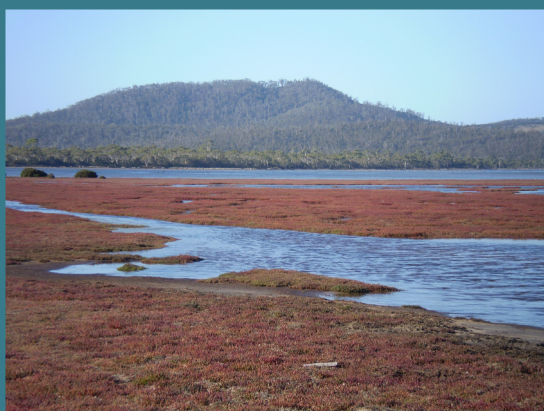
Australian Government

Department of Sustainability, Environment, Water, Population and Communities



Moulting Lagoon

Ramsar Site

Ecological Character Description

Image credits: Ken Morgan

Introductory Notes

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

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

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

Disclaimer

Acknowledgements

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The assistance of a number of people, from both government agencies and from the local community at Swansea and Coles Bay is acknowledged. The project advisory committee – Prof Alastair Richardson, Ian Houshold, Danielle Hardie, Imogen Birley, Stewart Blackhall, Christine Crawford, and Kayleen Allen – provided valuable input into the structure and review of the Ecological Character Description, as did reviewers Jennifer Hale, Rhonda Butcher and Lance Lloyd. Data was made available from Department of Primary Industries Parks, Water and Environment, Tasmanian Aquaculture and Fisheries Institute, Bureau of Meteorology. Community members, farmers, marine farmers, bird and fish enthusiasts gave freely of their time to offer information and some important historical insights into the nature of Moulting Lagoon, both prior to listing and since

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List of Abbreviations

AAR	Annual Average Rainfall
BoM	Bureau of Meteorology
CAMBA	China-Australia Migratory Bird Agreement
DEWHA	Department of the Environment, Water, Heritage and the Arts
DPIPWE	Department of Primary Industries, Parks, Water and Environment (formerly DPIW)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (formerly DEWHA)
EAASSN	East Asian-Australian Shorebird Site Network
ECD	Ecological Character Description
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
HAT	Highest astronomical tide
LAT	Lowest astronomical tide
JAMBA	Japan-Australia Migratory Bird Agreement
MAR	Mean annual runoff
MDS	Multi-Dimensional Scaling
MEA	Millennium Ecosystem Assessment
PWS	Parks and Wildlife Service
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
TAFI	Tasmanian Aquaculture and Fisheries Institute
TSPA	*Threatened Species Protection Act 1995* (Tas)
UNESCO	United Nations Educational, Scientific and Cultural Organization
WIST	Water Information System of Tasmania

Executive Summary

Ecological character is the combination of the ecosystem components, processes and benefits and services that characterise the wetland at a given point in time (Ramsar Convention 2005a, Resolution IX. 1 Annex A). An Ecological Character Description (ECD) of a Ramsar site provides a baseline for monitoring change and guidance in the management of the site to maintain and protect its values. Changes to the ecological character of the wetland beyond natural variation may be a warning that use of the site or external stresses are adversely affecting the values. This ECD is compiled as at the time of listing of the site in 1982, and has been compiled with reference to the National Framework and Guidance for Describing the Ecological Character of Australian Ramsar Wetlands (DEWHA 2008).

Moulting Lagoon and Great Oyster Bay are situated in a downthrown block (graben) which developed as the Tasman Sea opened approximately 80 million years ago. Underlying rocks are predominantly Jurassic dolerite and Permian and Triassic sediments (DPIWE 2005). Rivers flowing through this valley then deposited tens of metres of clay-rich sediment derived from erosion of nearby hills. These sediments were subsequently eroded by wind action during dry phases of the Quaternary (the last 2 million years) to form a series of deflation basins, connected by stream channels and bedrock valleys.

Moulting Lagoon Ramsar Site (Moulting Lagoon) is one of ten listed Ramsar sites (Wetlands of International Importance) in Tasmania. Moulting Lagoon was listed based on meeting the following criteria:

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Moulting Lagoon/Great Oyster Bay is a site of geoconservation significance, and the spit at Nine Mile Beach is one of only two mid-bay spits in Tasmania. Little Bay (a drowned deflation basin) and its intact lunette together form an excellent example of this aeolian landform system commonly degraded elsewhere in Tasmania. Wetland habitats found within the site include extensive saltmarsh communities and subtidal aquatic beds of seagrass, intertidal and subtidal flats and islands connected by subtidal channels and a sea water channel, tidal and subtidal sand banks, salt pans, beaches and dunes. This mosaic of wetland habitats is representative of saltmarsh communities and morphology within the bioregion (Tasmania). The lower estuary is dominated by the wetland habitat of estuarine waters and subtidal aquatic beds. Moulting Lagoon is a good example of a coastal estuarine lagoon system, relatively unimpacted by urban development and upstream river abstractions (Edgar et al. 1999; DPIWE 2005).

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Moulting Lagoon is one of the largest and most significant wetland areas in Tasmania and supports considerable biodiversity. Moulting Lagoon supports large numbers and a high diversity of waterbirds including shorebirds and waders. Twenty-two species of resident and migratory waders have been recorded onsite, with nine species regularly using the area. The site supports a number of threatened species listed under the Tasmanian *Threatened Species Protection Act 1995* (TSPA) including the white-bellied sea eagle (*Haliaeetus leucogaster*; vulnerable); eastern curlew (*Numenius madagascariensis*, endangered); and great-crested grebe (*Podiceps cristatus* vulnerable); 13 plant species and a number of saltmarsh communities. The estuary also supports substantial populations of fish and diverse floristic communities. The fish fauna of Great Swanport estuary is similar to those of other open lagoon estuaries in Tasmania, with a total of 37 species from within its limits representing about 60 percent of all species found in open lagoons in Tasmania (Edgar et al. 1999). Wetland vegetation is dominated by two key types: saltmarsh and seagrass. These vegetation associations are critical components of the site's ecological character playing central roles in the provision of physical habitat for aquatic species as well providing key food resources, particularly for the waterbirds.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Moulting Lagoon supports a large number of waterbirds, particularly black swans (*Cygnus atratus*) and Australian shelducks (*Tadorna tadorniodes*), at key stages of their lifecycles. It provides year-round habitat for around 5,000 to 10,000 black swans and is a critical late summer staging area for Australian shelducks, chestnut teal (*Anas castanea*), and several shorebird species. The largest Tasmanian flock of common greenshank (*Tringa nebularia*) also occurs at the lagoon. Several of the shorebird species found at the site are listed under bilateral agreements such as the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA) and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA), which protect the passage of migratory birds between our countries, and the maintenance of their habitats.

Criterion 6: A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.
Moulting Lagoon Ramsar Site regularly supports at least one percent of the global individuals of three waterbird species in Australia (Wetlands International 2006): black swan, pied oystercatcher (*Haematopus longirostris*), and Pacific gull (*Larus pacificus*).

Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Moulting Lagoon and the Apsley Marshes provide a linkage between the inland waters of the Apsley River and the Southern Ocean. Regular migrations of short-finned eels (*Anguilla australis*), both on their seaward migration to breed as well as returning juveniles, are reported (Hale and Butcher 2011). In addition, black bream (*Acanthopagrus butcheri*) are known to travel up the drains, via Moulting Lagoon into the Apsley Marshes Ramsar site in order to spawn. Australian grayling (vulnerable, EPBC Act and TSPA) have also been recorded in the river upstream and presumably would use the site as a migratory route during breeding.

Estuaries and coastal wetlands have long been recognised as essential nursery areas for a myriad of marine species. The area provides a range of recreational and economic opportunities, and has commercial value for the local tourism and aquaculture industries. The lagoon is also highly valued for hunting and fishing. The reserve's continued conservation contributes to the economic and social well-being of the local community. Moulting Lagoon is managed to protect its outstanding natural and cultural values, and provide for a range of recreational opportunities under a Game Reserve Management Plan administered by the Tasmanian Parks and Wildlife Service (PWS 2007).

Moulting Lagoon provides a number of significant cultural services. At the time of European settlement Moulting Lagoon was part of the territory occupied by the Oyster Bay nation. Wildlife around Moulting Lagoon, black swan eggs in particular, were an important food source to Aboriginal people. The majority of bands in this nation used the lagoon on a seasonal basis, while the Linetemairrener people lived at the lagoon year round.

Since European settlement, recreational hunting has been a common use for the lagoon, owing to the large numbers of ducks and swans. Up to 150 duck hunters, mostly from the local area, still use the lagoon. While it is important to protect native species, the Ramsar Convention acknowledges that wise use of wetlands is also important, and the open season between March and June is well regulated to ensure that the harvest of birds is sustainable.

The ecological character of Moulting Lagoon is controlled by geomorphic history, and present-day geomorphic and hydrologic processes. The way in which the ecosystem functions is a result of interaction between several components, some of which arise beyond the geographic boundary of the site: volume and variability of flow of freshwater via the Swan and Apsley Rivers; tidal regime; water depth and evaporation; sediment transport and deposition; and effects of biota such as seagrass beds and swan numbers. These shape the biology and hence the values and ecosystem services, as well as determining the health and sustainability of the site. These components and processes impact upon function both in the short-term and in the long-term. Short term effects include, for example, lowering the salinity in the lagoon and increasing suspended sediment following a flash flood in the Apsley River. Long-term effects include increased rates of evaporation as a result of incremental temperature rise and higher average wind speeds.

This ECD identifies four critical components and processes for Moulting Lagoon Ramsar Site as:

- hydrology,
- wetland vegetation,
- fish, and
- waterbirds.

Critical services for the site were identified as:

- supports near natural wetland types,
- provides physical habitat for waterbird breeding, roosting and feeding,
- provides drought refuge, and
- supports biodiversity.

The critical components, processes and services meet the four criteria provided by DEWHA (2008):

- central to the character of the site,
- directly linked to the Ramsar criteria for which the site was listed,
- could potentially change in the next 100 years, and
- change in these components would result in a negative change in the ecological character of the site.

In addition to the critical components, process and services a number of essential elements were also identified. These are components and process which support the critical components, processes and services, but if they change may not cause a change in the ecological character of the site. They include:

- geomorphology,
- climate,
- water quality, and
- invertebrate fauna.

The identified critical components, processes and services and associated essential elements for the Moulting Lagoon Ramsar Site, together with the linkages between them, is illustrated in Figure E1.

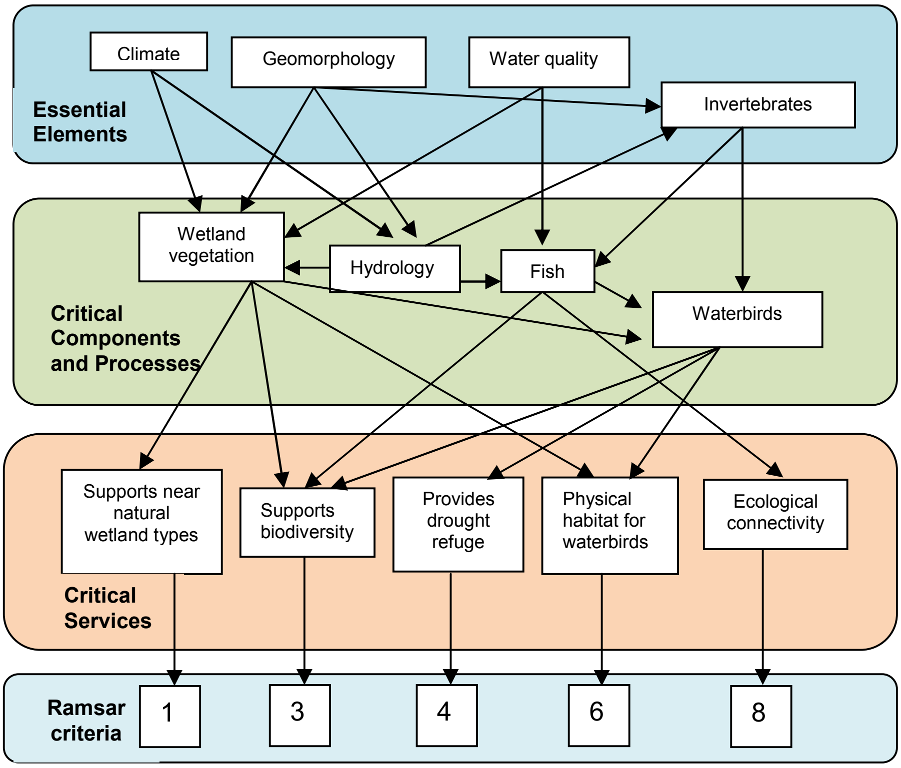


Figure E1: Conceptual model of the components, processes and services of the site, and their links to the Ramsar criteria.

Based on these components, processes and services Limits of Acceptable Change have been derived as follows:

Critical Component, Process or Service	**Limits of Acceptable Change***
Hydrology	No change in wetland hydrological types present within the site. That is, the following hydrological wetland types are maintained: • Dominance of estuarine waters. • Presence of marine subtidal aquatic beds - seagrass beds. • Presence of sand bars, spits, dune systems. • Presence of intertidal mud, sand and salt flats. • Presence of intertidal saltmarsh and salt meadows. • Presence of brackish to saline lagoons.
Wetland vegetation - saltmarsh	No less than 90 percent of the current extent of saltmarsh communities within the Ramsar site.
Wetland vegetation – seagrass	No less than 1650 hectares of *Ruppia* and 700 hectares of seagrass (*Heterozostera tasmanica* and *Zostera muelleri*).
Wetland vegetation – threatened species	Continued presence of the following species within the Ramsar site: *Ruppia megacarpa;* *Lepilaena patentifolia* *Amphibromus neesii* *Viminaria juncea*

Critical Component, Process or Service	Limits of Acceptable Change*
Fish	No less than 28 fish species (Last 1983) are present at least once every 10 years.
Waterbirds – abundance	No less than 7000 black swan (*Cygnus atratus*) in eight out of 10 years.
	No less than 200 pied oystercatcher (*Haematopus longirostris*) in five out of 10 years.
	No less than 80 Pacific gulls (*Larus pacificus*) in five out of 10 years.
Waterbirds – breeding	Presence of black swan (*Cygnus atratus*) breeding within the site on an annual basis.
Supports near natural wetland types	See LAC for hydrology and vegetation communities.
Physical habitat for waterbird (breeding, roosting and feeding).	See LAC for hydrology, vegetation and waterbirds.
Provides drought refuge	See LAC for hydrology
Supports biodiversity including threatened species	See LAC for vegetation, fish and waterbirds.
Ecological connectivity	No barriers to hydrological connectivity between Moulting Lagoon and the Apsley Marshes within the site.

