend to congregate around the permanent freshwater springs causing damage such as trampling vegetation, pugging soft sediments and increasing nutrient concentrations (Graham 1999).

The area within the Ramsar site that is currently under pastoral lease to Anna Plains, is subject to a 2015 exclusion and is proposed to become conservation estate managed by the Department of Environment and Conservation. As a consequence, after this time, the land will no longer be subject to domestic cattle grazing.

The Eighty-mile Beach Ramsar site lies within the La Grange groundwater subareas. Current groundwater extraction is limited and estimated to be approximately 4.8 GL/year for stock, domestic and small scale horticultural purposes (Department of Water 2008). There are plans for future horticultural developments in the region and diversification of current pastoral landuse to include a range of more water intensive practices and activities such as irrigated agriculture and aquaculture. This has the potential to affect the ecological character of the site and particularly the groundwater dependant ecosystems such as the mound springs at Mandora Salt Marsh. The La Grange groundwater subareas water management plan – allocation (Department of Water 2008) seeks to ensure that additional water extraction will be sustainable and protect existing environmental assets. One of the key actions of the plan is to identify investigations for determining ecological water requirements for groundwater dependant ecosystems such as those at Mandora Salt Marsh.

5.3 Introduced species

Camels occur at Mandora Salt Marsh in moderate numbers causing similar impacts to cattle, as described above (Graham 1999). Unlike domestic stock grazing, however, this threat will remain post 2015 when the pastoral lease expires. In addition, feral cats are a significant problem at the marsh causing impacts to waterbirds and other native animals (Graham 1999).

Foxes and feral cats have also been reported at Eighty-mile Beach and are considered a serious threat to turtle hatchlings and other native fauna (T. Sinclair; DEC pers. comm.).

Weeds do not appear to be a significant problem at the site and the percentage of exotic species in the survey at Mandora Salt Marsh was very low (Willing and Handasyde 1999). However there is anecdotal evidence of invasions of Buffel Grass (*Cenchrus ciliaris*) invading the dunes on the beach portion of the site and the wetlands at Mandora Salt Marsh during dry periods (T. Sinclair; DEC pers. comm.).

5.4 Mining leases

Data supplied by DEC Marine Policy and Planning Branch (Figure 6) indicates that much of the Eighty-mile Beach site is subject to mining tenements or exploration licenses. Although it is unlikely that mining would be permitted within the Ramsar site boundary, mining in adjoining areas has the potential to impact on the site. Of particular concern is the increase in groundwater extraction that would likely occur as a consequence of mining and the associated impacts on the groundwater dependant ecosystems at Mandora Salt Marsh.

Shipping and off-shore petroleum / gas extraction are a potential threat in the event of a major oil spill. This could be expected to have a catastrophic impact on the biota using Eighty-mile Beach, particularly if a spill were to occur in the September to April period, which would significantly impact on international migratory species such as shorebirds and marine turtles (Watkins et al. 1997). In addition, construction activities as a result of off-shore mining could result in changes to water quality and sediment transfer which may impact on the intertidal habitat and fish.

5.5 Commercial fishing

Commercial fishing has operated in the waters adjacent to the beach portion of the Ramsar site. This includes gill-netting for Blue and King Threadfin salmon and trapping of demersal fish in inshore waters (Department of Fisheries 2006). These fisheries are managed by the WA Department of Fisheries and annual catches, including a report on sustainability are released. Bycatch of sharks is mentioned as a possible impact, but is described by Department of Fisheries (2007) as having a low impact. There are also concerns about the illegal taking of sharks along the coast and in January 2009 a report of hundreds of sharks with their fins removed, dumped on Eighty-mile Beach was released to the media.

Although commercial fishing in general and the taking of sharks and rays, specifically, may be impacting the marine environments within the North-west Coast bioregion, the impact to the ecological character of the Eighty-mile Beach Ramsar site is not known. The fish communities of the site are a recognised knowledge gap, and as such they have not at this point in time been identified as a critical ecosystem component in their own right (with the exception of the role they play in the food chain and sustaining waterbird populations). Therefore, until further information about the significance of the site for fish can be established, this threat cannot be properly assessed.

The waters off Eighty-mile Beach are the most significant site for wild pearl oyster harvesting in Western Australia (Department of Fisheries 2007). Over 450,000 South Sea Pearls (*Pinctada maxima*) are hand collected each year by divers from the area adjacent to the Ramsar site. Department of Fisheries is responsible for managing and reporting on this operation as well as the pearl aquaculture facilities that are located along the coast. Their annual assessment indicates that only a small fraction of the total population is collected and that the collection and the aquaculture activities result in negligible impacts to the pearl oyster community and surrounding habitat.

5.6 Climate change

There are few published climate change predictions for north-western Australia. Hennessy et al. 2006 provides climate change prediction for 10 regions of Australia including the North Western Australia (Table 19). The figures indicate the large uncertainty around the predictions. However, it is expected that it will be slightly warmer, rainfall will be slightly less and tropical cyclones more severe. Potentially this could result in greater lengths in the dry phase of the intermittent wetlands at Mandora Salt Marsh. However this may be off-set by the increased incidence and or extent of widespread flooding following cyclonic rainfall.

Impacts at the beach portion of the site are also difficult to predict. The increase in sea level rise (between 3 and 17cm) is relatively small compared to the daily tidal regime of approximately 8m. However, changes in extent of intertidal mudflat could occur and perhaps increased inundation of the sandy margins of the beach, which could negatively impact on turtle nesting sites.

The impact of increased cyclonic activity on the beach is also unknown. Eighty-mile Beach is currently located in a cyclone intensive zone and disturbance from cyclones is a part of the ecological character of the site. However an increase in frequency or intensity of cyclones may affect the sites ability to recover between disturbance events.

Table 19: Climate change predictions for North Western Australia (Hennessy et al. 2006).

Feature	Low Global Warning Scenario		High Global Warning Scenario	
	Change	Uncertainty	Change	Uncertainty
Annual average temperature	+0.6°C	±0.2°C	+1.3°C	±0.6°C
Average sea level	+3cm		+17cm	
Annual average rainfall	-1.5%	±5%	-3.5%	±11%
Seasonal average rainfall Summer Autumn	 -1.5% 0%	 ±5% ±6.5%	 -3.5% 0%	 ±11% ±15%
Annual average potential evaporation	+1.6%	±1.1%	+3.7%	±2.5%
Tropical cyclone wind-speeds	+5%		+10%	

Regardless of the predicted impacts, climate change cannot be addressed at the site scale. However, increased knowledge of the potential impacts of climate change to this site, may lead to the identification of management activities that can be applied to help reduce impacts to ecological character.

5.7 Summary of threats

The threats considered in the previous sections have been summarised in Table 20.

Table 20:Summary of the main threats to the Eighty-mile Beach Ramsar site.

Actual or likely threat or threatening activities	Potential impact(s) to wetland components, processes and/or service	Likelihood[1]	Timing of threat
Recreation – driving on the beach	• Erosion of coastal dunes • Disturbance of migratory birds • Disturbance of turtle nesting sites	Certain	Immediate – long-term
Recreation – shell collection	• Direct removal of invertebrates and / or decrease in habitat.	Certain	Immediate – long-term
Agriculture – cattle grazing.	• Trampling of vegetation. • Erosion of wetland shores • Increased nutrients	Certain	Immediate – medium term (until 2015)
Agriculture – extraction of groundwater for irrigation.	• Altered hydrology in groundwater dependant wetlands • Water quality impacts	Medium-low	Medium-long term
Introduced species	• Weeds displacing native vegetation • Feral predators impacting on turtles and waterbirds	Certain	Immediate – long term
Mining	• Increased water extraction leading to decreased wetland habitat (breeding and feeding habitat for waterbirds) • Off-shore activities could impact on intertidal habitats	Low	Medium term
Commercial fishing	• Changes to community composition and abundance of fish communities (including sharks and rays) • Decrease in food resources for piscivorous birds	Unknown	Immediate – medium term
Climate change – increase in cyclones	• Increase in disturbance of intertidal and beach areas • Changes in inundation frequency and duration across Mandora Marshes	Medium	Long term
Climate change – sea level rise	• Changes to intertidal mudflat extent	Medium	Long term

[1] Where Certain is defined as known to occur at the site or has occurred in the past' Medium is defined as not known form the site but occurs at similar sites; and Low is defined as theoretically possible, but not recorded at this or similar sites.