Exceeding or not meeting a LAC does not necessarily indicate that there has been a change in ecological character.

In the absence of sufficient data to develop quantitative LAC, qualitative LAC are proposed.

The most significant threats to Moulting Lagoon emerge from immediate human use and from climate change. Already there is evidence of an increase in average temperature for the nearby town of Swansea and a pattern of shifting wind direction generating more westerlies that erode the shoreline and increase evaporation. Both these observations are consistent with climate change. The area has suffered declining annual rainfall, hence lower flows in the rivers, and increasing demands for water for irrigation and town water supply.

Moulting Lagoon is a changing and evolving system. Many geomorphic changes occur naturally in this dynamic estuarine system. Deposited sediment is slowly filling the central basin. This is a change noted since the site was first listed in 1982, although it is more likely an ongoing trend. The disposition of sand bars and the Swan delta at King Bay tend to be naturally mobile. However, changes in Moulting Lagoon may also be attributable to other reasons, including changes in the catchment, land use and climate change. Catchment changes include ongoing modification of the vegetation, forestry activities, and increasing abstraction and impedance of natural flow patterns (flushing floods are important for this system).

A risk assessment approach underpins the proposals for monitoring. Those components of the ecological character that are crucial to the maintenance of a healthy system, notably environmental flows and sediment transport, appear to be at a critical point. A range of specific indicators is offered, together with practical suggestions for data collection and monitoring. A suite of baseline information requirements is also proposed, along with suggestions for possible research that will further inform this ECD.

1. Introduction

Statement of purpose

The ECD of a Ramsar listed site must meet a suite of objectives, including meeting general requirements as part of the Ramsar process, as well as site-specific objectives based on the intrinsic social, cultural and environmental features of the site.

The Statement of Purpose originates from the National Framework and Guidance for Describing the Ecological Character of Australian Wetlands (DEWHA 2008):

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.
7. To develop a dynamic model of the Moulting Lagoon system integrating descriptive data from the time of listing with more recent and extensive data, including predictive modelling of climate change.
8. To elaborate upon the links between the hydrogeomorphic processes and geomorphic features and their role in supporting the diversity of habitats and services.

1.1 Site Details

The Moulting Lagoon Ramsar Site is located on the east coast of Tasmania between the townships of Bicheno and Swansea, approximately 190 kilometres north-north east of Hobart and six kilometres north west of Coles Bay. The site is an estuarine system which lies at the head of Great Oyster Bay where the Freycinet Peninsula extends offshore. Moulting Lagoon was originally nominated as a Wetland of International Importance under the Ramsar Convention in November 1982. Site details for this Ramsar wetland are provided in Table 1.

Table 1: Site details for Moulting Lagoon Ramsar site.

Site Name	Moulting Lagoon Ramsar Site
Geographical coordinates	The midpoint of the site lies at approximately 42°02'S, 148°11'E: 598000E, 5346000N. (Map Grid of Australia (GDA 94 Zone 55)
General location of site	The lagoon is situated on the east coast of Tasmania between the townships of Swansea and Bicheno. The lagoon flows into Great Oyster Bay where Freycinet Peninsula extends southwards
Area	4507 hectares
Date of Ramsar designation	16/11/1982
Ramsar criteria met by the wetland	1,3,4, 6 and 8
Management Authority	Parks and Wildlife Service, Tasmania
Date the Ecological Character Description (ECD) applies	1982
Date of compilation	May 2010
Names of Compilers	Dr Helen Dunn, Dr Frances Mowling, University of Tasmania, Mr Peter Voller, Mr Ian Houshold, Mr Stewart Blackhall, Ms Alexandra Spink, DPIPWE Mr Lance Lloyd, Lloyd Environmental. Dr Rhonda Butcher, Water's Edge Consulting Ms Jennifer Hale, independent ecologist
Reference for Ramsar Information Sheet	http://www.environment.gov.au/water/topics/wetlands/database/pubs/3-ris.pdf Moulting Lagoon
Reference to the Management Plan	Moulting Lagoon Game Reserve (Ramsar site) Management Plan 2007 Parks and Wildlife Service, Tasmania, Department of Tourism, Parks, Heritage and the Arts, Hobart Tasmania.

1.2 Relevant treaties, legislation and regulations

Australia's obligations under the Ramsar Convention are primarily met through legislation and administration arrangements governed by the Australian, state and territory governments.

The Commonwealth EPBC Act provides a national legislative framework for the protection of Ramsar wetlands and listed migratory species, and came into effect in July 2000. This Act:

- recognises that Ramsar Wetlands of International Importance (and listed threatened and migratory species) are matters of National Environmental Significance
- introduces an environmental assessment and approval regime for actions that are likely to have a significant impact on Ramsar wetlands (and listed threatened and migratory species)
- provides for improved management of Ramsar wetlands.

The Moulting Lagoon Ramsar Site is within a proclaimed game reserve. The boundary of the site differs from that of the game reserve boundary in that the game reserve includes small areas of the adjoining Apsley Marshes Ramsar Site and also includes an isolated block of land to the north of the wetland. The game reserve has an area of approximately 4760 hectares while the Ramsar site has an area of 4507 hectares.

Game reserves are proclaimed under the *Nature Conservation Act 2002*, managed under the *National Parks and Reserves Management Act 2002* and are subject to the National Parks and Reserved Land Regulations 1999 and Wildlife Regulations 1999. Section 27(2) of the *National Parks and Reserves Management Act 2002* provides that no statutory powers may be exercised in a game reserve unless specifically provided for in a management plan and approved by both Houses of the Tasmanian Parliament.

All items of Aboriginal heritage in the state are protected under the state *Aboriginal Relics Act 1975*. The Commonwealth *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* empowers the Commonwealth to protect threatened Aboriginal heritage at the request of Aboriginal people.

The state *Threatened Species Protection Act 1995* also applies whilst management of marine animals in Tasmania is governed by the *Living Marine Resources Management Act 1995*.

The *National Parks and Reserves Management Act 2002* requires that development on reserved land such as game reserves, must have regard for the Resource Management and Planning System objectives. The legislative framework for dealing with development continues to be refined and updated.

The Tasmanian State Coastal Policy 1996 also applies to Moulting Lagoon.

Complementary to the above, the following legislative instruments and agreements apply to the management and conservation of Moulting Lagoon Ramsar Site:

- Japan-Australia Migratory Bird Agreement (JAMBA)
- China-Australia Migratory Bird Agreement (CAMBA)
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)
- Convention on Wetlands (Ramsar, Iran, 1971)
- *Marine Farming Planning Act 1995*, Tasmania
- East Asian-Australian Shorebird Site Network (EAASSN)
- *Forestry Act 1920* Tasmania
- Forestry Regulations 1999 Tasmania
- *Forest Practices Act 1985* Tasmania
- Forest Practices Code 2000 Tasmania
- *Water Management Act 1999* Tasmania
- *Weed Management Act 1999* Tasmania
- Glamorgan/Spring Bay Planning Scheme 1994
- State Policy on Water Quality Management 1997

2. General Description

2.1 Location, regional context

Moulting Lagoon is located in the Glamorgan Spring Bay Municipality about mid point on the east coast of Tasmania, with a central coordinate of the reserve lying at approximately 42^{0}02'S, 148^{0}11'E 598000E, 5346000N (PWS 2007). The site is adjacent to the Apsley Marshes Ramsar site (Figure 1).

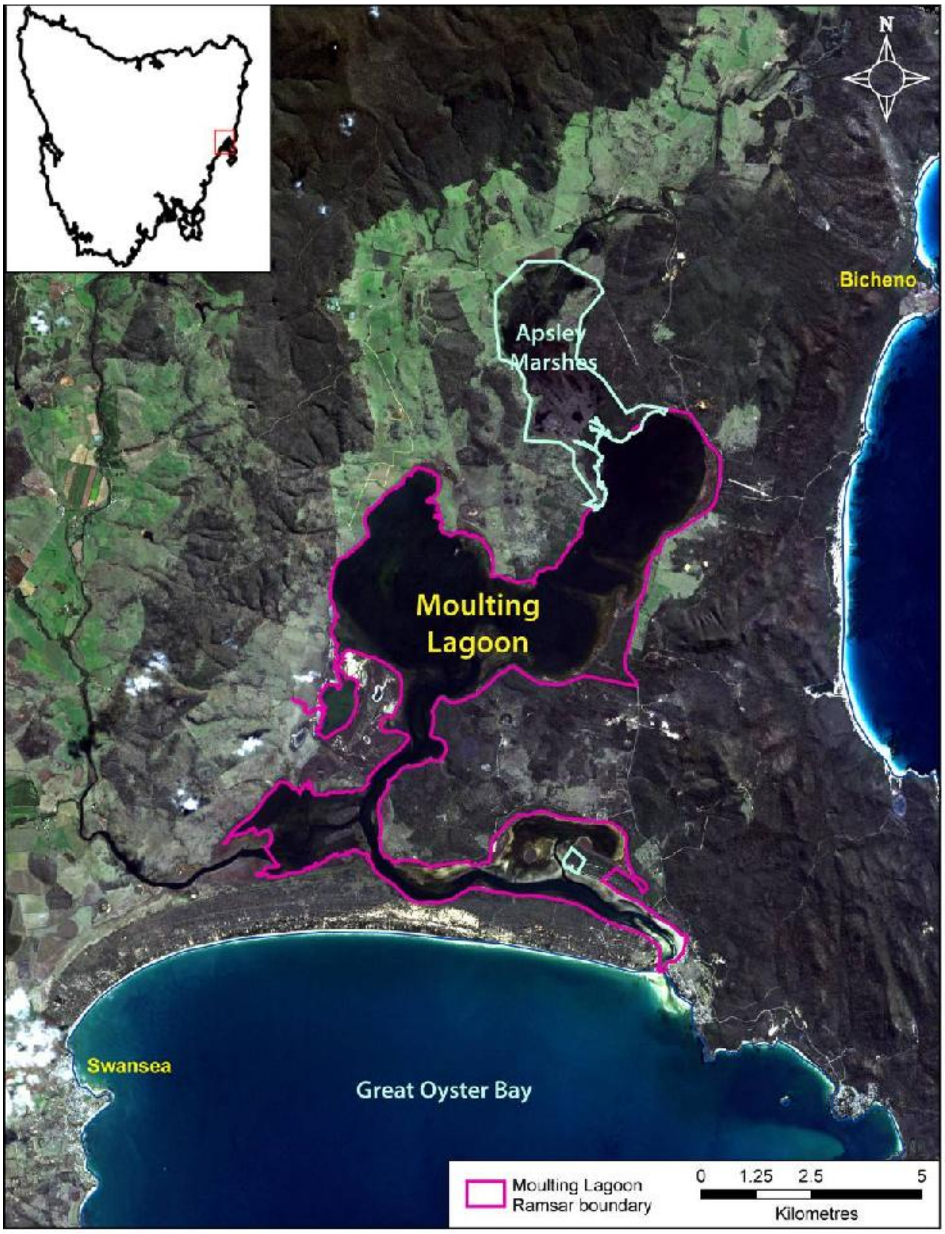


Figure 1: Location of Moulting Lagoon.

Moulting Lagoon is within the Freycinet Region of the Interim Marine and Coastal Regionalisation (DEWHA 2007) and lies at the end of the Swan and Aspley catchments, draining eastwards from the Eastern Tiers with a combined catchment area of 910 square kilometres (PWS 2007).

Moulting Lagoon has areas of both shallow and deep water and is surrounded by periodically exposed mudflats and saltmarsh. The western shore has been largely cleared and is used for livestock grazing and viticulture while the eastern shore is relatively undisturbed and covered with native vegetation. Moulting Lagoon has an area of approximately 4507 hectares.

2.2 Land tenure

The entire area of Moulting Lagoon is Crown Land, variously protected under successive reserve designations since 1918. In 1988 it was designated as Game Reserve under the management of the Tasmanian Parks and Wildlife Service (PWS). The boundary of the Game Reserve includes an area of land to the north east of Moulting Lagoon, which is not included in the Ramsar site.

The Game Reserve is an area used on an annual basis for recreational duck shooting, controlled under the provisions of the Wildlife Regulations 1999 of the *Nature Conservation Act 2002*, Tasmania. The northern basin of the main lagoon is known as ‘the Sanctuary’ and is designated as an area where shooting is prohibited. Land adjacent to Moulting Lagoon is privately owned with land uses including grazing, viticulture, nature conservation, tourism and semi-urban developments.

2.3 Wetland types

Wetland types (as defined by Ramsar) in the site are described below and shown in Figure 2. Whilst influenced by inflowing freshwater from the Swan River and Apsley Marshes, these permanent freshwater river channels are not within the boundary of the site. There are small areas of freshwater wetland within the boundary, such as Charlie Diglers Hole, which is a small peatland on the eastern shore. However, the vast majority of the site comprises estuarine and marine waters.

Marine subtidal aquatic beds (Ramsar type B); *includes kelp beds, sea-grass beds, tropical marine meadows.*
This Ramsar type is represented by substantial seagrass beds, which are a significant feature of the Ramsar site occurring throughout Great Swanport estuary as well as in the central basin of Moulting Lagoon. Rees (1993) stated that seagrass covered approximately 2492 hectares of the Ramsar site, which equates to 40 to 70 percent of the lagoon substrate (PWS 2007). Species composition differs across the site with dense beds of *Zostera muelleri* dominating the more saline reaches in the Great Swanport and into Pelican Bay. In the upper reaches of the lagoon and in King Bay, where fresh water enters from the Swan and Apsley Rivers, several species of *Ruppia* replace the *Zostera* (PWS 2007).

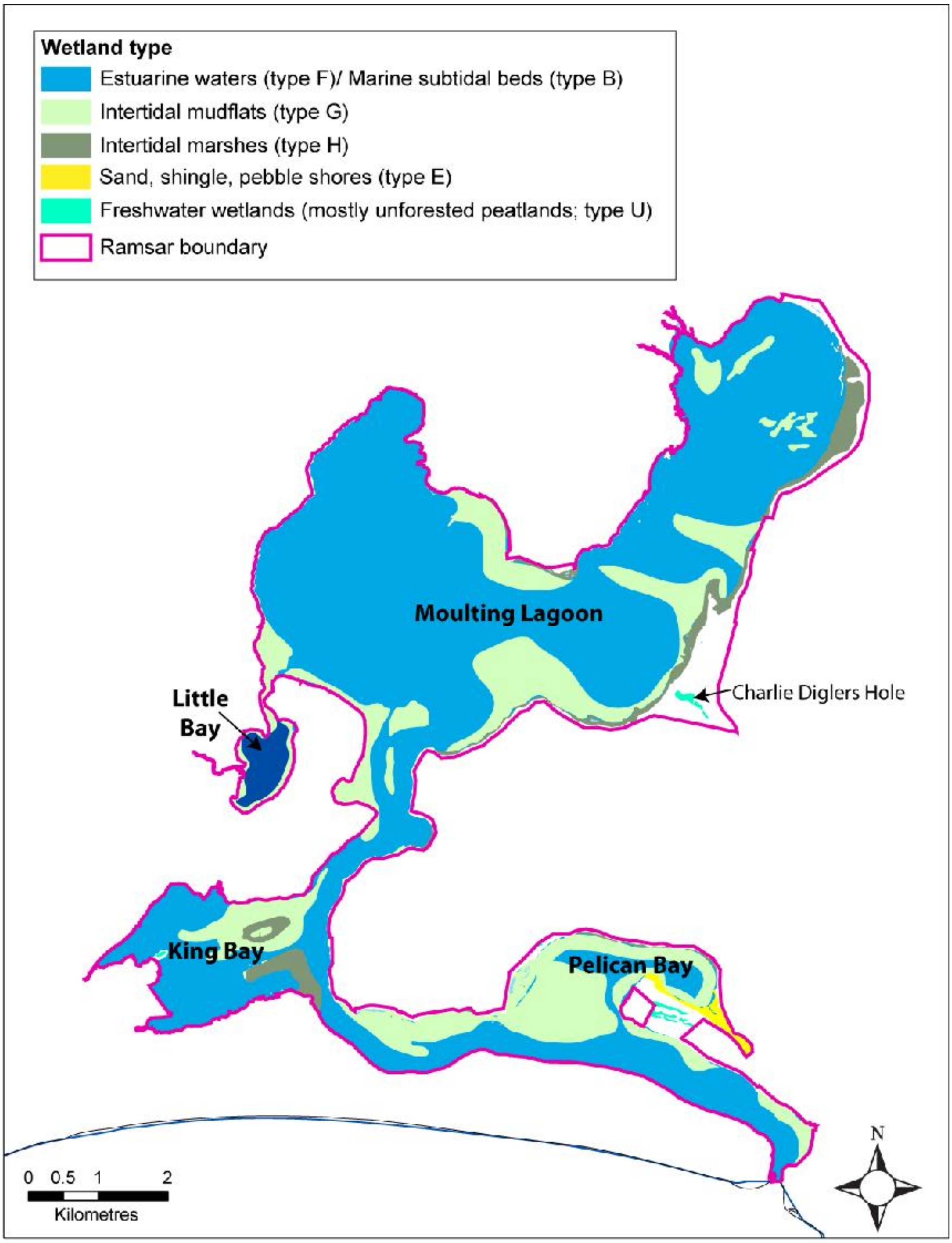


Figure 2: Ramsar wetland types (note estuarine waters and marine subtidal aquatic beds cover the same area).

Estuarine waters (Ramsar type F); *permanent water of estuaries and estuarine systems of deltas (*Figure 3*).*
This is the dominant wetland type and overlaps strongly with the subtidal aquatic bed wetland type. Hydrological characteristics are described in section 3.2.1.

Figure 3: Example of estuarine waters (wetland type F) at Moulting Lagoon (photo R. Butcher, 2005).

Sand, shingle or pebble shores (Ramsar type E); *includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks (*Figure 4*).*
This wetland type is limited to the southern shore along the Great Swanport upstream to King Bay in the north shore of Great Swanport and into Pelican Bay.

Figure 4: Example of sandy shores (wetland type E) at Moulting Lagoon (photo R. Butcher, 2005).

Intertidal mud, sand or salt flats (Ramsar type G).
The shallow and deep water areas in the site are often surrounded by periodically exposed intertidal mud and sand flats. The lower estuary of King Bay and Pelican Bay have areas of intertidal mudflats which are particularly important in that they are regularly used as roosting and feeding sites for waterbirds, notably migratory shorebird species.

Intertidal marshes (Ramsar type H); *includes saltmarshes, salt meadows, saltings, raised saltmarshes; includes tidal brackish and freshwater marshes (*Figure 5*).*
The majority of the saltmarsh habitat at the Moulting Lagoon system actually lies outside the boundary of the site. Despite this, the wetland type is a characteristic feature of the site, supporting a range of habitat types. Saltmarsh is considered threatened in Tasmania. Saltmarsh, dominated by *Sarcocornia quinqueflora*, occurs along the immediate edge of most of the site (PWS 2007). The characteristics of the saltmarsh communities are presented in more detail in section 3.2.2.

Figure 5: Example of intertidal marshes (wetland type H) at Moulting Lagoon (photo R. Butcher, 2005).

Coastal brackish/saline lagoons (Ramsar type J); b*rackish to saline lagoons with at least one relatively narrow connection to the sea.*
This wetland type is represented by Little Bay, a drowned deflation basin located off the central basin. Details regarding the geomorphic characteristics of Little Bay are presented in section 3.1.1.

Non-forested peatlands (Ramsar type U); *includes shrub or open bogs, swamps, fens.*
Although the majority of the site comprises estuarine and marine waters, there are small areas of freshwater within the Ramsar boundary. An example is Charlie Dilgers Hole, a small, freshwater peatland on the eastern edge of the Ramsar site.

2.4 Ramsar Listing Criteria

The Ramsar site was designated in November 1982 under the (then) criteria 1(a), 2(c), and 3(b) (Ramsar Information Sheet 2005). In 1999, the Ramsar criteria were revised and as a result, Ramsar sites are now designated under criteria one to nine (Table 2). The Moulting Lagoon Ramsar Site is listed under five Ramsar criteria one, three, four, six and eight.

Table 2: Ramsar criteria under which Ramsar sites are listed.

Group A: Sites containing representative, rare or unique wetland types	
Criterion one:	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	
Criteria based on species and ecological communities	
Criterion two:	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion three:	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 four:	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Specific criteria based on waterbirds	
Criterion five:	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion six:	A wetland should be considered internationally important if it regularly supports 1 percent of the individuals in a population of one species or subspecies of waterbird.
Specific criteria based on fish	
Criterion seven:	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 eight:	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Specific criteria based on other fauna	
Criterion nine:	A wetland should be considered internationally important if it regularly supports 1 percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

2.4.1 Review of listing criteria

Criterion one: Representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

The application of this criterion must be considered in the context of the Australian Drainage Division system. Moulting Lagoon lies within the Tasmanian Drainage Division and falls within an area of high regional geoconservaiton significance (Tasmanian Geoconservation Database v6.0, 2008).The site includes Little Bay, a drowned deflation basin, and associated lunettes which are representative of significant geomorphic features at the bioregional scale, being a product of a drier palaeoclimate. Wetland habitats found within the site include extensive saltmarsh communities, intertidal and subtidal flats and islands connected by subtidal channels and a sea water channel, tidal and subtidal sand banks, salt pans, beaches and dunes. This mosaic of wetland habitats is representative of saltmarsh communities and morphology within the bioregion (Tasmania). The lower estuary is dominated by the wetland habitat of estuarine waters and subtidal aquatic beds. These habitats consist of the seagrass *Zostera muelleri. Heterozostera tasmanica* and *Ruppia* spp. which occur in the middle estuary and around the delta of the Swan River, the main lagoon is almost entirely dominated by *Ruppia* spp.

Overall, Moulting Lagoon is a good example of a coastal estuarine lagoon system, relatively unimpacted by urban development and upstream river abstractions (Edgar et al. 1999; DPIWE 2005).

It is likely that the site met this criterion at the time of listing as well as currently, even though the evidence is mostly provided after listing.

Criterion three: Supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Moulting Lagoon is one of the largest and most significant wetland areas in Tasmania, and supports large numbers and a high diversity of waterbirds including shorebirds and waders. Twenty-two species of resident and migratory waders have been recorded onsite, with nine species regularly using the area, particularly the lower estuary at King Bay and Pelican Bay along the intertidal mudflats (Wakefield 1984; Schokman 1991; PWS 2007).

Three bird species are listed under the TSPA: the white-bellied sea eagle (*Haliaeetus leucogaster*; vulnerable); eastern curlew (*Numenius madagascariensis*; endangered); and great-crested grebe (*Podiceps cristatus*; vulnerable).

The estuary also supports substantial populations of fish and diverse floristic communities. The fish fauna of Great Swanport estuary is similar to those of other open lagoon estuaries in Tasmania, with a total of 37 species from within its limits representing about 60 percent of all species found in open lagoons in Tasmania (Edgar et al. 1999).

Saltmarsh communities are considered threatened in Tasmania, with substantial loss in saltmarsh vegetation since pre-European times (DPIPWE in prep). While much of the surrounding saltmarsh is outside the site boundary, there are significant areas of saltmarsh within the intertidal shorelines. In addition, the site supports extensive seagrass beds within the Great Swanport estuary and parts of the central basin (Rees 1993; Mount et al. 2005).

The Management Plan for the Moulting Lagoon Game Reserve (PWS 2007) lists 13 plant species listed under the TSPA as occurring “in and around” the site (Appendix 2). This includes a number of species that are aquatic ecosystem dependent, such as: *Viminaria juncea* (endangered), *Amphibromus neesii* (rare), *Lawrencia spicata* (endangered), *Ruppia megacarpa* (rare) and *Lepilaena patentifolia* (rare).

The evidence indicates that the site met this criterion at the time of listing as well as currently.

Criterion four: Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Moulting Lagoon provides an important resting and feeding ground for many species of migratory birds. It is a significant site for the common greenshank (*Tringa nebularia*) which is listed under the China - Australia Migratory Bird Agreement (CAMBA), the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) and the Japan - Australia Migratory Bird Agreement (JAMBA). The lagoon regularly supports the largest known Tasmanian flock of this migratory species, recording a maximum count of 164 individuals between the counting periods of 1990-1999 (Bryant 2002; Blackhall unpublished – count data updated 2008).

Moulting Lagoon is the prime site for black swan (*Cygnus atratus*) breeding in Tasmania, as it has been estimated that historically up to 85 percent of black swan breeding in Tasmania occurred at Moulting Lagoon (Hemsley 1973). The Lagoon provides year round habitat for generally over 7000 swans (median counts 7236 - Blackhall unpublished – count data updated 2008; PWS 2007).

The site provides a refuge under dry conditions both as a feeding site and nesting site, notably for swan and other waterfowl. Populations of black swan in dry periods have approached 19000 birds (Hemsley 1973; Blackhall unpublished – count data updated 2008).

The name Moulting Lagoon is derived from black swans shedding their flight feathers, which can often be seen piled up along the shoreline. Moulting is considered a critical life-stage for waterfowl, as the birds are flightless during the moult of primary flight feathers and require protection from predators. It is a critical late summer staging area for Australian shelducks, chestnut teal, and several shorebird species.

It is likely that this site met this criterion at the time of listing and recent information supports this.

Criterion six: Regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.
A site regularly supports more than one percent of the population of a waterbird if the population at the site exceeds the one percent in two out of three seasons for which there is data; or if the mean of the maxima exceeds the one percent level (Ramsar 2009). Moulting Lagoon Ramsar Site regularly supports at least one percent of the global individuals of three waterbird species in Australia (Wetlands International 2006):

- Black swan (*Cygnus atratus*) counts have exceeded this threshold (10000 individuals) in eight years of the 19 years of record (1992 – 2010), with an average maximum count of 10350 individuals.
- Pied oystercatcher (*Haematopus longirostris*) counts have exceeded this threshold (110 individuals) in 14 of the 19 years of record (1992 – 2010), and the average maximum count is 162 individuals.
- Pacific gull (*Larus pacificus*) Victorian/Tasmanian subspecies counts have exceeded this threshold (50 individuals) in 11 of the 19 years of record (1992 – 2010), and the average maximum count is 60 individuals.

It is likely that this site met this criterion at the time of listing as well as currently, even though the evidence is mostly provided after listing.

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

Moulting Lagoon and the Apsley Marshes provide a linkage between the inland waters of the Apsley River and the Southern Ocean. Regular migrations of short-finned eels (*Anguilla australis*), both on their seaward migration to breed as well as returning juveniles, are reported (Hale and Butcher 2011). In addition, black bream (*Acanthopagrus butcheri*) are known to travel via Moulting Lagoon up the drains, into the Apsley Marshes Ramsar Site in order to spawn. Australian grayling (vulnerable, EPBC Act and TSPA) have also been recorded in the river upstream and presumably would use the site as a migratory route during breeding.

It is likely that this site met this criterion at the time of listing as well as currently.