6. Limits of Acceptable Change

6.1 Process for setting LAC

Limits of acceptable change are defined by Phillips (2006) as:

"…the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. This may include population measures, hectares covered by a particular wetland type, the range of certain water quality parameter, etc. The inference is that if the particular measure or parameter moves outside the 'limits of acceptable change' this may indicate a change in ecological character that could lead to a reduction or loss of the values for which the site was Ramsar listed. In most cases, change is considered in a negative context, leading to a reduction in the values for which a site was listed".

Limits of acceptable change and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that limits of acceptable change should be beyond the levels of natural variability. Setting limits in consideration with natural variability is an important, but complex concept. As indicated in Section 3 above, 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 detected with sufficient time to instigate management actions to prevent an irrevocable change in ecological character is far from straight forward. This is especially difficult to achieve in northern Australia where great natural variability of wetland conditions occurs and where our knowledge of ecosystem components and processes, let alone their variability, is far from adequate.

Hale and Butcher (2008b) considered that it is not sufficient to simply define the extreme measures of a given parameter and to set limits of acceptable change beyond those limits. What is required is a method of detecting change in pattern and setting limits that indicate a trend away 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. Added to this is the need to be able to detect changes in the key determinants of ecological character *prior* to irrevocable changes in wetland ecology.

In a perfect world with complete scientific and ecological knowledge, the tolerances or optimum conditions for the key biological components and processes for which the site was listed would form the basis for decisions on LAC. In this manner, limits could be set within these specific tolerances and ecological character maintained. However, this information is rarely available for the most well studied species, let alone the more cryptic organisms.

In the absence of this complete knowledge, a conservative approach is most often adopted. It is in this context that the precautionary principle, originally appearing in the United Nations World Charter for Nature in 1982, has been adopted. The principle states:

"*Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation*."

This principle has been applied to the setting of interim LAC for the Eighty-mile Beach Ramsar site by setting conservative interim LAC, which can be reviewed in light of monitoring and additional information.

Limits of acceptable change are to be used in the management of the system to maintain ecological character. In order to detect if the limits of acceptable change are being met monitoring against these limits needs to occur. As such it is neither practical nor desirable to set limits for every component and process within a wetland system. Accordingly, components and processes for which limits of acceptable change can be established are those:

- For which there is adequate information to form a baseline against which change can be measured;
- For which there is sufficient information to characterise natural variability;
- That are primary determinants of ecological character;
- That can be managed; and
- That can be monitored.

There are a number of critical components and processes within the Eighty-mile Beach Ramsar site that do not meet these criteria. An example of this would be the extent of intertidal mudflats. This is something that is undoubtedly critical to the ecological character of the site, but which cannot be managed. Similarly, the widespread flooding of Mandora Salt Marsh is important for waterbird breeding. However cyclonic events and inundation across this landscape is also something that cannot be managed. Even direct measures of ecological character such as numbers of migratory shorebirds pose problems in the setting of LAC. Variability in counts and shorebird numbers at any point in time is high (Rogers et al. 2006) and any changes in populations may be more related to activities at other locations within the flyway, than at this particular Ramsar site.

This approach sets short-term limits of acceptable change (with a corresponding intensive monitoring program) on the key abiotic factors within the system. Abiotic components and processes impose a strong influence on the biotic components of wetland systems and are often considered the primary control factors (Mitsch and Gosselink 2000; Batzer et al. 2006). These are usually the easiest to monitor and change can be detected in the short term (within 1 or 2 years). The approach adopted with respect to abiotic components, follows the ANZECC (2000) guidelines for water quality in freshwater and marine systems. A set of guideline or trigger values[4] have been established for key components, based on site specific information, where possible, and using general values for Australian ecosystems in situations where there is insufficient data for the local system. In the case of the Eighty-mile Beach Ramsar site there are few existing limits and guideline values.

The second set of parameters for which limits of acceptable change can be set, is the primary responses to the abiotic components and processes. This includes primary production, and physical / biological habitat (mudflats, mangroves, paperbarks, samphire and wetland vegetation) extent and condition. Once again the focus is on the identified critical components and processes. Limits are set against baseline data and the habitat requirements or tolerances of key fauna. The limits of acceptable change for these parameters are set at time scales reflecting the different response times of the flora communities. For example, phytoplankton, which can respond rapidly, would have shorter-term limits of acceptable change than woody vegetation communities.

Finally the key biological components are considered. For most of these quantitative limits of acceptable change are difficult to determine, either due to a lack of baseline data, inherent high levels of natural variability, or in the case of many waterbird species, factors outside the site affecting their distribution and abundance observed at the site. Maintaining the conditions of the abiotic environment and the primary producers should protect these faunal components and processes. However, as stated above, limits of acceptable change have been set without complete knowledge or understanding of the system. As such, it is important that some of the assumptions made in setting limits for abiotic components and flora are tested and that the linkages between biotic and abiotic factors described in Section 4 above are sound. For this reason, although strict "limits of acceptable change" cannot be set for these components, they form an important element of the monitoring program. Outcomes of the monitoring program are to be reviewed for broad trends and the information used to review and refine the limits of acceptable change for the site (see Section 9).

4 Note that the concept of trigger values as described in ANZECC (2000) is that exceedence "triggers" action; be that increased monitoring and investigation or management actions. The management of the system is beyond the scope of the ECD, but it is recommended that this approach to monitoring and management be adopted in the management plan for the site.

6.2 LAC for the Eighty-mile Beach Ramsar site

Using the method described above, LAC and interim LAC have been set for the Eighty-mile Beach Ramsar site (Table 21). However, it should be noted that for many of the critical components and processes there is limited quantitative data on which to set limits. In these instances, qualitative interim LAC have been recommended, but these will require careful review with increased information gained from future monitoring.

Table 21: Proposed LAC for the beach portion of the Eighty-mile Beach Ramsar site.

Component/Process	Baseline/Supporting Evidence	Limit of Acceptable Change
Abiotic Components and Processes		
Hydrology	Macro-tidal regime that provides the significant habitat and productivity required to maintain the ecological character of the site	Unrestricted tides along the entire length of the beach site not impacted or modified by any artificial structure.
Primary Responses		
Primary production	Although this is undoubtedly a critical process within the inter-tidal mudflats, there is no quantitative information upon which a limit can be set.	Data deficient – baseline must be established before limits can be set.
Key Communities		
Invertebrates	There is no indication of biomass of invertebrates at Eighty-mile Beach, and the species list (abundance and number of taxa) is limited to data collected during one expedition only in 1999. Although invertebrates are undoubtedly important to the ecological character of the site and responsible for supporting the large number of shorebirds that occur on the beach, there is insufficient data upon which to base quantitative limits. Data from nearby sites (e.g. Roebuck Bay) indicates that there may be cyclic patterns in species compositions and abundance in tropical systems which can lead to high natural variability (de Goeij et al. 2008),	Data deficient – baseline must be established before limits can be set. Interim limit – biomass within 80 – 120th percentiles.
Fish	There is no published information on fish use of the site and no quantitative information on which to base a limit.	Data deficient – baseline must be established before limits can be set.
Waterbirds	Consistently > 200,000 shorebirds during summer and > 20,000 waterbirds during winter in the area 0 – 60 km south of Anna Plains (D. Rogers unpublished data). In an attempt to incorporate the level of variability in shorebird counts, limits are proposed based on mean ± 1 standard deviation.	Shorebird numbers > 200,000 during summer and > 20,000 during winter in the area 0 – 60 km south of Anna Plains
	Regularly supports > 1% of the flyway population of 20 species of waterbird . Limits have been proposed for shorebirds within this group that are consistently present in numbers sufficient to calculate practical statistics. In an attempt to incorporate the level of variability in shorebird counts, limits are proposed based on mean ± 1 standard deviation.	Summer counts in the area 0 – 60km south of Anna Plains: Bar-tailed Godwits > 35,000 Great Knot > 55,000 Greater Sand Plover > 23,000 Red-necked Stint > 18,000 Terek Sandpiper > 4,800
Flatback Turtles	Quantitative data on turtle nesting is very limited and is based predominantly on sample effort. There is no measure of variability of nest disturbance or of hatching success.	Data deficient – baseline must be established before limits can be set.

Table 22: Proposed LAC for Mandora Salt Marsh.

Component/Process	Baseline/Supporting Evidence	Limit of Acceptable Change
Abiotic Components and Processes		
Hydrology	Periodic wide scale flooding of the Mandora Salt Marsh and surrounding area following heavy rainfall.	Extent and duration of inundation to be maintained, with no additional barriers to flow or extraction of floodwaters.
	Mound springs and Salt Creek at Mandora Salt Marsh are maintained by groundwater flow. However, this is yet to be quantified.	Data deficient – baseline must be established before limits can be set. However a conservative limit of no decrease in groundwater discharge to the site should be established.
Nutrients	Range of nutrient concentrations recorded at wetlands in Mandora Salt Marsh. However, water quality data are from single samples collected during wide scale flooding (Storey et al. 1999).	Data deficient – baseline must be established before limits can be set.
pH	Wetlands at Mandora Salt Marsh are predominantly alkaline (Storey et al. 1999. However, water quality data are from single samples collected during wide scale flooding (Storey et al. 1999).	Data deficient – baseline must be established before limits can be set.
Salinity	Salt Creek salinity 35 – 50 ppt (storey et al. 1999), based on one sampling event only. Grey mangrove is tolerant of high salinity (up to 50 ppt), but with stunted growth (as observed at Salt Creek)	Data deficient – baseline must be established before limits can be set. Interim limit - Salinity in Salt Creek to be < 40 ppt during the wet season and < 55 ppt during the dry
	Mound springs varied in salinity from 0.5 to 6 ppt, based on single samples collected in 1999 (Storey unpublished). Salinity tolerances of some of the common plants associated with mound springs are as follows: Eleocharis sp - < 7 ppt (James and Hart 1993) Dragon Tree - < 10 ppt (Ismail 1998) Cumbungi - < 6 ppt (Morris 1998)	Data deficient – baseline must be established before limits can be set. Interim limit - salinity < 6 ppt
Primary Responses		
Mangrove	Grey Mangrove lines the banks of Salt Creek and although stunted still actively regenerates. However, the extent has not been mapped.	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent Evidence of regeneration present (after large flood events)
Paperbark	Thickets of low *Melaleuca alsophila* in clay soils at Mandora Salt Marsh. Extent and condition not known.	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent of paperbark communities within the Ramsar site
Samphire	Samphire dominated by *Tecticornia* surrounds the shores of Lake Walyarta and East Lake. Extent and condition not known.	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent of samphire communities within the Ramsar site
Freshwater aquatic vegetation	When inundated, freshwater, submerged aquatic vegetation has been recorded at Lake Walyarta. However, one-off observation following extensive rainfall and widespread inundation	Data deficient – baseline must be established before limits can be set.

Component/Process	Baseline/Supporting Evidence	Limit of Acceptable Change
	Complex vegetation communities at mound springs. Extent, composition and condition not known.	Data deficient – baseline must be established before limits can be set. Interim limit – no decrease in extent or change in community composition of spring vegetation communities within the Ramsar site
Key Communities		
Waterbirds	Waterbird usage at Mandora Salt Marsh is linked to episodic inundation events following cyclonic activity. The data available is from a single such inundation event in 1999 / 2000. There is no data upon which to assess variability with respect to species composition, abundance or breeding activity.	Data deficient – baseline must be established before limits can be set.

7. Current Ecological Character and Changes Since Designation

The Eight-mile Beach Ramsar site was first listed under the Ramsar Convention as a wetland of international importance in 1990. At this point in time, any impacts from landuse (cattle grazing at Mandora Salt Marsh and recreational access at the beach) were already in effect. The site is considered to be predominantly in good condition, with relatively low levels of impacts. There is no evidence of any change in ecological character at this site since listing.

8. Knowledge Gaps

Throughout the Ecological Character Description for the Eighty-mile Beach Ramsar site, mention has been made of knowledge gaps and data deficiencies for the system. Scientists and natural resource managers have requirements for knowledge and a desire to fully understand complex wetland systems. There is much still to be learned about the interactions between components and processes in this and other wetlands. In addition, for the Eighty-mile Beach Ramsar site there are a number of key attributes that have yet to be fully described or for which data is limited to isolated surveys. While it is tempting to produce an infinite list of research and monitoring needs for this wetland system, it is important to focus on the purpose of an ecological character description and identify and prioritise knowledge gaps that are important for describing and maintaining the ecological character of the system.

The key knowledge gaps that are required to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met are outlined in Table 23, together with a brief description of the action required to address these gaps.

Table 23: Knowledge Gaps for the Eighty-mile Beach Ramsar site

Component/Process	Knowledge Gap	Recommended Action
Hydrology	The hydrology of the Mandora Salt Marsh is poorly understood. The relative importance of surface water and freshwater flows is largely unknown, as are the environmental water requirements of these systems,	Investigations into the hydrogeology of the Mandora Salt Marsh and the environmental water requirements of the groundwater dependant ecosystems
	The potential groundwater connection to the intertidal mudflats at Eighty-mile Beach and the potential importance for these "freshwater" discharges to productivity at the site.	Investigation into the occurrence and ecological significance of groundwater discharges to the intertidal zone at Eighty-mile Beach
Water Quality	While water quality is arguably not an issue for the beach portion of the site, it is likely to be a significant ecological component of the Mandora Salt Marshes, particularly in the permanent wetlands such as the mound springs. Data is limited to one off sampling events in 1999 and 2008.	Annual water quality monitoring (salinity, pH, nutrients) at a selection of permanent wetlands within the Mandora Salt Marsh
Primary productivity and nutrient cycling	Primary productivity is an important driving factor in wetland ecosystems. However, there is no information on nutrient cycling or primary production within the intertidal mudflats at Eighty-mile Beach.	Investigation of sediment cores (chlorophyll *a*, nutrients) from Eighty-mile Beach to set a baseline against which change can be assessed.
Vegetation communities	With the exception of the extent of mangroves, there is no quantitative information on the extent and composition of vegetation communities within the Ramsar site	Mapping of extent of vegetation (remote sensing) and community composition (ground surveys) to set a baseline against which change can be assessed.
Fish, sharks and rays	Little is known about the fish at the Ramsar site. There is anecdotal evidence of a unique species of fish in Salt Creek and of ray and shark activities within the beach site during high tide	Annual fish surveys
Waterbirds	The abundance and species of waterbirds that regularly use Mandora Salt Marsh. Current knowledge is based on two surveys 1999 and 2000.	Annual waterbird surveys conducted at Eighty-mile Beach to be expanded to include Mandora Salt Marsh.
Marine Turtles	There is evidence that Eighty-mile Beach is a significant rookery for Flatback Turtles and that Green Turtles may also nest on the beach. However there is no quantitative data to support	Annual surveys of turtle nesting to set a baseline against which change can be assessed.

Component/Process	Knowledge Gap	Recommended Action
	this or to measure change against.	
Recreation numbers and potential impacts	Although the majority of the Ramsar site is largely inaccessible to the public, the area adjacent to the Eighty-mile Beach Caravan Park is a popular tourist destination and driving is permitted on the beach. This area is frequented by shorebirds and has the highest density of turtle nests. The numbers of visitors and their potential impact to the ecological character of the site are not known. More information is required in order to establish proper management initiatives.	Annual surveys of recreational visitors to the site, the areas visited and the activities that they undertake.

9. Monitoring needs

As a signatory to the Ramsar Convention, Australia has made a commitment to protect the ecological character of its Wetlands of International Importance. Under Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999* a person must not take an action that has, will have or is likely to have a significant impact on the ecological character of a declared Ramsar wetland. While there is no explicit requirement for monitoring the site, in order to ascertain if the ecological character of the wetland site is being protected a monitoring program is required.