2.4.2 Review of other listing criteria

Beyond the above four criteria, we have assessed the site against the remaining criteria, as discussed below.

Criterion two: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
This criterion is focused on species and communities listed at the international and national level, principally through the EPBC Act. Moulting Lagoon does not support any taxa listed nationally under section 179 of the EPBC Act and/or listed internationally (IUCN Red List). Although there is an isolated record for the Australasian bittern (*Botaurus poiciloptilus*) from the site (PWS 2007) it is possible that the observation was of birds from the nearby Apsley Marshes, where the species is known to regularly occur (Hale and Butcher 2011). Alternatively, it is possible that this species persists separately within the Moulting Lagoon but

lack of survey effort, coupled with the cryptic nature of the birds, has resulted in no recent sightings.

It is currently considered that, the Moulting Lagoon does not meet this criterion. It is unknown if it was met at the time of listing.

Criterion five: A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.
Blackhall unpublished (bird count data updated 2010) has recorded counts of 33 waterbird species since 1992. The largest total waterbird count was 25069 in 2002 (Figure 6) which including 18788 black swan. However the 2002 count was considerably higher than the preceding 10 years and the years following to 2010.

Therefore, the site does not meet this criterion. In addition, it is unlikely that it was met at the time of listing, given the consistency of counts for waterbirds spanning two decades.

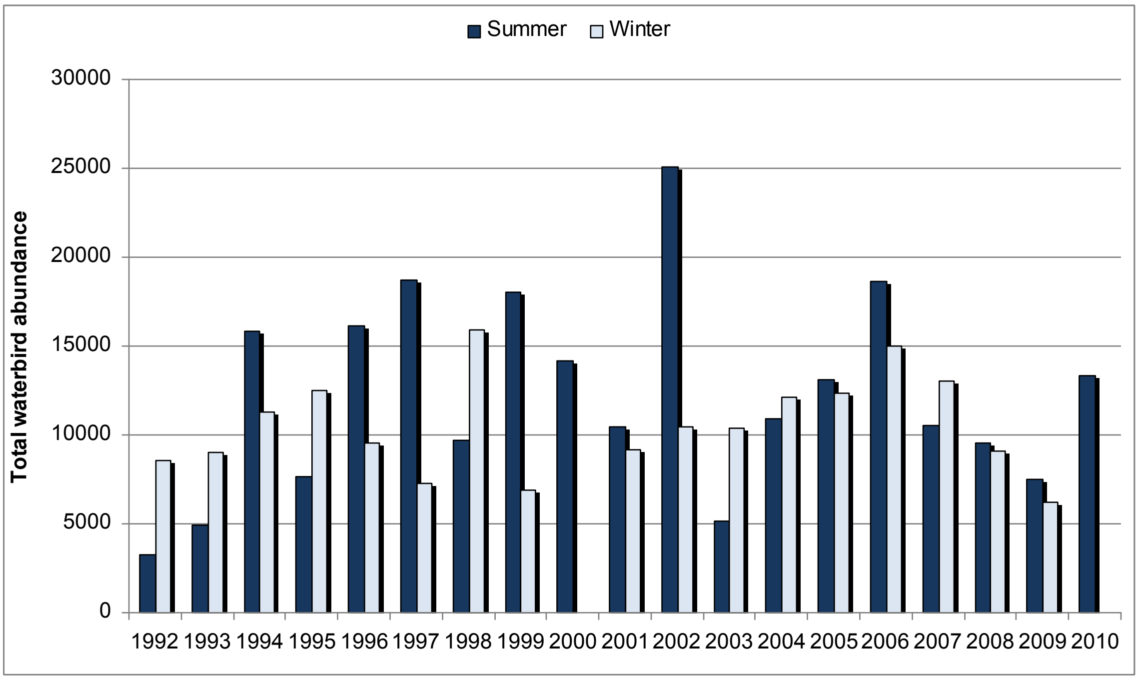


Figure 6: Total number of waterbirds at Moulting Lagoon Ramsar site 1992 to 2010 (S. Blackhall unpublished data).

Criterion seven: 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.
While the estuary also supports substantial populations of fish, the fauna of Great Swanport estuary is similar to those of other open lagoon estuaries in Tasmania. There are no endemic fish to the region present in Moulting Lagoon and while the site is important for fish, the site does not meet this criterion nor was it likely that the criterion was met at the time of listing.

Criterion nine: A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.
There are no data to support this criterion being met at the time of listing or currently.

3. Components and Processes

The production of an ECD requires the identification, description and where possible, quantification of the critical components, processes, benefits and services that characterise the site. Critical components, process and services 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. As a minimum, DEWHA (2008) recommends the selection of critical components, processes, benefits and services as those:

1. that are important determinants of the site's unique character;
2. that are important for supporting the Ramsar criteria under which the site was listed;
3. for which change is reasonably likely to occur over short to medium time scales (<100 years); and
4. that will cause significant negative consequences if change occurs.

The role that components and processes play in the provision of critical ecosystem services should also be considered in the selection of critical components and processes. The linkages between components, processes, benefits and services and the criteria under which Moulting Lagoon Ramsar Site was listed are illustrated conceptually in Figure 7.

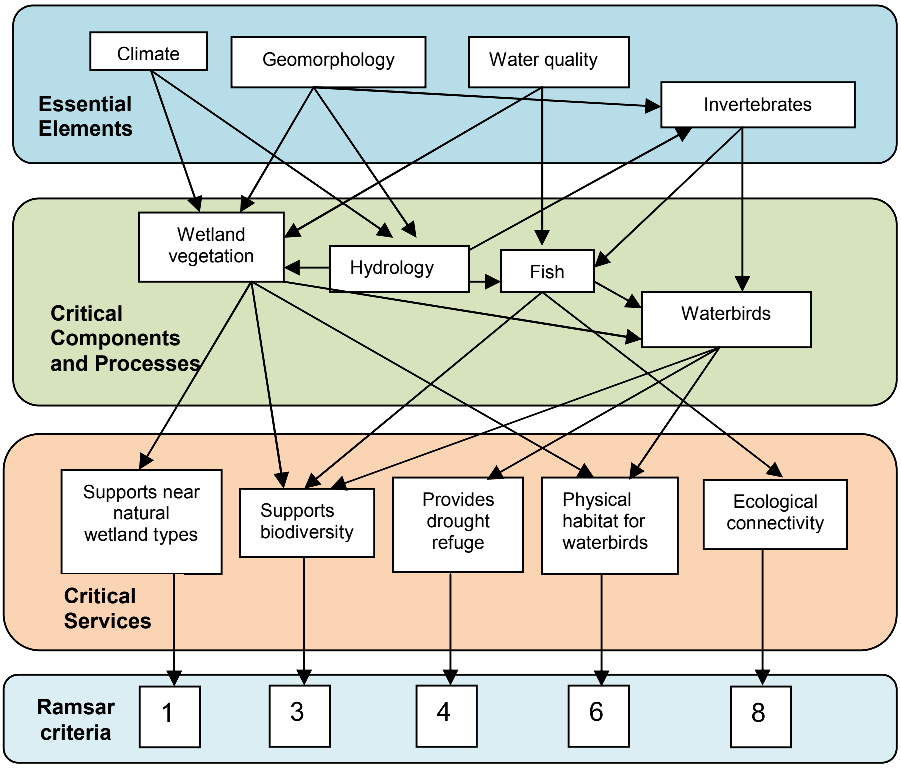


Figure 7: Conceptual model of the components, processes and services of the site, and their links to the Ramsar criteria.

Each of the identified critical components and processes meet the four criteria provided by DEWHA (2008) in that they are central to the character of the site, are directly linked to the Ramsar criteria for which the site was listed, could potentially change in the next 100 years and for which change would result in negative consequences and a change in the ecological character of the site. In addition, they are important in providing the benefits and services that the site provides. The identified critical components and processes of the Moulting Lagoon Ramsar Site are:

- hydrology,
- wetland vegetation,
- fish, and
- waterbirds.

In addition to the identified critical components and processes are characteristics of the site which are not critical (that is, if they were to change, they would not lead directly to a change in character) but are still important in the ecology of the system. These are termed “essential elements” and include some of the characteristics of the site, which may act as early warning indicators of a potential change in character and therefore should be considered in management planning for the site. The identified essential elements for Moulting Lagoon are:

- geomorphology,
- climate,
- water quality, and
- invertebrates.

3.1 Essential elements

3.1.1 Geomorphology

Moulting Lagoon and Great Oyster Bay are located in a graben (or downthrown block) which is an area of the earth’s crust which has fallen relative to surrounding faults and formed following the separation of Antarctica and Australia approximately 80 million years ago. Underlying rocks are predominantly Jurassic dolerite and Permian and Triassic sediments. Up to 300 metres of Tertiary (probably Oligocene – Miocene) sediment also occupies the basin. Rivers flowing through this valley then deposited tens of metres of gravel and clay-rich sediment upstream of a bedrock constriction across the Swan and Apsley valleys. In the vicinity of Moulting Lagoon, these sediments were subsequently eroded by wind action during dry phases of the Quaternary (the last 2 million years) to form a series of deflation basins, connected by stream channels.

In response to rising sea levels, which commenced some 10000 years before present, and fluvial inputs, a mid-bay spit gradually formed at the head of Great Oyster Bay through longshore drift. The increase in width is evident today in a series of sand ridges that run parallel to, but behind, the present frontal dune. This barrier system obstructed the flow of the Apsley and Swan Rivers, resulting in the flooding of basins and bedrock valleys and the deposition of extensive recent alluvial sandy/silt mudflats. A smaller spit, with parallel sand ridges, bars Pelican Bay. This may have formed during an earlier period of sea-level rise, prior to the last glacial period (approximately 120000 years ago). The irregular shape of Moulting Lagoon reflects the topography of drowned deflation basins, bedrock valleys, and associated sediment infill comprising bars and deltas within the estuarine system.

Moulting Lagoon is primarily a wave dominated estuary (Edgar et al. 1999; Ryan et al. 2003). Ryan et al. (2003) define wave dominated estuaries as coastal waterways in which waves are the principal factor in shaping the overall geomorphology. They are characterised by a sandy barrier partially constricting the entrance that is backed by a broad central basin and a fluvial delta, where the river enters the basin. Moulting Lagoon is episodically flushed by two rivers, the Apsley and Swan, and by intermittent flows from adjacent streams. Moulting Lagoon is comprised of two distinct hydro-geomorphic systems: a northern low energy central basin, and a long narrow high energy estuary, which are connected by a topographically constrained narrow neck with channels up to four metres deep (Mount et al. 2005). A barrier (mid-bay spit) at the head of Great Oyster Bay protects the estuarine system from storm waves and slows flushing.

Within Moulting Lagoon are a series of major geomorphic features, (Figure 8) including the Swan River delta (King Bay), low energy shallow basins (Moulting Lagoon, the Sanctuary, Little Bay), fluvial deposits on the periphery of water bodies and 15 islands occupied by saltmarsh communities, intertidal and subtidal flats connected by subtidal channels, sea water channel, tidal and subtidal sand banks, salt pans, beaches and dunes. The diversity of geomorphic and sedimentary environments identified within the Moulting Lagoon system provides a range of benthic and terrestrial habitats.

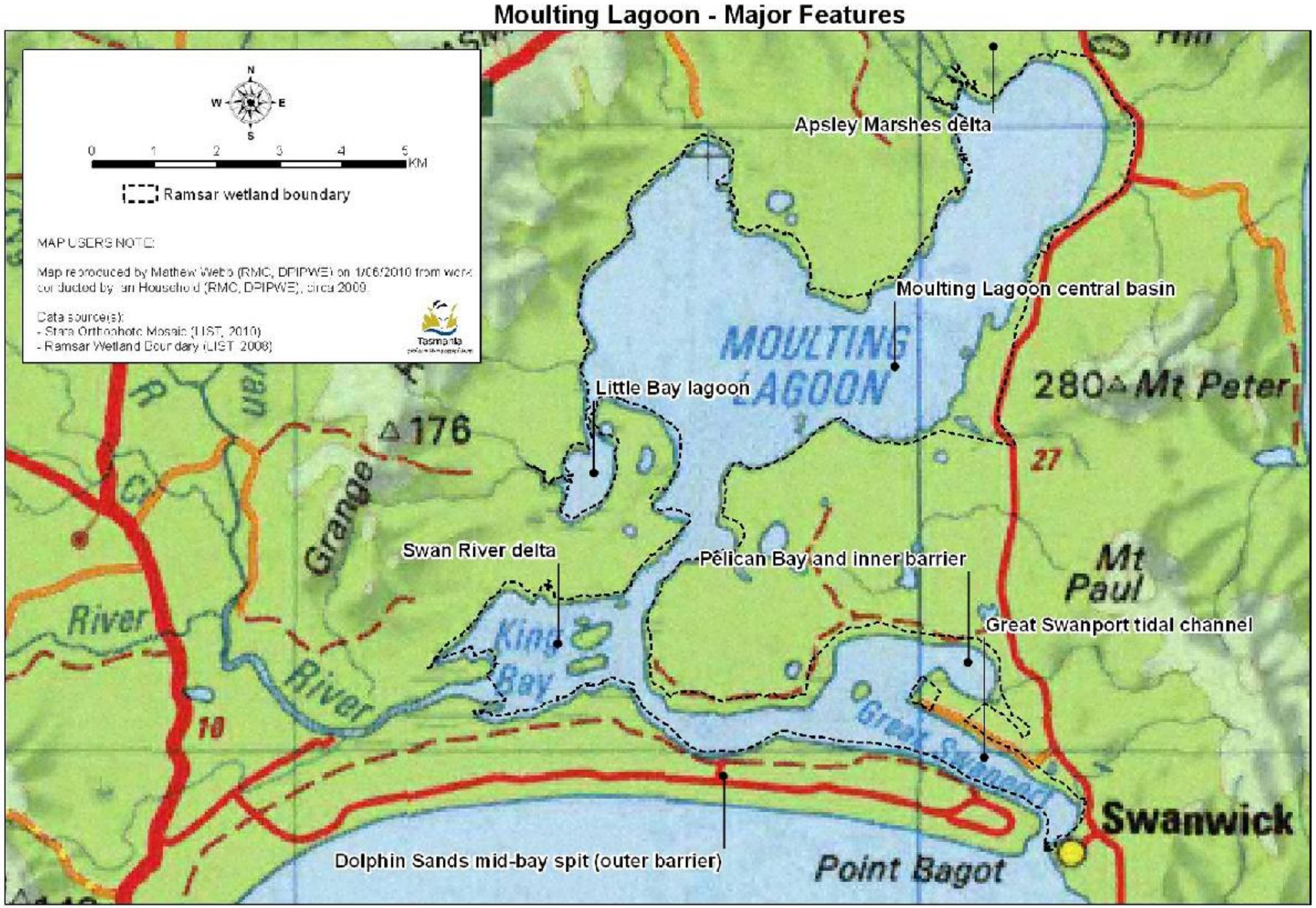


Figure 8: Moulting Lagoon Ramsar site, major geomorphic features.