While there may be existing monitoring programs in place for components within the Eighty-mile Beach Ramsar site, there is no over-arching monitoring program designed to detect and manage changes to the ecological character of the wetlands. An interim management plan is currently in preparation for the beach portion of the system, which will act as an overarching guide for decision makers and stakeholders in the region. This will include monitoring actions for part of the site.

A comprehensive monitoring program is beyond the scope of this ecological character description. What is provided is an identification of monitoring needs required to both set baselines for key components and processes and to assess against limits of acceptable change.

9.1 Monitoring of Ecological Character

The recommended monitoring to meet the obligations under Ramsar and the EPBC Act (1999) with respect to the Eighty-mile Beach Ramsar site are provided in Table 24. There are few current programs in place and so much of this represents establishing new monitoring initiatives. In recognition that there will be limited funds for monitoring, a priority has been assigned to each component.

Detailed monitoring design is essential to ensure that appropriate and useful data is collected. Although a detailed monitoring program design for each of these components is beyond the scope of an ecological character description, it is recommended that the Ramsar framework for monitoring wetlands be used as a guide in developing monitoring programs (Text Box 2).

Finlayson (2001) describes the difference between monitoring and surveillance:

"Wetland Monitoring: Collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management. (Note that the collection of time-series information that is not hypothesis-driven from wetland assessment should be termed surveillance rather than monitoring.)"

While there has been a number of scientific research projects and some ad hoc surveys, there has been little "monitoring" (as defined above) conducted in the Eighty-mile Beach Ramsar site. The exceptions to this are shorebirds on the beach. The need for co-ordinated, purpose designed, objective driven monitoring of ecological character in the Eighty-mile Beach system must be emphasised.

Problems/issues - State clearly and unambiguously - State the known extent and most likely cause - Identify the baseline or reference situation

Objective - Provides the basis for collecting the information - Must be attainable and achievable within a reasonable time period

Hypothesis - Assumption against which the objectives are tested - Underpins the objective and can be tested

Methods & variables - Specific for the problem and provide the information to test the hypothesis - Able to detect the presence, and assess the significance, of any change - Identify or clarify the cause of the change

Feasibility / cost - Determine whether or not monitoring can be done regularly effectiveness and continually - Assess factors that influence the sampling programme: availability of trained personnel; access to sampling sites; availability and reliability of specialist equipment; means of analysing and interpreting the data; usefulness of the data and information; means of reporting in a timely manner - Determine if the costs of data acquisition and analysis are within the existing budget

Pilot study - Time to test and fine-tune the method and specialist equipment - Assess the training needs for staff involved - Confirm the means of analysing and interpreting the data

Sampling - Staff should be trained in all sampling methods - All samples should be documented: date and location; names of staff; sampling methods; equipment used; means of storage or transport; all changes to the methods - Samples should be processed within a timely period and all data documented: date and location; names of staff; processing methods; equipment used; and all changes to the protocols - Sampling and data analysis should be done by rigorous and tested methods

Analyses - The analyses should be documented: date and location (or boundaries of sampling area), names of analytical staff; methods used; equipment used; data storage methods

Reporting - Interpret and report all results in a timely and cost effective manner - The report should be concise and indicate whether or not the hypothesis has been supported - The report should contain recommendations for management action, including further monitoring

Text Box 2: Ramsar framework for monitoring wetlands (Annexure to Resolution VI.1:http://www.ramsar.org/res/key_res_vi.1.htm)

Table 24: Monitoring needs for the Eighty-mile Beach Ramsar site

Component/Process	Purpose	Indicator	Locations	Frequency	Priority
Hydrology	Establishment of baseline and then detection of change	Extent and duration of inundation	Mandora Salt Marsh	Seasonal	Moderate
	Establishment of baseline and then detection of change	Depth to groundwater	Bores (wells) with Mandora Salt Marsh	Seasonal	Moderate
Water Quality	Establishment of baseline and then detection of change	Nutrients (total nitrogen, ammonium, nitrate-nitrite, total phosphorus, orthophosphate); salinity, dissolved oxygen, pH, colour	Mandora Salt Marsh – permanent wetlands	Annual	High
Vegetation - extent	Establishment of baseline and then detection of change	Extent of broad vegetation types (remote sensing)	Entire Ramsar site	Every 5 years	High
Vegetation -community composition	Establishment of baseline and then detection of change	Community composition of vegetation types (field surveys)	Entire Ramsar site	Every 5 years	High
Weeds	Determination of impact	Location, extent, species	Mandora Salt Marsh	Annual	Low
Macroinvertebrates	Establishment of baseline and then detection of change	Abundance, community composition	Mudflats	Annual	Moderate
Fish	Establishment of baseline and then detection of change	Community composition and abundance of fish in inland wetlands	Entire Ramsar site	Annual	Moderate
Waterbirds	Detection of change (beach) Establishment of baseline and then detection of change (Mandora Salt Marsh	Counts and species identifications, breeding observations	Entire Ramsar site	Seasonal	High
Turtles	Establishment of baseline and then detection of change	Species identification and nesting records	Beach	Annual	High
Recreation use	Establishment of baseline and then detection of change	Location and number of vehicles	Beach	Monthly from March to October	High

10. Communication and Education Messages

Under the Ramsar Convention a Program of Communication, Education and Public Awareness 2003-2008 was established to help raise awareness of wetland values and functions. The program calls for coordinated international and national wetland education, public awareness and communication. In response to this, Australia has established the Wetland Communication, Education and Public Awareness (CEPA) National Action Plan 2001-2005. Australia's National Action Plan provides an umbrella for coordinated activities across Australia. It is an evolving plan that will document and provide guidance towards the collaboration of effectively delivered CEPA activities.

A management plan for the marine portion of the Eighty-mile Beach Ramsar site is currently under development. This will include consideration of CEPA activities and a range of communication and education messages and actions. Following on from the identified threats to the ecological character of the Eighty-mile Beach Ramsar site (see Section 6, above), there are a number of communication and education messages that could be given priority. These include:

- Effect of disturbance on migratory birds – the importance of energy conservation for migratory birds and steps the community can take to minimise shorebird disturbance by walking and recreational vehicles;

- The ecological effects of shell collecting, including flow on effects to migratory birds and other animals;

- The importance of the site for nesting turtles and steps the community can take to minimise disturbance to nesting sites; and

- The cultural significance of the site and the indigenous associations with wetlands in the Ramsar site.

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Appendix A: Methods

A.1 Approach

The method for compiling this ECD comprised of the following tasks:

Project Inception:
Consultant team leader Jennifer Hale met with the Western Australian Department of Environment and Conservation (DEC) project manager to confirm the scope of works and timelines as well as identifying relevant stakeholders that would be consulted.

Task 1: Review and compilation of available data
The consultant team undertook a thorough desktop review of existing information on the ecology of Eighty-mile Beach. This task also involved the consultant team leader travelling to the site to gather local data and information sources. The consultant met with the DEC marine planning staff that are drafting the marine management plan which includes part of the Ramsar site to align the ECD process with the management planning process.

Task 2: Stakeholder engagement and consultation
DEC formed a Technical Advisory Group (TAG) specifically for the Eighty-mile Beach Ramsar site ECD. This group was comprised of the following stakeholders with an interest in the ECD and management planning process:

Sharon Ferguson – Department of Environment and Conservation Kimberley
Matt Fossey – Department of Environment and Conservation Marine Policy & Planning
Sarah Greenwood – Department of Environment and Conservation Planning & Estate
Chris Hassell – Community representative
Jennifer Higbid – Department of Environment and Conservation Wetlands Section
Leanne Thompson – Department of Environment and Conservation Marine Policy & Planning
John Lloyd – Department of Environment and Conservation Marine Policy & Planning
Fiona Lynn – Department of Water
Grant Pearson – Bennelongia Pty. Ltd.
Danny Rogers – Birds Australia
Troy Sinclair – Department of Environment and Conservation Kimberley
Gareth Watkins – Department of Environment and Conservation Wetlands Section
Judy Zuideveld – Department of Environment and Conservation Marine Policy & Planning

The TAG met in Perth on the February 23, 2009 to discuss the components, processes, services and benefits of the Eighty-mile Beach Ramsar site. In addition, members of the TAG provided written comments on drafts of the ECD.

Task 3: Development of a draft ECD
Consistent with the national guidance and framework (2008) the following steps were undertaken to describe the ecological character of the Ord River Floodplain Ramsar site.

Steps from the national draft (2008) framework	Activities
1. Document introductory details	Prepare basic details: site details, purpose, legislation
2. Describe the site	Based on the Ramsar RIS and the above literature review describe the site in terms of: location, land tenure, Ramsar criteria, wetland types (using Ramsar classification).
3. Identify and describe the critical components, processes and services	Identify all possible components, services and benefits. Identify and describe the critical components, services and benefits responsible for determining ecological character
4. Develop a conceptual model of the system.	Two types of models were developed for the system: A series of control models that describe important aspects of the ecology of the site, including feedback loops. Aiding in the understanding of the system and its ecological functions. A stressor model that highlights the threats and their effects on ecological components and processes. Aiding in understanding management of the system.
5. Set Limits of Acceptable	For each critical component process and service, establish the

Steps from the national draft (2008) framework	Activities
Change	limits of acceptable change.
6. Identify threats to the site	This process identified both actual and potential future threats to the ecological character of the wetland system.
7. Describe changes to ecological character since the time of listing	This section describes in quantitative terms (where possible) changes to the wetlands since the initial listing in 1990
8. Summarise knowledge gaps	This identifies the knowledge gaps for not only the ecological character description, but also for its management.
9. Identify site monitoring needs	Based on the identification of knowledge gaps above, recommendations for future monitoring are described.
10. Identify communication, education and public awareness messages	Following the identification of threats, management actions and incorporating stakeholder comments, a general description of the broad communication / education messages are described.

Task 4: Revision of the Ramsar Information Sheet (RIS)
The information collated during Task 1, together with the draft Ecological Character Description was used to produce a revised RIS in the standard format provided by Ramsar.

Task 5 Finalising the ECD and RIS
The draft ECD and RIS were submitted to DEC, the TAG and the Department of Environment, Water Heritage and the Arts (DEWHA) for review. Comments from agencies and stakeholders were incorporated to produce revised ECD and RIS documents. DEC contributed to the updating of the boundary information for the RIS and finalised both documents.

A.2 Consultant Team

Jennifer Hale (team leader)
Jennifer has over eighteen years experience in the water industry having started her career with the State Water Laboratory in Victoria. Jennifer is an aquatic ecologist with expertise in wetland, riverine and estuarine systems. She is qualified with a Bachelor of Science (Natural Resource Management) and a Masters of Business Administration. Jennifer is an aquatic ecologist with specialist fields of expertise including phytoplankton dynamics, aquatic macrophytes, sediment water interactions and nutrient dynamics. She has a broad understanding of the ecology of aquatic macrophytes, fish, waterbirds, macroinvertebrates and floodplain vegetation as well as geomorphic processes. She has a solid knowledge of the development of ecological character descriptions and has been involved in the development of ECDs for the Ord River Floodplain, Peel-Yalgorup, Piccaninnie Ponds, Central Murray Forests, the Coorong, Lake MacLeod, Elizabeth and Middleton Reefs, Ashmore Reef and the Coral Seas Ramsar sites. Jennifer also has a solid knowledge and understanding of estuarine systems.

Roger Jaensch
Roger Jaensch is a waterbird expert of national and international repute. He has extensive on-ground experience on a range of wetlands across Australia, including Eighty-mile Beach. He has been working in the field of wetlands and waterbirds for over 25 years and has extensive experience in the description, management and nomination of Ramsar sites. He is currently a senior program officer with Wetlands International, and has held high level positions with Birds Australia and the Asian Wetland Bureau here and overseas. He has not only an understanding of the site and extensive knowledge on waterbirds, but also a sound background in the Ramsar Convention and its application to the management of Australian Wetlands.

Doug Watkins
Doug has over 25 years experience working as a wetland ecologist in Australia and Asia. For the past decade Doug has worked full time with Wetlands International from the Oceania Office based in Canberra, Australia. He is the Manager for Wetlands International – Oceania and oversees the work of two staff in Brisbane and two in Fiji. His work has concentrated on the development and implementation of a collaborative framework for the conservation of migratory waterbirds and their habitats through-out the East Asian – Australasian Flyway. This collaboration has included activities across 16 countries involving national governments,

Conventions, non-government organisations, site managers and technical experts. In addition to his broad international experience, Doug is familiar with the Eighty-mile Beach Ramsar site and has been involved with the nomination of the site for listing as a Ramsar site as well as more recent research.

Halina Kobryn

Dr Halina Kobryn has over fifteen years of experience in applications of GIS and remote sensing in environmental applications. She is a GIS and remote sensing expert, specialising in natural resource assessment. Dr Kobryn has a BSc in Physical Geography and Cartography, Graduate Diploma in Surveying and Mapping and a PhD which explored impacts of stormwater on an urban wetland and explored GIS methods for such applications. She has worked at a university as a lecturer for over 15 years and taught many subjects including GIS, remote sensing, environmental monitoring and management of aquatic systems. She has developed the first course in Australia (at a graduate level) on Environmental Monitoring. She has been involved in many research and consulting projects and her cv outlines the breadth of her expertise. She has also supervised over 20 research students (honours, Masters and PhD). She has worked in Indonesia, Malaysia (Sarawak) and East Timor on projects related to water quality and river health.