Estuarine Environments (after Heap et al, 2001)

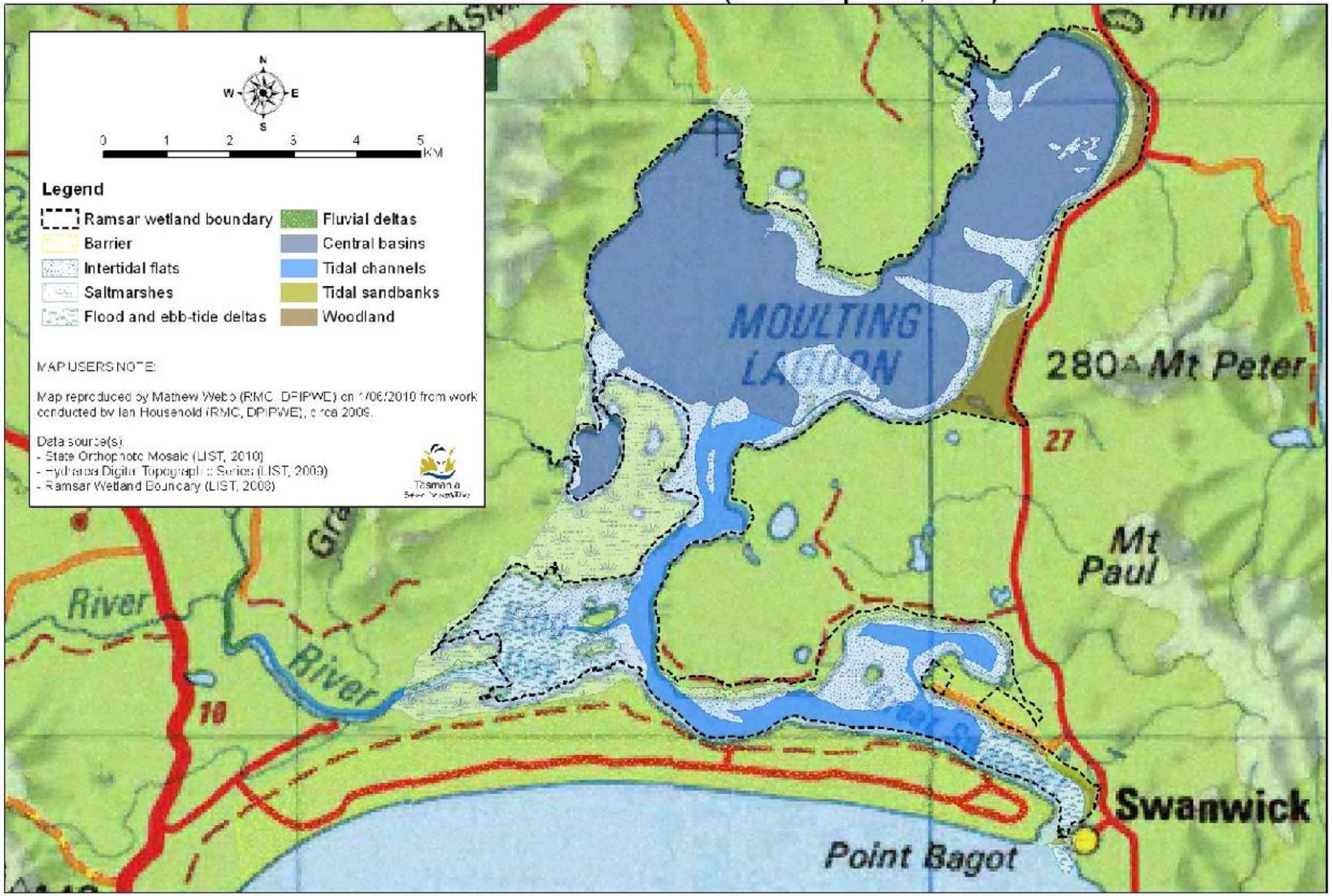


Figure 9: Location of estuarine environments and geomorphic features (after Heap et al. 2001).

Moulting Lagoon is composed of two main estuary types (Ryan et al. 2003). The wave dominated estuary includes the central basin and Great Swanport channel, Pelican Bay and Little Bay; while a tide-dominated delta has formed at the mouth of the Swan River. The estuary has a tidal range of some 0.8 metres near the mouth to 0.3 metres in the central basin. Barometric pressure, wind strength and wind direction play a significant part in the hydrology of the estuary. The estuaries are episodically flushed by two rivers, the Apsley and Swan, and intermittent flows from local streams. Figure 8 and Figure 9 show the location of major geomorphic features, which are discussed in greater detail below.

Central basin

The central basin (1556 hectares), located in the northern sector, is essentially a low-energy shallow water system, with distinct meandering and branching of subtidal flow channels, water bodies with sufficient depth to obscure deeper subaqueous features, intertidal flats and mud flats, areas with lee eddy flows, sheltered water bodies with coarse grained shell flats and/or fine grained mudflats, and several islands (Figure 10). On the periphery of the basin saltmarshes incorporate drainage channels, occasional salt pans, shell grit or sand beaches backed by dunes. The tidal range of 0.3 metres varies in response to fresh water inflows, wind strength and wind direction, and barometric pressure (DPIW 2003). Depth and turbidity of water is influenced by wind (Hughes 1987).

Seawater penetrates the basin during high tides. The salinity gradient varies within and between compartments in the basin in response to changes in climatic elements, river flows, water temperatures, water quality and stratification (Last 1983). Evaporation associated with hot and dry conditions can generate salinity levels more than twice that of seawater (Last 1983; Blackhall 1984).

Rainfall in the catchment flushes large volumes of sediment from the basin, out the estuary mouth, with discolouration of sea water extending to Coles Bay. Sediment sources include reworking of fluvial saltmarshes, land clearance and fluvial erosion in the catchment. A less important sediment source is re-working of bank materials by wave action.

Following a quantitative analysis of 283 of Australia's wave and tide dominated estuaries and deltas, Heap et al. (2004) reported that the accumulation or infilling by sediment in central basins is currently a moderately fast process. Analysis of a series of air photographs of Moulting Lagoon, in addition to oral history, suggests that due to infilling, connectivity between channel drainage networks and intertidal and subtidal flats has been reduced, and that outlets have become constricted. In response to these changes it remains to be determined whether the vertical accumulation of sediment is creating environmental pressure (via a reduction in flushing, an increase in salinity, and fragmentation), leading to a reduction in available habitats, or whether, from an ecological perspective, sediment deposition diversifies available habitats and buffers habitat loss. It may also be that the combination of estuarine and freshwater episodically flushing channels, flats, bays, and lagoons introduces a pulse in the system that provides diversity for feeding and promotes the recruitment of organisms.

To date, no sediment core samples have been collected within the basin to describe substrate composition or phases of deposition. Disturbance by burrowing invertebrates may obscure the latter. The magnitude and frequency of flushing (tidal and fresh water), water turnover and channel flow rates are currently unknown.

Little Bay

Little Bay is a low energy, inundated deflation basin fed by narrow drainage channels from Moulting Lagoon central basin and intermittent flows from a stream. The status of groundwater inputs to this basin is unknown. At the interface between the channels connecting Little Bay with the central basin is a sheltered intertidal and subtidal flat, backed by a shellgrit dune and saltmarsh flats with deflating salt pans (Figure 11). This flat appears to be currently growing into the central basin. Within the inundated deflation basin are extensive flats and a water body (depth of the water body is undetermined).

Figure 10: Clockwise left to right. Central basin view SW: wind driven waves onto NE shore; inter and subtidal flats with channels; Kittys Mistake with saltmarsh zonation, salt pans, and islands. View west of Pelican Lagoon, portion of Great Swanport estuary, barrier, Great Oyster Bay and beach. (Photos: AP Jenny Davis, School of Biological Science, Monash University).

Figure 11: Clockwise from left to right. Swan delta with islands, channel, intertidal flats, view to SE with Great Swanport estuary, barrier and Great Oyster Bay; lagoon, saltmarsh, saltpan and drainage channels complex, eastern portion Pelican Lagoon; Great Swanport estuary, marine channel, sub and intertidal flats; channel connecting Little Bay with intermediate central basin. (Photos: AP Jenny Davis, School of Biological Science, Monash University).

Great Swanport estuary
The Great Swanport estuary is a long, narrow, high energy water body with distinct channel geometries. The primary channels have longer straighter lengths compared with the meandering channels in the central basin and the Swan River delta. Aerial photography indicates that the narrow marine channel is characterised by bare sand on its floor and walls. The marine channel terminates six kilometres up river extending about 450 metres beyond, the primary channel that connects and mixes flows from the central basin with flows from the Swan River delta (Figure 11). Where these two channels overlap there are distinct meander features that taper in width to the east. On the northern shore is an intertidal mudflat, on the south shore a lateral, supratidal saltmarsh. These features may indicate a change in water chemistry accompanied by flocculation of fine sediment, rather than a change in the rate of flow of water. The estuary also has extensive inter-tidal flats, discreet sub-tidal sand beds and sub-tidal flats. There are several branches of the marine channel interspersed by tidal sand banks and sub-tidal flats at the estuary mouth.

Sediment core samples were collected in February 2001 from intertidal flats located on the northern shore of the barrier, opposite the Pelican Bay channel (Aquenal 2001). Analysis revealed a mixture of marine and fluvial sediment sources. Flows range from energetic tidal currents, depositing a mixture of sand and shell-grit, to low energy systems depositing fine silt and clay. Flows are likely to be buffered by sea-grass beds.

Tidal period is diurnal with an average range of half a metre. Exceptions occur, and at nearby Spring Bay (Triabunna) Highest Astronomical Tide (HAT) of 1.832 metres, and a Lowest Astronomical Tide (LAT) of minus 0.03 metres have been recorded. Several studies have addressed water chemistry, including an analysis of the river water of the Swan and Apsley (Hughes 1987), and on the seasonal variations in the estuarine channel located between the Swan River delta and the marine channel transition (Murphy et. al. 2002; Mount et. al. 2005). Last (1983) and Mount et al. (2005) reported vertical salinity stratification in the estuary, whilst Murphy et al. (2002) found no vertical stratification.

Swan River delta
The Swan River delta (King Bay) contains five sedimentary islands with saltmarsh communities, meandering branching channels, as well as intertidal and subtidal flats which drain into the Great Swanport channel (Figure 11). The delta is truncated by current flow in the upper reaches of the Great Swanport estuary. Mount et al. (2005) reported that the primary channel in proximity to the delta has an average depth of four metres, and a ‘substrate of moderately well sorted medium to fine sand with up to 20 percent silt at some locations’. Opposite the delta, east of the primary channel, are a complex of sedimentary environments including subtidal flats, a narrow straight channel, intertidal flats and saltmarsh.

Pelican Bay
Pelican Bay basin has diverse sedimentary environments and geomorphic features, including a spit, with parallel sand ridges, that bars Pelican Bay. On the lee of the bar is a diverse complex of intermittently flowing creeks, a small lagoon, saltmarsh with salt pans, and beaches backed by a low dune. On the periphery of Pelican Bay are extensive low gradient saltmarsh communities with distinct zonation from intertidal to intermittent inundation (Harris and Kitchener 2005). The majority of the lagoon comprises inter-tidal flats of well-sorted medium to fine sand substrate, with small central water bodies and subtidal flats flushed through a narrow meandering channel.

Air photo analysis indicates that Pelican Bay has become shallower, and flow channels have reduced in number, depth, and width, due to deposition of sediment in the lee of the island and at the head of the spit, resulting in reduced connectivity (Figure 11). Due to the combination of decline in water depth and hyper-salinity, Marine Farming Lease 008 (Aquenal 2001, Map one) was relocated into the marine channel. Aerial photographs show shallow dendritic flow channels on the low gradient mud flat located between the island and the marine channel. Deposition of sediment is likely to have significantly altered the flushing regime of this system.

3.1.2 Climate

Tasmania has a temperate maritime climate. The average areal actual annual evapotranspiration for Swansea is 600 millimetres. The Bureau of Meteorology (BoM) records for the period 1884-2007 from Swansea indicates that the mean annual rainfall is 589.9 millimetres, and the mean number of days of rain greater than one millimetre is 69.8 per year.

The general rainfall pattern is evenly spread throughout the year, with slightly higher falls in the summer months (December, January, February) when the evaporation rate is high (Figure 12). Effective precipitation occurs during late autumn to early spring. An orographic rain shadow occurs on the east coast of Tasmania.