Appendix B: Flora

Abutilon lepidum	*Eragrostis speciosa*	*Minuria integerrima*
Abutilon macrum	*Eriachne aristidea*	*Muellerolimon salicorniaceum*
Acacia adoxa	*Eriachne obtusa*	*Muntingia calabura*
Acacia ampliceps	*Eriachne sp.*	*Neobassia astrocarpa*
Acacia ampliceps x bivenosa	*Eucalyptus victrix*	*Newcastelia cladotricha*
Acacia anaticeps	*Euphorbia australis*	*Nicotiana heterantha*
Acacia ancistrocarpa	*Euphorbia myrtoides*	*Otion simplicifolium*
Acacia ancistrocarpa x drepanocarpa	*Euphorbia sp.*	*Owenia reticulata*
Acacia colei	*Fimbristylis caespitosa*	*Paractaenum refractum*
Acacia drepanocarpa	*Fimbristylis ferruginea*	*Paspalum vaginatum*
Acacia glaucocaesia	*Fimbristylis tristachya*	*Phyla nodiflora*
Acacia melleodora	*Flaveria australasica*	*Pluchea ferdinandi-muelleri*
Acacia monticola	*Frankenia ambita*	*Pluchea rubelliflora*
Acacia sabulosa	*Frankenia sp.*	*Pluchea sp. B*
Acacia sp. (Kimberley region)	*Fuirena incrassata*	*Polymeria ambigua*
Acacia sp. Ripon Hills	*Gardenia pyriformis*	*Ptilotus astrolasius*
Acacia stellaticeps	*Genus sp.*	*Ptilotus lanatus*
Acacia tumida	*Glinus oppositifolius*	*Ptilotus polystachyus*
Acrostichum speciosum	*Goodenia armitiana*	*Samolus sp. Millstream*
Adriana urticoides	*Gossypium australe*	*Santalum lanceolatum*
Aenictophyton reconditum	*Grevillea pyramidalis*	*Scaevola amblyanthera*
Aerva javanica	*Grevillea stenobotrya*	*Scaevola parvifolia*
Aristida contorta	*Grevillea wickhamii*	*Scaevola spinescens*
Aristida holathera	*Gymnanthera cunninghamii*	*Schoenoplectus subulatus*
Aristida sp.	*Gyrostemon tepperi*	*Schoenus falcatus*
Avicennia marina	*Hakea chordophylla*	*Senna glutinosa*
Bergia ammannioides	*Halgania solanacea*	*Senna notabilis*
Bonamia pannosa	*Halosarcia auriculata*	*Sesbania formosa*
Bulbostylis barbata	*Halosarcia auriculata*	*Sesuvium portulacastrum*
Calytrix carinata	*Halosarcia halocnemoides*	*Sida arenicola*
Cassytha filiformis	*Halosarcia indica*	*Sida fibulifera*
Cenchrus ciliaris	*Halosarcia sp.*	*Sida sp. B*
Centaurium spicatum	*Heliotropium curassavicum*	*Solanum esuriale*
Cleome uncifera	*Heliotropium glanduliferum*	*Solanum oligandrum*
Corchorus incanus	*Heliotropium sp.*	*Solanum sp.*
Corchorus sidoides	*Heliotropium transforme*	*Sorghum stipoideum*
Corchorus sp.	*Hemichroa diandra*	*Spermacoce occidentalis*
Corchorus walcottii	*Hibiscus apodus*	*Sporobolus virginicus*
Corymbia zygophylla	*Hibiscus leptocladus*	*Stemodia grossa*
Cressa australis	*Hibiscus pentaphyllus*	*Stemodia viscosa*
Crotalaria cunninghamii	*Indigofera haplophylla*	*Stigmina sp.*
Crotalaria ramosissima	*Indigofera linnaei*	*Streptoglossa bubakii*
Cucumis sp.	*Indigofera monophylla*	*Stylidium desertorum*
Cullen corallum	*Jacksonia aculeata*	*Stylobasium spathulatum*
Cullen pustulatum	*Keraudrenia nephrosperma*	*Tecticornia auriculata*
Cyanostegia cyanocalyx	*Lawrencia glomerata*	*Tephrosia rosea*
Cynanchum carnosum	*Lawrencia sp.*	*Tephrosia sp. D*
Cyperus conicus	*Lawrencia viridigrisea*	*Tephrosia uniovulata*
Cyperus squarrosus	*Leptochloa fusca*	*Terminalia cunninghamii*
Cyperus vaginatus	*Melaleuca alsophila*	*Timonius timon*
Dampiera cinerea	*Melaleuca argentea*	*Tinospora smilacina*
Digitaria brownii	*Melaleuca glomerata*	*Trianthema pilosa*
Dolichandrone heterophylla	*Melaleuca lasiandra*	*Trianthema triquetra*
Duboisia hopwoodii	*Melaleuca leucadendra*	*Trianthema turgidifolia*
Ehretia saligna	*Melaleuca nervosa*	*Tribulopis sp.*
Enneapogon robustissimus	*Melaleuca sp.*	*Velleia panduriformis*
Eragrostis cumingii	*Melaleuca viridiflora*	*Xerochloa imberbis*
Eragrostis eriopoda	*Melhania oblongifolia*	*Yakirra australiensis*
Eragrostis falcata	*Mimulus uvedaliae*	*Zygophyllum compressum*

Appendix C: Invertebrates

Taxon list of intertidal invertebrate macrofauna found in the quantitative samples from Eighty-mile Beach 1999. (adapted from ANABIM 1999). Chironomidae (1 specimen referred to as mosquito larvae) and three fish taxa were excluded from the table below as not being considered part of the intertidal invertebrate microfauna. Family names in parenthesis are the valid name according to ITIS http://www.itis.gov/index.html accessed in December 2008. Information on feeding modes for polychaetes sourced from http://researchdata.museum.vic.gov.au/polychaetes/index.htm accessed December 2008.

Phylum	Class	Order	Family	Number taxa	Feeding modes/comments
Mollusca	Bivalvia	Veneroida	Galeommatidae (clams)	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Montacutidae (Lasaeidae)(clams)	1	Suspension feeders
Mollusca	Bivalvia	Nuculoida	Nuculidae (clams)	1	Deposit feeders
Mollusca	Bivalvia	Mytiloida	Mytilidae (mussels)	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Lucinidae	2	Suspension feeders on phytoplankton. Endosymbiotic with sulphide oxidizing bacteria
Mollusca	Bivalvia	Veneroida	Mactridae (clams – trough shells or duck clams)	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Kelliidae (Lasaeidae)	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Cultellidae (Pharidae)	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Tellinidae	4	Suspension feeders
Mollusca	Bivalvia	Veneroida	Psammobiidae (sunset clams)	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Semelidae	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Mesodesmatidae	1	Suspension feeders
Mollusca	Bivalvia	Veneroida	Donacidae (bean clams or wedge clams)	1	Suspension feeders - important in coastal food chains. Sensitive to coastal industry such as dam building and dredging
Mollusca	Bivalvia	Veneroida	Solenidae	1	Suspension feeders
Mollusca	Gastropoda	Neotaenioglossa	Epitoniidae (Wentletraps, or staircase, ladder shells)	1	Predators, parasitic of sea anemones
Mollusca	Gastropoda	Neotaenioglossa	Eulimidae	1	Predators, ectoparasites on echinoderms
Mollusca	Gastropoda	Neotaenioglossa	Naticidae (Moon snails)	2	Predators
Mollusca	Gastropoda	Neogastropoda	Columbellidae (Dove snails)	1	Predators – active
Mollusca	Gastropoda	Neogastropoda	Nassariidae (Nassa mud snails, dogwhelk, large Ingrid	1	Predators and scavengers – active. Observed feeding on bird droppings at Eighty-mile Beach.

			eating snail)		
Mollusca	Gastropoda	Neogastropoda	Marginellidae (Margin snails)	1	Predators and scavengers
Mollusca	Gastropoda	Cephalaspidea	Ringiculidae	1	Predators
Mollusca	Gastropoda	Heterostropha	Acteonidae (Barrel bubble snails)	1	Predators on polychaete worms
Mollusca	Gastropoda	Heterostropha	Pyramidellidae (pyramid shells)	3	Predators - ectoparasitic
Mollusca	Scaphopoda (tusk shells)	Dentaliida	Dentalidae (Laevidentaliidae)	1	Deposit feeders - mainly found in the subtidal not intertidal
Mollusca	Scaphopoda (tusk shells)	Galilida	Cadulidae (Gadilidae)	1	Deposit feeders
Nemertini (ribbon worms)				1	Predators and scavengers
Phoronida (horseshoe worms)				1	Suspension feeders
Sipunculida (peanut worms)				1	Deposit feeders – non selective
Echiura (spoon worms)				1	Deposit feeders
Hemichordata	Enteropneusta (acorn worms)		Ptychoderidae	1	Deposit feeders
Annelida	Polychaeta (bristle worms)		Orbiniidae	1	Deposit feeders - subsurface
Annelida	Polychaeta (bristle worms)	Aciculata	Polynoidae (scale worms)	4	Predators – active. One species is symbiotic with *Amphiura tenuis* (brittle star)
Annelida	Polychaeta (bristle worms)	Aciculata	Sigalionidae	1	Predators
Annelida	Polychaeta (bristle worms)	Aciculata	Amphinomidae (fire worms)	1	Predators - sluggish carnivores feeding on sedentary prey
Annelida	Polychaeta (bristle worms)	Aciculata	Onuphidae	1	Omnivore – takes prey and algae
Annelida	Polychaeta (bristle worms)	Aciculata	Pilargidae	1	Family includes omnivores, predators and scavengers
Annelida	Polychaeta (bristle worms)	Aciculata	Hesionidae	1	Predators and scavengers
Annelida	Polychaeta (bristle worms)	Aciculata	Nereidae	1	Family includes predators, herbivores, surface deposit feeders, omnivores and suspension feeders (using a mucus net). Feeding behaviour can vary even within and between

					populations of a single species
Annelida	Polychaeta (bristle worms)	Aciculata	Phyllodocidae	3	Mostly predators
Annelida	Polychaeta (bristle worms)	Aciculata	Nephtyidae	1	Predators - prey include other polychaetes, oligochaetes, crustaceans and molluscs
Annelida	Polychaeta (bristle worms)	Aciculata	Glyceridae	1	Predators
Annelida	Polychaeta (bristle worms)	Canalipalpata	Spionidae	2	Predators – many species prey on molluscs being able to bore into shells and other calcareous substrates
Annelida	Polychaeta (bristle worms)	Canalipalpata	Cirratulidae	1	Deposit feeders - subsurface
Annelida	Polychaeta (bristle worms)		Capitellidae	1	Deposit feeders
Annelida	Polychaeta (bristle worms)		Maldanidae	2	Deposit feeders – non selective subsurface
Annelida	Polychaeta (bristle worms)	Canalipalpata	Sternaspidae	1	Deposit feeders.
Annelida	Polychaeta (bristle worms)	Canalipalpata	Oweniidae	1	Suspension and deposit feeders.
Annelida	Polychaeta (bristle worms)	Canalipalpata	Sabellariidae	1	Suspension feeders, some may be deposit feeders.
Annelida	Polychaeta (bristle worms)	Canalipalpata	Pectinariidae	1	Deposit feeders – selective subsurface
Crustacea	Malacostraca	Amphipoda	Oedicerotidae (sandhopper)	1	
Crustacea	Malacostraca	Amphipoda	Corophiidae (mud shrimp)	1	
Crustacea	Malacostraca	Isopoda	Anthuridae	1	
Crustacea	Malacostraca	Isopoda	Cirolanidae	1	
Crustacea	Malacostraca	Cumacea (comma shrimp, hooded shrimp)		1	Deposit feeders – surface
Crustacea	Malacostraca	Mysidacea (Lophogastrida – opossum shrimp)		1	Predators
Crustacea	Malacostraca	Stomatopoda	Squillidae (mantis shrimp)	1	Predators
Crustacea	Malacostraca	Decopoda, Infraorder Caridea (shrimp)	Unknown	1	
Crustacea	Malacostraca	Decopoda	Callianassidae (ghost shrimp)	1	Predators
Crustacea	Malacostraca	Decopoda	Paguridae (right handed	1	

			hermit crabs)		
Crustacea	Malacostraca	Decopoda	Dorippidae (sumo crabs)	1	
Crustacea	Malacostraca	Decopoda	Raninidae (frog crabs)	1	
Crustacea	Malacostraca	Decopoda	Leucosiidae (purse crabs)	3	Scavengers
Crustacea	Malacostraca	Decopoda	Portunidae (swimming crabs)	1	
Crustacea	Malacostraca	Decopoda	Mictyridae	1	Deposit feeder - burrowing and also grazing surface sediments in large ‘herds’ or ‘armies’.
Crustacea	Malacostraca	Decopoda	Goneplacidae	1	Omnivores
Crustacea	Malacostraca	Decopoda	Ocypodidae (sentinel crab)	1	Predator and scavengers
Cnidaria	Anthoza	Actiniaria (sea anemones)	Edwardsiidae	4	Predators
Cnidaria	Anthoza	Pennatulacea (sea pens)		1	Predators – feed on zooplankton small organisms, capturing them with tentacles on the end of their polyps
Cnidaria	Hydrozoa			1	Predators – feed on zooplankton
Brachiopoda	Inarticulata	Lingulida	Lingulidae (burrowing lampshell)	1	Suspension feeder
Echinodermata	Ophiuroidea	Ophiurida	Amphiuridae	1	Deposit feeders - surface
Echinodermata	Echinoidea (flat sanddollar)			1	Deposit feeders – surface
Echinodermata	Holothuroidea (sea cucumbers)			4	Deposit feeders – surface
Echinodermata	Holothuroidea (sea cucumbers)	Denidrochirotida	Cucumariidae	1	
Echinodermata	Holothuroidea (sea cucumbers)	Apoidida	Syanptidae	3	Deposit feeders – surface
Echinodermata	Holothuroidea (sea cucumbers)	Molpadiida	Caudinidae	1	Deposit feeders - surface

Appendix D: Wetland birds recorded in the Eighty-mile Beach Ramsar Site

Location: B = Beach; MSM = Mandora Salt Marsh
X = present; B = breeding
Species listing: M = Listed as marine under the EPBC Act; J = JAMBA; C= CAMBA; R = ROKAMBA,; V = Vulnerable under the EPBC Act (Australian Painted Snipe); E = Endangered under IUCN Red List (Nordmann's Greenshank)
Species list compiled from Birds Australia Bird Atlas, Shorebirds 2020 and Halse et al 2005)

Common Name	Species Name	Location		Listing
		B	MSM	
Ducks and Allies				
Australasian Shoveler	*Anas rhynchotis*		X	
Australian Shelduck	*Tadorna tadornoides*	X	X	
Black Swan	*Cygnus atratus*	X	B	
Freckled Duck	*Stictonetta naevosa*		X	
Green Pygmy-goose	*Nettapus pulchellus*		X	M
Grey Teal	*Anas gracilis*	X	B	
Hardhead	*Aythya australis*	X	B	
Pacific Black Duck	*Anas superciliosa*	X	B	
Pink-eared Duck	*Malacorhynchus membranaceus*	X	B	
Plumed Whistling-Duck	*Dendrocygna eytoni*	X	B	
Wandering Whistling-Duck	*Dendrocygna arcuata*	B		M
Grebes				
Australasian Grebe	*Tachybaptus novaehollandiae*	X	B	
Hoary-headed Grebe	*Poliocephalus poliocephalus*	X	B	
Pelicans, Cormorants and Darters				
Australian Pelican	*Pelecanus conspicillatus*	X	B	M
Australian Darter	*Anhinga melanogaster*		B	
Little Black Cormorant	*Phalacrocorax sulcirostris*		X	
Little Pied Cormorant	*Microcarbo melanoleucos*	X	X	
Pied Cormorant	*Phalacrocorax varius*	X		
Herons, Ibis, Egrets and Spoonbills				
Australian White Ibis	*Threskiornis molucca*	X	X	M
Black-necked Stork	*Ephippiorhynchus asiaticus*	X	X	
Eastern Reef Egret	*Egretta sacra*	X		M, C
Glossy Ibis	*Plegadis falcinellus*	X	X	M, C, J
Eastern Great Egret	*Ardea modesta*	X	B	M, C, J
Intermediate Egret	*Ardea intermedia*		B	M
Little Egret	*Egretta garzetta*	X	X	M
Nankeen Night-Heron	*Nycticorax caledonicus*	X	B	M
Royal Spoonbill	*Platalea regia*	X		
Straw-necked Ibis	*Threskiornis spinicollis*	X	B	M
Striated Heron	*Butorides striatus*	X	X	
White-faced Heron	*Egretta novaehollandiae*	X	B	
White-necked Heron	*Ardea pacifica*	X	B	
Hawks, Eagles and Falcons				
Eastern Osprey	*Pandion haliaetus*	X		M
Swamp Harrier	*Circus approximans*	X	X	M
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	X	X	M, C
Cranes, Crakes and Rails				
Australian Spotted Crake	*Porzana fluminea*	X	X	
Baillon's Crake	*Porzana pusilla*	X	X	M
Black-tailed Native-hen	*Gallinula ventralis*	X	X	
Brolga	*Grus rubicunda*	X	X	
Buff-banded Rail	*Gallirallus philippensis*		X	
Eurasian Coot	*Fulica atra*	X	B	
Purple Swamphen	*Porphyrio porphyrio*		X	
Spotless Crake	*Porzana tabuensis*		X	M
Shorebirds				
Asian Dowitcher	*Limnodromus semipalmatus*	X		M, C, J, R