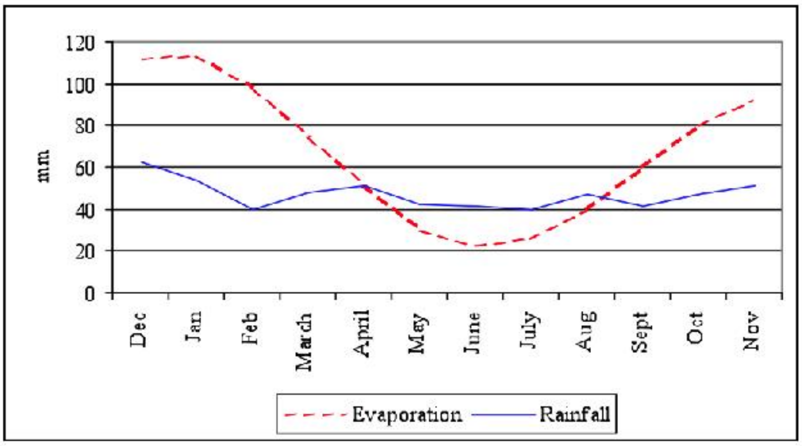


Figure 12: Mean monthly rainfall and evaporation, 1960 to 2006. Data collected at Swansea, located approximately 10 kilometres southeast of the centre of Moulting Lagoon (BoM Hobart 2007).

BoM records from Swansea for the period 1960 to 2006 indicate that the mean annual maximum and minimum temperatures are 17.9 degrees Celsius and 7.7 degrees Celsius. January and February are the warmest months with maximum and minimum temperatures of 22.2 and 11.7 degrees Celsius respectively; the coolest month is July when maximum and minimum temperatures are 13.3 and 3.6 degrees Celsius respectively. Data from Swansea over the period 1960 to 1990 indicates a very weak trend towards increasing air temperatures, which is in accord with the findings of McInnes et al. (2004) and McIntosh et al. (2005).

Wind speed (kilometres per hour) is consistently stronger in the afternoon (BoM 2007). Effective wind speed and wind direction for the period late spring to mid autumn (October to March, 3:00 pm reading) originates from the north east (24 percent of all flows), and the proportion of calm wind speeds is low (two percent). The proportion of wind speeds above 21 kilometres per hour is higher (Figure 13). Effective wind flows originating from the south sector, which may be linked with tides obstructing flushing events, are more likely to occur from October to January, and less frequently in other months.

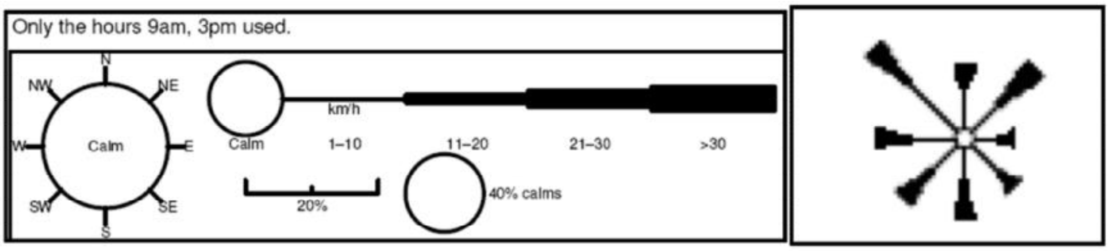


Figure 13: Wind rose data (kilometres per hour) collected at Swansea for the period January 1957 to February 2007, (Source: BoM 2007).

3.1.3 Water quality

Although there have been some investigations into water quality within the Moulting Lagoon Ramsar Site (Hughes 1987; Murphy et al. 2002; and Temby and Crawford 2008), these have all been relatively short studies (up to one year) and provide only a snapshot in time. However, there are clear trends in water quality that were confirmed by all three studies and this forms the baseline for the description of this essential element.

Water quality varies spatially and temporally within the site and is strongly influenced by freshwater inflows from the rivers, which in turn are affected by climate and seasonal patterns. Salinity is variable in areas adjacent to river inflows (Swan and Apsley River deltas) where water can be brackish (as low as 5 parts per thousand) during later winter and early spring when river flow is greatest (Temby and Crawford 2008), but near sea water (30 parts per thousand) during late summer and autumn (Murphy et al. 2002). Conversely, salinity near the mouth varies little and remains on average, approximately 35 parts per thousand year round (Murphy et al. 2002). Hypersaline conditions (45 parts per thousand) have been observed in areas such as Sherbourne Bay, which are distant from both tidal exchange of the mouth and river inflows (Temby and Crawford 2008). Despite the variability in salinity, the water column remains well mixed and salinity stratification is not known to occur. This is probably due to the shallow-pan nature of the lagoon (approximately one metre deep), allowing wind forces to drive mixing.

Turbidity is generally low (less than 5 NTU) across the site (Temby and Crawford 2008). However, the Apsley River is known to discharge significant loads of suspended sediment and this can result in elevated turbidity near the freshwater inflow during winter and spring (Hughes 1987; Temby and Crawford 2008).

Dissolved oxygen can also vary seasonally and spatially. Anoxic conditions were observed near Apsley Marshes during summer of 2007/2008, which coincided with a large amount of decaying organic matter (seagrass wrack and cygnet carcasses) at the site. In contrast, dissolved oxygen levels at the sites with better/higher flushing capability (such as lower Moulting Lagoon) were relatively stable and generally remained higher than 80 percent saturation (Temby and Crawford 2008).

Typically pH levels are similar to that of marine waters ranging from 7.5 to 8.3 (Temby and Crawford 2008). However, in winter 2007, elevated pH levels of up to 9.5 were recorded, indicating alkaline conditions. The potential causes of the anomaly remain unknown, but conditions returned to normal in spring.

The Swan and Apsley Rivers discharge nutrients into the Ramsar site, resulting in a pattern of increased nutrients following peaks in river flow (Hughes 1987; Temby and Crawford 2008). Despite this, chlorophyll-a concentrations remained stable year round during 2007 and 2008 and for the most part were less than five micrograms per litre (Temby and Crawford 2008). The exception to this was adjacent to the Apsley Marshes where chlorophyll-a peaked at over 130 micrograms per litre during December 2007 (Temby and Crawford 2008).

3.1.4 Invertebrates

Information on the invertebrate fauna of the site is scanty. There has been no integrated study or systematic long-term sampling of potentially rich and certainly important habitats for invertebrates either within the water body or the adjacent foreshores or saltmarshes.

Edgar et al. (1999) sampled the benthic fauna at Woolshed Point, in the estuary just downstream of King Bay (Swan River delta). Thirty-six invertebrate taxa were collected, all widely represented in Tasmanian estuaries. In a Multi-Dimensional Scaling (MDS) analysis, the benthic invertebrate community at Moulting Lagoon lay at the approximate centroid of the array. The main groups collected were crustacea (16 species), gastropods (eight species), followed by polychaetes (six species), bivalves (three species) and three other taxa. From 30 cores, a total of 4406 individuals were collected, with a biomass of 13.8 giving a productivity of 174.8 micrograms per square metre per day. This is a moderate level of productivity common in Tasmanian estuaries. The 4406 individuals were numerically dominated by a single species, the micro-clam, *Arthitica semen*.

Whilst there have been no studies of the pelagic invertebrates of the estuary or the lagoon, Last (1983) provides evidence of a range of invertebrates inhabiting the water column and within the extensive seagrass beds as key food sources for the estuarine fish. Analysis of stomach contents of all the fish captured showed that Crustacea were the dominant food source, though there was variation in percentage composition according to the sites.

Invertebrate fauna have been recorded for two saltmarsh sites in a one-off sampling (Wong et al. 1993). One saltmarsh site on the eastern shore of the main lagoon exhibited low species diversity (three species) while a second site in the Swan estuary mouth indicated a wider range of fauna (11 species). This state-wide survey of saltmarsh invertebrate fauna concluded that 'salinity, organic content and moisture content of the soil do not control animal distributions or the composition of the saltmarsh fauna'. However, the duration of inundation was influential on the species composition.

3.2 Critical Components and Processes

3.2.1 Hydrology

Moulting Lagoon receives a largely natural flow regime with minimal impact from water allocation in terms of the flow regime components that influence the hydrological character (M. Read, DPIPWE, personal communication, 2009). The total yield of the Swan - Apsley catchment at the entry into Moulting Lagoon is 339 000 megalitres.

The majority of the water allocation from the Swan – Apsley Catchment is for irrigation (10 835 megalitres), with the remainder used for stock and domestic water supply (1669 megalitres) (DPIWE 2007). Water is drawn from the Apsley River for the domestic supply of Bicheno and Coles Bay.

Hydrologic inputs include precipitation, ground water discharge, and surface or near surface inflow sourced potentially from tides, flow from river and stream channels and from higher water table levels in the wetland (Brinson 1993). Hughes (1987) reported that the mean annual runoff (MAR) for the Swan and Apsley catchments at 142 millimetres, is comparable, with those of semi-arid regions in Australia and the world, where the UNESCO classification for semi-arid regions is 50 – 250 millimetres.

The Swan River (catchment area: 682 square kilometres) and Apsley River (catchment area: 228 square kilometres) (Figure 14) provide freshwater input to Moulting Lagoon and both of these rivers have highly variable flow (DPIWE 1998). Fluctuations in flow significantly affect salinity in parts of Moulting Lagoon (DPIWE 1998).

Whilst trends in rainfall are difficult to determine, due to the spatial distribution of the rainfall stations in Tasmania, the relatively short 35 year record, and the confounding influence of interdecadal variations, be they natural or anthropogenic, some patterns can be seen. Figure 15 shows that the catchment received above average rainfall for the period 1969-1971, (averages of over 900 millimetres per year). This three-year period of higher than average rainfall was associated with a lower than average maximum air temperature. For the same period, above average peak flows were recorded for the Swan River at The Grange stream gauge. The period 1979 to 1994 received below average rainfall for 62 percent of this interval, which is reflected in the below average flows. Sixty eight percent of maximum and 56 percent of minimum air temperatures were above average for the 1979 to 1994 period. There has been a significant reduction in annual runoff since 1979 and this is important because the decrease in estuarine freshwater inflows is likely to have a significant effect on estuarine processes over time.

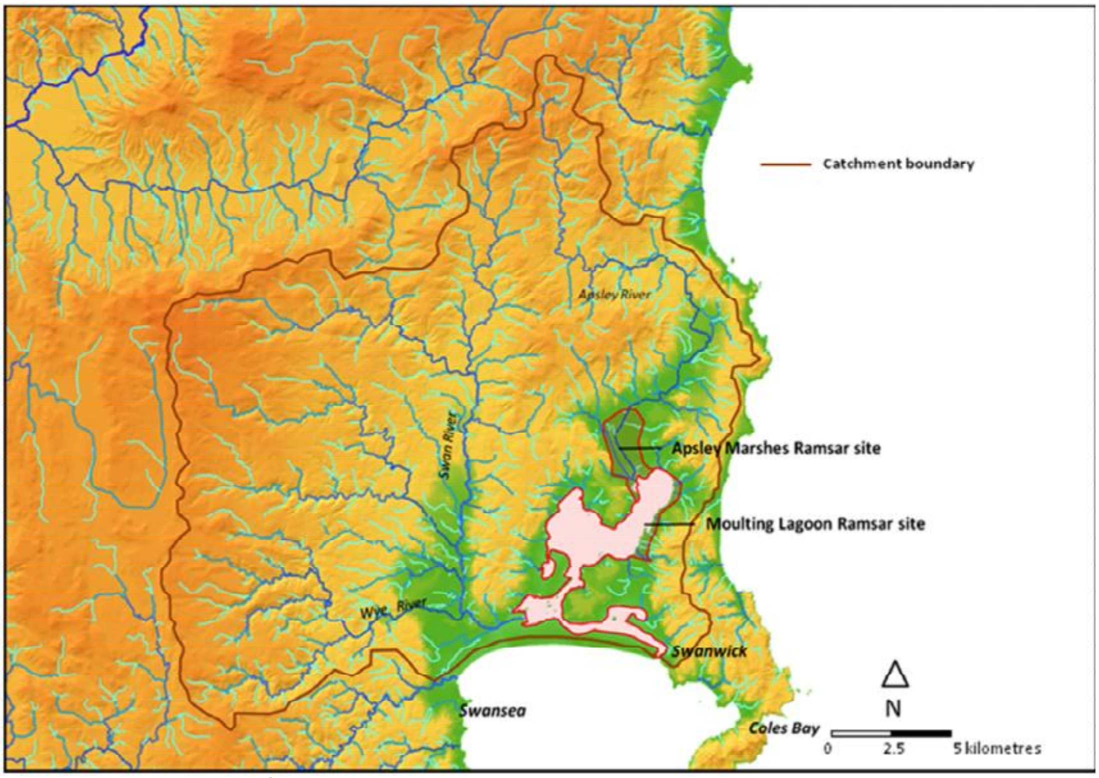


Figure 14: Location of Moulting Lagoon Ramsar site showing streams and drainage.

East coast streams in Tasmania are characterised by high magnitude, low frequency (episodic) stream flow events in summer and more consistent moderately high flow events in winter. This is evident in stream flows monitored for the Swan and Apsley catchments as recorded by DPIPWE through the Water Information System of Tasmania (WIST 2009).

The functional capacity of the site is regulated by the hydrogeomorphic attributes of the low energy shallow basins, where the quality of water suitable to sustain an appropriate hierarchy of habitats for swans, several species of seagrass, and fin fish species, is influenced by freshwater inputs (base and peak flows). These inputs are regulated by low annual rainfall and low mean annual catchment runoff accompanied by a high variability in annual flow from both rivers, with the greatest variability occurring in monthly flows particularly in the low flows.

Salinity and turbidity are controlled by tides, evaporation rate, fresh water flushing, wind generated 'set-up' of water level and suspension of sediment. Effective connectivity within the wetland ecosystem is maintained through the meandering channels which transport bidirectional flows of fresh and high tide water into basins, which flush the seagrass beds located on the lower intertidal and subtidal flats, and provide corridors for fin fish.

The principal function of the channels is the maintenance of effective connectivity within the wetland ecosystem. Variability in the energy of flows is influenced by rainfall and tides, providing a temporal and spatial variability within the system, including the flushing of flats, and the transporting of chemicals/nutrients/sediment into and out of the different hydrogeomorphic features. Spatial diversity in channel morphologies contributes towards the diversity in aquatic habitats. The bidirectional flow of fresh, estuarine or marine waters provides corridors for migrating and breeding fin fish, and a range of habitats for different seagrass species on the walls of the channels and abutting subtidal and intertidal flats.

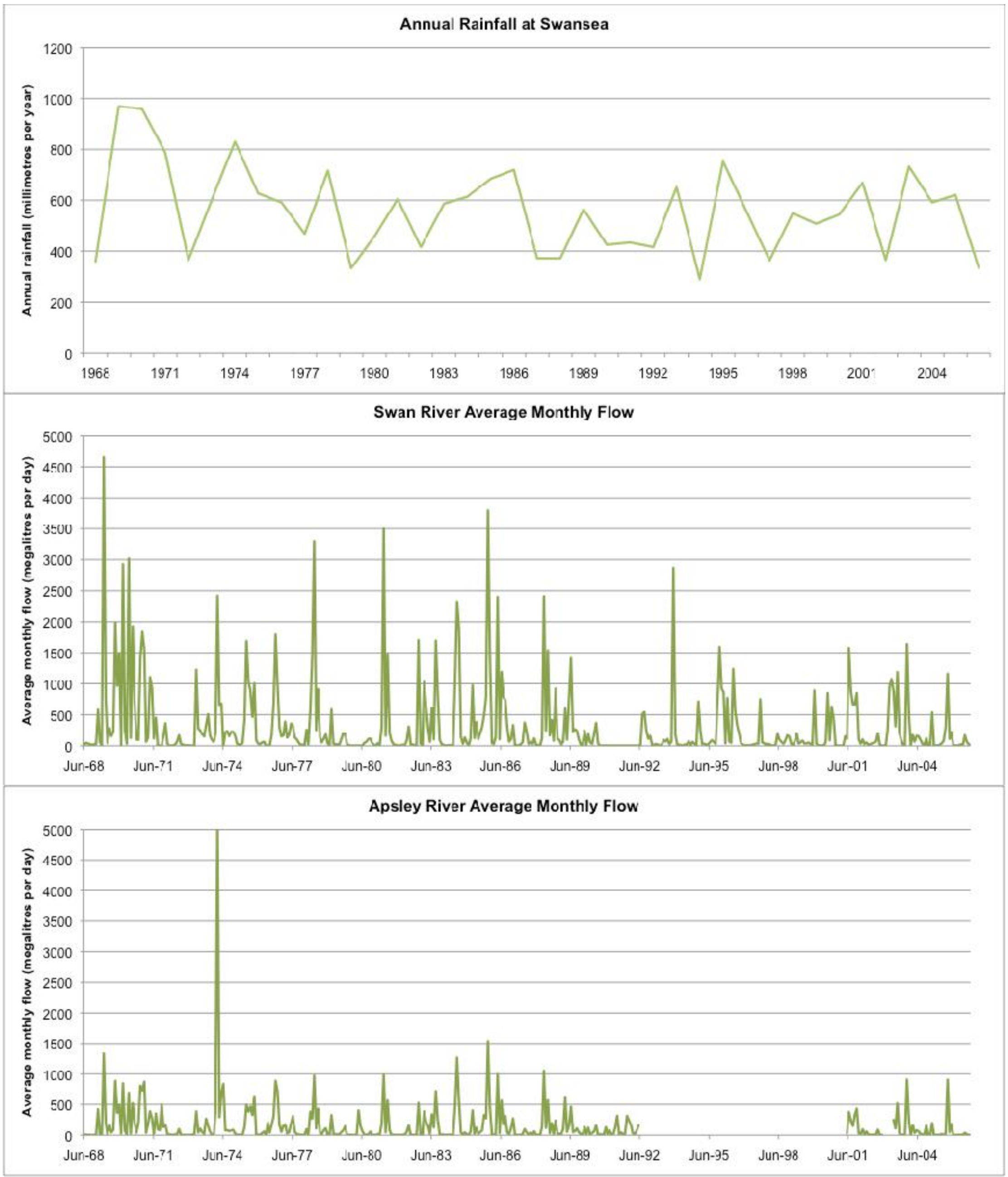


Figure 15: Comparison of the annual rainfall and river flows for the period 1968 – 2006. Rainfall recorded at Swansea; flow recorded at stream gauges located at Swansea Grange and Apsley upstream at Coles Bay Road. Source: BoM, Swansea; and WIST (The Water Information System of Tasmania). Note that flow data for the Apsley River from 1992 to 2000 is unavailable.

3.2.2 Wetland vegetation

The boundary of the Moulting Lagoon Ramsar site, for a large proportion of the perimeter, follows the high water mark. As such, the majority of the vegetation within the site is at the least inundation tolerant, if not inundation dependent. While there may be small areas of terrestrial native vegetation within the site that are important in terms of management of the Moulting Lagoon Game Reserve, these are not related to the “wetland” values of the site and are therefore not considered critical to the ecological character of the Moulting Lagoon Wetland of International Importance.

The Management Plan for the Moulting Lagoon Game Reserve (PWS 2007) which covers a larger area than the Ramsar site, indicates that 13 plant species listed under the Tasmanian TSPA occur “in and around” the game reserve (Appendix 2). Moulting Lagoon is recognised as being important for the conservation of some of these species such as: large fruit sea tassel (*Ruppia megacarpa*; rare) and the spreading watermat (*Lepilaena patentifolia*; rare) both of which are marine angiosperms; southern swampgrass (*Amphibromus neesii;* rare), which is found at Charlie Diglers Hole; and native broom (*Viminaria juncea*), for which Moulting Lagoon is the only known Tasmanian population (DPIPWE 2010). However, how many of the 13 species occur within the Ramsar site and are important to the ecological character of the site remains unknown.

The critical vegetation associations which support other components of the site are seagrass / *Ruppia* beds and salt marsh which are described in detail below. A diversity of aquatic plants are found in the small areas of freshwater around the main lagoon (for example *Triglochin procerum, Myriophyllum* spp. and *Eleocharis sphacelata*). Other species of water plants and algae, including *Chara* species, occur notably within the central basin where the distribution varies with depth, salinity and turbidity.

Seagrass beds

Extensive seagrass beds (Figure 16) are present in the Great Swanport estuary and smaller areas of the central basin (Rees 1993; Mount et al. 2005). The seagrass beds of Great Swanport are dominated by *Heterozostera tasmanica* with *Zostera muelleri* in the intertidal areas Mount et al. (2005) and Rees (1993). *Ruppia* occurs extensively in the lower salinity areas of the central basin of Moulting Lagoon and in the mouth of the Swan River (Hughes 1987; Lucieer et al. 2009). Mapping of seagrass (Mount et al. 2005) and Lucieer et al. (2009) indicates that there is 2205 hectares of *Ruppia* spp.; approximately 940 hectares of seagrass (*Heterozostera tasmanica* and *Zostera muelleri*) and approximately 50 hectares of macroalgae within the site (Figure 17).

Figure 16: Seagrass beds and channels off Long Point. Note dead trees stranded on shoreline, possibly washed down Apsley River in flood.

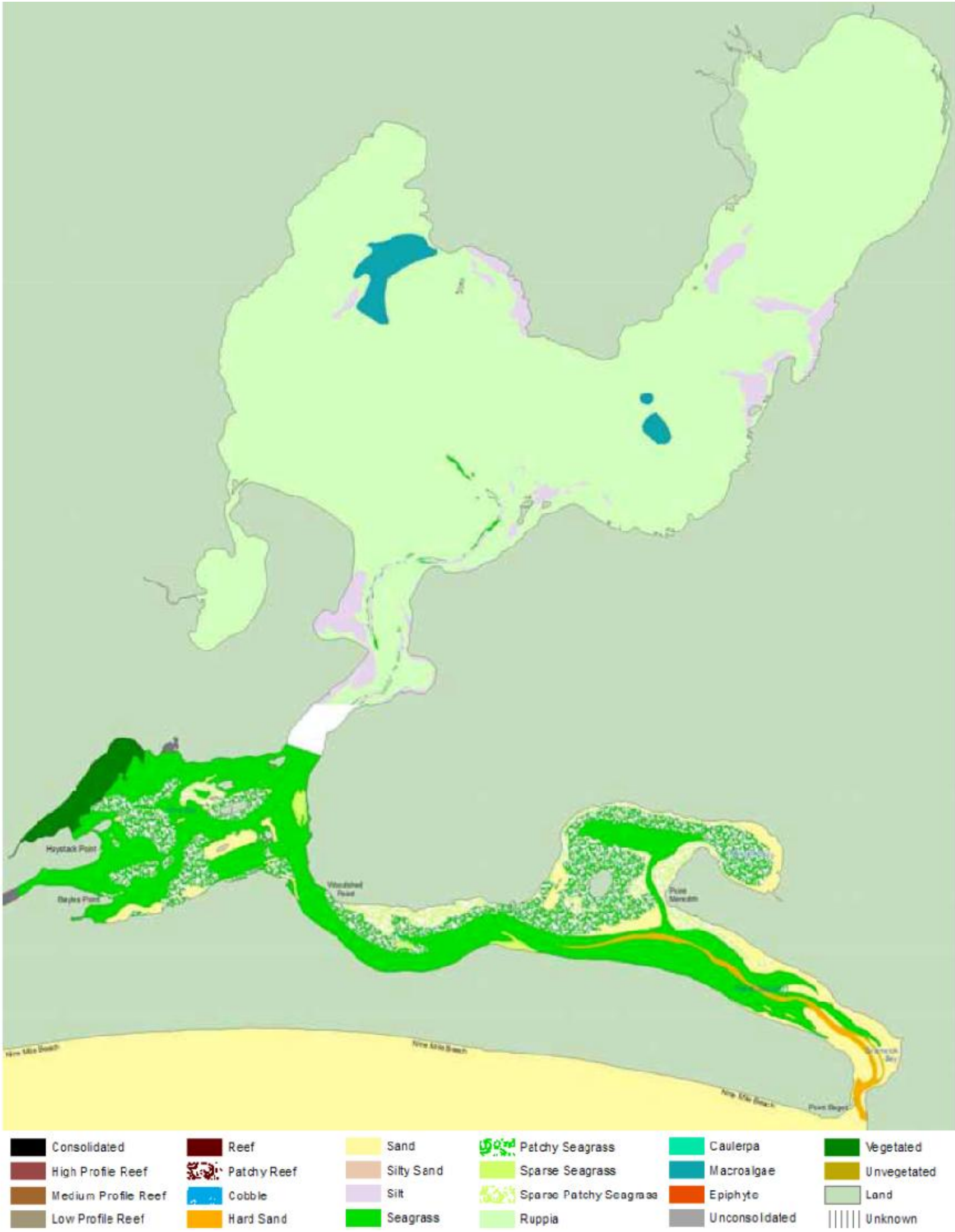


Figure 17: Distribution of seagrass in the Moulting Lagoon Ramsar site (Temby and Crawford 2008).

Seagrass/ microalgal assemblage

Recent work indicates there is a cyclical pattern of population dynamics between seagrass and microalgae. Indications are that the assemblage has an internally generated asymmetrical long term (25 to 30 year) dynamic inclusive of physical factors and other biotic components of the ecosystem (Barry Gallagher, University of Tasmania, personal communication).

Ward (1985) demonstrated a transition threshold for resuspension of bottom sediments below a certain dry weight density of seagrass. Resuspension of sediments, by wind or other factors, can lead to reduced light penetration and ultimately loss of seagrass and a shift to an alternative stable state dominated by microalgae. Gallagher (University of Tasmania, personal communication) suggests that the likely transition biomass threshold for the Little Swanport area is 175 grams seagrass dry weight per square metre. Densities below this level are suspected to predispose the system to increased resuspension of bottom sediments with an increase in microalgal productivity and biomass. After this point, wind resuspension kicks in to a low light algal dominated stable state.

Moore (2004) suggests that whilst existing seagrass beds recover from resuspension events where bed biomass exceeded 50–100 grams dry matter per square metre or 25–50 percent vegetative cover, unvegetated sites are less resilient. An unvegetated site that previously supported seagrass demonstrated little capacity to reduce measurable levels of suspended particles or nutrients, and resuspension of bottom sediments contributed to higher levels of suspended particle concentrations and turbidity in the unvegetated shallows compared to adjacent waters. The capacity of seagrass beds to improve local water-quality conditions such as turbidity and nutrients, during the spring when suspended particle concentrations are highest, may be key to their continued long-term survival in the lower bay region.

Saltmarsh

Moulting Lagoon has extensive halophytic saltmarsh communities, both succulent and graminoid, which are associated with fluvial sediments forming islands or flats bordering saline water bodies whose water levels fluctuate in response to tidal or river flows (Figure 18). Sediment sources originate from erosion within the catchments and erosion of the banks of the Swan and Apsley Rivers (riverine sediment), reworking of in situ sediments by wave action, and probably from organic production within the marsh. In the lower reaches of the estuary there is also the influence of reworked marine sediments.

Saltmarsh communities in their various geomorphic elements have not been subjected to detailed analysis in Tasmania, apart from work done by Kirkpatrick and Glasby (1981). Nevertheless, the different geomorphic settings for saltmarsh development and expression are evidence of the diversity of saltmarsh ecosystems within Moulting Lagoon and indicative of the site's importance for this vulnerable community type. The majority of the saltmarshes occur in embayment marshes (intermediate central basin), with areas of back-barrier (Pelican Bay basin), deltaic marshes (Swan River estuary) and small areas of fringing estuarine marsh (Great Swanport estuary).