Australian Pratincole	*Stiltia isabella*	X	X	M
Banded Lapwing	*Vanellus tricolor*		X	
Banded Stilt	*Cladorhynchus leucocephalu*	X		
Bar-tailed Godwit	*Limosa lapponica*	X		M, C, J, R
Black-fronted Dotterel	*Elseyornis melanops*	X	B	
Black-tailed Godwit	*Limosa limosa*	X		M, C, J, R
Black-winged Stilt	*Himantopus himantopus*	X	B	M
Broad-billed Sandpiper	*Limicola falcinellus*	X		M, C, J, R
BushStone-curlew	*Burhinus grallarius*	X	X	
Common Greenshank	*Tringa nebularia*	X	X	M, C, J, R
Common Sandpiper	*Actitis hypoleucos*	X	X	M, C, J, R
Curlew Sandpiper	*Calidris ferruginea*	X	X	M, C, J, R
Eastern Curlew	*Numenius madagascariensis*	X		M, C, J, R
Eurasian Curlew	*Numenius arquata*	X		M, C
Great Knot	*Calidris tenuirostris*	X		M, C, J, R
Greater Sand Plover	*Charadrius leschenaultii*	X	X	M, C, J, R
Grey Plover	*Pluvialis squatarola*	X		M, C, J, R
Grey-tailed Tattler	*Heteroscelus brevipes*	X	X	M, C, J, R
Lesser Sand Plover	*Charadrius mongolus*	X		M, C, J, R
Little Curlew	*Numenius minutus*	X		M, C, J, R
Little Ringed Plover	*Charadrius dubius*		X	M, C, J, R
Long-toed Stint	*Calidris subminuta*		X	M, C, J, R
Marsh Sandpiper	*Tringa stagnatilis*	X	X	M, C, J, R
Masked Lapwing	*Vanellus miles*	X	B	
Nordmann's Greenshank	*Tringa guttifer*	X		M, J, E
Oriental Plover	*Charadrius veredus*	X	X	M, J, R
Oriental Pratincole	*Glareola maldivarum*	X		M, C, J, R
Pacific Golden Plover	*Pluvialis fulva*	X		M, C, J, R
Australian Painted Snipe	*Rostratula australis*		X	M, V, C
Pectoral Sandpiper	*Calidris melanotos*	X		M, J, R
Australian Pied Oystercatcher	*Haematopus longirostris*	X		
Red Knot	*Calidris canutus*	X		M, C, J, R
Common Redshank	*Tringa totanus*	X		M, C, J, R
Red-capped Plover	*Charadrius ruficapillus*	B	B	M
Red-kneed Dotterel	*Erythrogonys cinctus*	X	B	
Red-necked Avocet	*Recurvirostra novaehollandiae*	X	B	M
Red-necked Stint	*Calidris ruficollis*	X	X	M, C, J, R
Ruddy Turnstone	*Arenaria interpres*	X	X	M, C, J, R
Sanderling	*Calidris alba*	X		M, C, J, R
Sharp-tailed Sandpiper	*Calidris acuminata*	X	X	M, C, J, R
Sooty Oystercatcher	*Haematopus fuliginosus*	X		
Terek Sandpiper	*Tringa terek*	X		M, C, J, R
Whimbrel	*Numenius phaeopus*	X		M, C, J, R
Wood Sandpiper	*Tringa glareola*	X	X	M, C, J, R
Gulls and Terns				
Caspian Tern	*Sterna caspia*	X	X	M, C, J
Common Tern	*Sterna hirundo*	X		M, C, J, R
Crested Tern	*Thalasseus bergii*	X		M
Gull-billed Tern	*Sterna nilotica*	X	B	M
Lesser Crested Tern	*Sterna bengalensis*	X		M, C
Little Tern	*Sterna albifrons*	X		M, C, J, R
Roseate Tern	*Sterna dougallii*	X		M, J
Sabine's Gull	*Xema sabini*	X		M
Silver Gull	*Larus novaehollandiae*	X	X	M
Whiskered Tern	*Chlidonias hybridus*	X	B	M
White-winged Black Tern	*Chlidonias leucopterus*	X	X	M, C, J, R
Other Birds				
Australian Reed-Warbler	*Acrocephalus australis*		X	

Waterbird feeding and dietary guilds.

Feeding Guilds: F1= dense inundated vegetation; **F2** = Shallows (<0.5m) &/or mud; **F3=** Deep water (>1m); **F4** = Away from wetland habitats
Dietary Guilds: D1= Plants and animals; **D2** = Mostly plants; **D3=** Mostly animals; **D4** = Fish
X = Common or usual, O = Occasional

Waterbirds	Feeding Guilds				Dietary Guilds			
	F1	F2	F3	F4	D1	D2	D3	D4
Ducks and Allies								
Australasian Shoveler		X	X		X			
Black Swan		X	X	X		X		
Freckled Duck		X	X		X			
Green Pygmy-goose		X	X			X		
Grey Teal		X	X		X			
Hardhead		X	X		X			
Pacific Black Duck		X	X	X	X			
Pink-eared Duck		X	X		X			
Plumed Whistling-Duck		X		X		X		
Wandering Whistling-Duck		X	X		X			
Grebes								
Australasian Grebe		X	X				X	X
Hoary-headed Grebe		X	X				X	X
Pelicans, Cormorants and Darters								
Australian Pelican			X				X	X
Darter			X		X			X
Little Black Cormorant			X				X	X
Little Pied Cormorant		X	X				X	X
Pied Cormorant			X				X	X
Herons, Ibis, Egrets and Spoonbills								
Australian White Ibis		X		X			X	X
Black-necked Stork		X					X	X
Eastern Reef Egret		X					X	X
Glossy Ibis		X			X			X
Great Egret		X		X			X	X
Intermediate		X		X			X	X
Little Egret		X					X	X
Nankeen Night Heron	X	X		X			X	X
Royal Spoonbill		X					X	X
Straw-necked Ibis		X		X			X	X
Striated Heron		X					X	X
White-faced Heron		X		X			X	X
White-necked Heron		X					X	X
Hawks, Eagles and Falcons								
Osprey			X				X	X
Swamp Harrier	X	X		X			X	X
White-bellied Sea-Eagle		X	X	X			X	X
Cranes, Crakes and Rails								
Australian Crake	X	X			X			
Baillon's Crake	X	X	X		X			
Black-tailed Native-hen	X	X		X	X			
Brolga		X		X	X			
Buff-banded Rail	X	X		X	X			
Eurasian Coot		X	X		X			
Purple Swamphen	X	X		X	X			
Spotless Crake	X	X			X			
Shorebirds								
Australian Painted Snipe		X			X			
Asian Dowitcher		X					X	
Australian Pratincole		X		X			X	
Banded Lapwing		X		X	X			
Banded Stilt		X	X		X			O
Bar-tailed Godwit		X					X	

Waterbirds	Feeding Guilds				Dietary Guilds			
	F1	F2	F3	F4	D1	D2	D3	D4
Black-fronted Dotterel		X		X			X	
Black-tailed Godwit		X					X	
Black-winged Stilt		X					X	
Broad-billed Sandpiper		X					X	
Common Greenshank		X					X	
Common Sandpiper		X					X	
Curlew Sandpiper		X					X	
Eastern Curlew		X					X	
Eurasian Curlew		X					X	
Great Knot		X					X	
Greater Sand Plover		X					X	
Grey Plover		X					X	
Grey-tailed Tattler		X					X	
Lesser Sand Plover		X					X	
Little Curlew		X		X	X			
Little Ringed Plover		X		X			X	
Long-toed Stint		X					X	
Marsh Sandpiper		X					X	
Masked Lapwing		X		X			X	
Nordmann's Greenshank		X					X	
Oriental Plover		X		X			X	
Oriental Pratincole		X		X			X	
Pacific Golden Plover		X		X	X			
Pectoral Sandpiper		X			X			
Pied Oystercatcher		X					X	X
Red Knot		X					X	
Common Redshank		X					X	
Red-capped Plover		X		X	X			
Red-kneed Dotterel		X			X			
Red-necked Avocet		X					X	
Red-necked Stint		X			X			
Ruddy Turnstone		X					X	
Sanderling		X			X			
Sharp-tailed Sandpiper		X			X			
Sooty Oystercatcher		X					X	
Terek Sandpiper		X					X	
Whimbrel		X					X	
Wood Sandpiper		X					X	
Gulls and Terns								
Caspian Tern			X				X	X
Common Tern			X				X	X
Crested Tern			X				X	X
Gull-billed Tern		X	X	X			X	X
Lesser Crested Tern			X				X	X
Little Tern			X				X	X
Roseate Tern			X				X	X
Sabine's Gull			X				X	X
Silver Gull		X	X	X	X		X	X
Whiskered Tern		X	X				X	X
White-winged Tern		X	X				X	X