On the periphery of Moulting Lagoon, the location and zonation of saltmarsh species occur in response to frequency of flooding with lower marshes being flooded daily and higher marshes being flooded at irregular periods. Salinity of the inundating water and salt build up from evaporation between flushing events also influences zonation. *Tecticornia arbuscula* may have had a more extensive distribution in the past at Moulting Lagoon. Blackhall (1986) suggests that grazing pressure especially by cattle has had a particular impact on the succulent shrubs. In addition to the earlier grazing pressure, observations made during field work suggest that flats exposed to prolonged wave action are eroding, resulting in the reduction of suitable habitat. A comparative example is the north eastern sector of the central basin where a low foredune has been eroded accompanied by several metres of retreat (S. Blackhall, DPIPWE, personal communication 2009). On the same flat in the lee of an island, a remnant of shellgrit foredune remains and clusters of *Tecticornia arbuscula* in association with *Sarcocornia quinqueflora* occur. Similarly, on the Long Point sheltered shore a low shellgrit foredune has a substantial low shrubland of *Tecticornia arbuscula*. This area had been grazed by sheep until 2006. The isolated *Tecticornia arbuscula* plants located at Pelican Bay require further work to resolve the reasons underlying the reduction in abundance of this species, changes in salinity or inundation regime may also be a contributing factor. This plant species may be an indicator of changes within the Moulting Lagoon system. Examples of saltmarsh from within the Ramsar site are illustrated in Figure 18 to Figure 21.

Figure 18: Saltmarshes at Moulting Lagoon Ramsar site, foreground succulent saltmarsh with drainage channels and ponding, background graminoid saltmarsh with adjacent intact natural backing vegetation, eastern shoreline of Moulting Lagoon.

Figure 19: Zones of graminoid and succulent saltmarsh with bare ground at Kitty's Mistake.

Figure 20: Succulent saltmarsh shrubland of *Tecticornia arbuscula* at Long Point on low shellgrit dune.

Figure 21: *Tecticornia arbuscula* forms a dense shrubland abutting the extensive Sarcocornia marshland around Little Bay.

3.2.3 Fish

The estuarine environment at Moulting Lagoon provides habitat for a range of fish communities and species (Last 1983). The fish fauna of Great Swanport estuary is similar to those of other open lagoon estuaries in Tasmania, with a total of 36 species from within its limits representing about 60 percent of all species found in open lagoons in Tasmania. The communities respond to differing salinity regimes and benthic substrates. The two channel sites where seagrass is abundant (Main channel and Yellow Sandbanks) exhibit the greatest similarity of fish communities and the highest number of species. The presence of higher salinities and a sandy bottom at the estuary mouth and Pelican Bay is confirmed by the abundance of bottom feeders, such as flounder species, while active free swimmers such as mullet (*Aldrichetta forsteri*), prettyfish (*Atherinosoma presbyteroides*) and *Nesogobius sp*. are common at the faster flowing site at the estuary mouth. The highest number of individuals occurs at Barney Ward's Bay, dominated by a single species, hardyhead (*Atherinosoma microstoma*).

Species tolerant of more brackish conditions such as flathead (*Pseudaphritis urvillii*) and hardyhead occur in areas most remote from the river mouth (Yellow Sandbanks and Barney Wards Bay). Two goby species particularly tolerant of extended meso- or oligo-haline conditions (*Pseudogobius olorum* and *Favonogobius tamarensis)* may be considered indicator species of the estuarine salinity regime (Last, personal communication 2006). Habitat preferences and tolerances for the most numerous species are shown in Table 3. Dominant species in the community at each of the sampling sites is shown in Table 4.

Table 3: Preferred habitat of most numerous fish species at Great Swanport (Last 1983).

Common name	Species	Spatial*	Substrate	Locality	Salinity range (ppt)	Temp range °C
Garfish	*Hyporamphus melanochir*	P	Sand	Estuary	23.3-34.8	10.5-26.4
Hardyhead	*Atherinosoma microstoma*	B.P	Brackish weed and seagrass	Middle and upper estuary	0.5-34.3	6.0-27.7
Prettyfish	*Atherinosoma presbyteroides*	B.P	Sand and seagrass	Lower estuary	1.0-35.0	6.0-27.7
Pipefish	*Urocampus carinirostris*	Bv	Brackish weed and seagrass	Middle and upper estuary	0.5-34.6	7.8-24.4
Pipefish	*Stigmatophora nigra*	Bv	Seagrass	Lower and Middle estuary	5.8-34.8	6.0-23.1
Soldierfish	*Gymnapistes marmoratus*	B	Sand and seagrass	Upper estuary	0.5-34.0	6.8-23.1
Mullet	*Aldrichetta forsteri*	B.P	No clear preference	Middle estuary	0.5-34.8	6.0-27.7
Flathead	*Pseudaphritis urvillii*	B	Sand and seagrass	Lower and middle estuary	0.5-30.4	6.1-27.7
Goby	*Favonigobius tamarensis*	B	Sand and seagrass	Lower and middle estuary	0.5-34.6	6.0-27.7
Goby	*Nesogobius sp 2*	B	Sand	Lower estuary	1.0-34.8	6.0-23.5
Goby	*Pseudogobius olorum*	Bb	Mud and brackish	Upper estuary	0.5-31.9	6.0-27.7
Flounder	*Ammotretis rostratus*	Bb	Sand	Lower estuary	1.0-35.0	6.8-23.0
Flounder	*Rhombosolea tapirina*	Bb	Sand	Lower estuary	0.5-35.0	6.0-26.4

*Spatial: P= Pelagic, B.P = Benthopelagic, B = benthic, Bv= benthic amongst vegetation, Bb = benthic burrower.

Table 4: Occurrence of the five most frequently occurring species from Great Swanport estuary sites (Last 1983).

Site	Name	Common name	Occurrence % of samples
Estuary mouth	*Rhombosolea tapirina*	Flounder	92
	Aldrichetta forsteri	Mullet	85
	Ammotretis rostratus	Flounder	85
	Atherinsoma presbyteroides	Prettyfish	77
	Nesogobius sp 2	Goby	62
Main channel	*Nesogobius sp 2*	Goby	100
	Favonigobius tamarensis	Goby	92
	Aldrichetta forsteri	Mullet	85
	Atherinsoma presbyteroides	Prettyfish	77
	Stigmatopora nigra	Pipefish	77
	Rhombosolea tapirina	Flounder	77
Pelican Bay	*Atherinosoma microstoma*	Hardyhead	100
	Aldrichetta forsteri	Mullet	100
	Rhombosolea tapirina	Flounder	100
	Favonigobius tamarensis	Goby	92
	Atherinsoma presbyteroides	Prettyfish	77
Yellow Sandbanks	*Atherinosoma microstoma*	Hardyhead	100
	Aldrichetta forsteri	Mullet	92
	Favonigobius tamarensis	Goby	85
	Urocampus carinirostris	Pipefish	85
	Atherinsoma presbyteroides	Prettyfish	77
	Gynapistes marmoratus	Soldierfish	77
	Pseudaphritis urvillii	Flathead	77
Barney Wards Bay	*Atherinosoma microstoma*	Hardyhead	100
	Aldrichetta forsteri	Mullet	85
	Pseudogobius olorum	Goby	77
	Pseudaphritis urvillii	Flathead	62
	Favonogobius tamarensis	Goby	62

Ten of the most numerous fish species are known to spawn within the Moulting Lagoon estuary (Last 1983). Table 5 shows spawning areas and seasons.

Hardyhead, the gobiid *Pseudogobius olorum* and the sygnathid *Urocampus carinirostris* appear to spawn in the less saline conditions of the upper and middle estuary, while the pipefish, flathead, gobiids *Nesogobius* sp 2 and *Favonogobius tamarensis*, cobbler, and flounder are found in spawning condition in the lower areas of the estuary. The black bream and flathead are also known to use the area for spawning. *Galaxias maculatus*, a freshwater species that migrates into estuaries to spawn, occurs in upper reaches of the estuary. The seagrass beds are believed to be important for attachment and protection of eggs for some fish species (Last 1983).

The largest proportion of the most abundant species that spawn in the estuary favour spawning periods of summer and early autumn, possibly associated with the time of greatest hydrological stability (Last 1983). Few flounder occur as mature adults despite their large numbers, suggesting that the estuary is particularly important as a spawning ground and habitat for juveniles. The Great Swanport estuary may be a secondary breeding area for the gummy shark (*Mustelus antarcticus*) (P. Last, personal communication 2006).

Black bream (*Acanthropagus butcheri*) inhabit the lower reaches of the Swan River and the drains in the Apsley Marshes as adults migrating upstream to spawn. Black bream can tolerate a wide range of salinities (0 parts per thousand to over 35 parts per thousand), and freshwater discharges as well as salinity influence their distribution. Successful spawning of this species requires salinity above about 10 parts per thousand because eggs sink when water is too fresh and float when water is too salty.

Native short finned eel (*Anguilla australis*) have been seen both in Moulting Lagoon and the adjoining Apsley Marshes where they are regularly observed by the landowner. The Australian grayling (*Prototroctes maraena*) has been recorded in the Apsley River upstream of both sites and must migrate through Moulting Lagoon and Apsley Marshes to complete its lifecycle.

Table 5: Relative numbers, maturity and spawning information for the most numerous fish species (Last 1983).

Common name	Species	No. of individuals	Size class range mm	Ppn. of adults (%)	Spawning period	Spawning Locality
Garfish	*Hyporamphus melanochir*	953	60-300	0.8	Summer	Marine
Hardyhead	*Atherinosoma microstoma*	21515	10-100	99.9	Aug-Jan	Estuary (upper)
Prettyfish	*Atherinosoma presbyteroides*	13933	10-100	65.6	Sept-Feb	Estuary (lower)
Pipefish	*Urocampus carinirostris*	83	45-105	94.7	Nov-Jan	Estuary (middle and upper)
Pipefish	*Stigmatophora nigra*	917	25-140	70.7	Jan-Feb	Estuary (lower and middle
Soldier Fish	*Gymnapistes marmoratus*	240	30-185	54.5	Sept-Oct	Estuary (mouth)
Mullet	*Aldrichetta forsteri*	5409	20-370	0.4.	Spring	Marine
Flathead	*Pseudaphritis urvillii*	197	25-230	45.1	Sept-Oct	Estuary (lower and middle)
Goby	*Favonigobius tamarensis*	930	15-90	97.4	Nov-Feb	Estuary (lower and middle)
Goby	*Nesogobius sp 2*	519	20-90	73.1	Sept-Feb	Estuary (lower)
Goby	*Pseudogobius olorum*	126	15-45	95.0	Nov-Feb	Estuary (upper)
Flounder	*Ammotretis rostratus*	677	10-310	0.1	Continuous (mainly early spring)	Marine (off-shore)
Flounder	*Rhombosolea tapirina*	620	10-330	3.8	As above	Marine (off-shore and estuary)

3.2.4 Waterbirds

Ninety three native species of bird have been recorded at Moulting Lagoon. This includes 53 species of waterbirds (Appendix 1), with seventeen species listed on the JAMBA, the ROKAMBA and/or the CAMBA. Three waterbird species are listed under the Tasmanian TSPA: white-bellied sea eagle (*Haliaeetus leucogaster*; vulnerable), eastern curlew (*Numenius madagascariensis*; endangered) and great-crested grebe (*Podiceps cristatus*; vulnerable).

The Moulting Lagoon area offers a range of different habitats and resources for bird life. Waterfowl, notably swans, occur in large numbers at Moulting Lagoon while migratory waders feed in shallow intertidal areas in the summer months. Other species use the marshland, saltmarshes, woodland and adjacent pastures, while gulls and seabirds use the area to feed and roost. Population counts for waterbirds from summer and winter over the period 1992 to 2010 are presented in Figure 22.

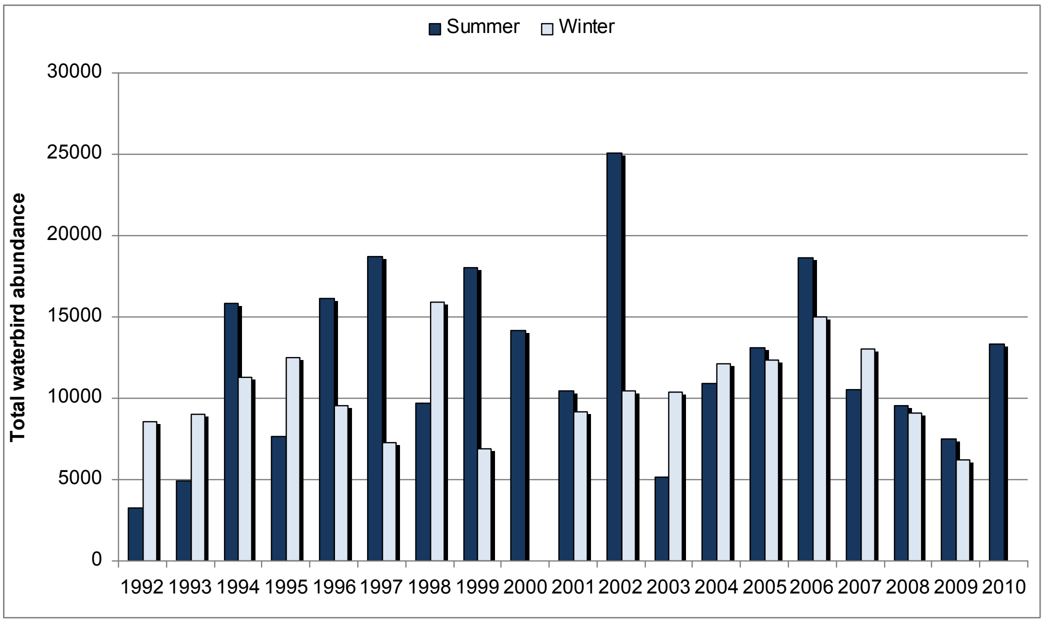


Figure 22: Abundance of waterbirds at Moulting Lagoon 1992 – 2010 (S. Blackhall, unpublished data).

Black swan

Black swan (*Cygnus atratus*) are the most obvious and numerous birds in the area, accounting for over 50 percent of total numbers of waterbirds in most years (Figure 23). It has been estimated that historically up to 85 percent of the swan breeding in Tasmania occurred at Moulting Lagoon (Hemsley 1973) with records over a period of 30 years indicating numbers up to 18 000 birds (PWS 2007). Moulting Lagoon is the prime site for black swan in Tasmania. Numbers exceed one percent of the total Australian estimated population on a regular basis (Figure 24). Large numbers of black swan are seen throughout the year, although the flocks move around Moulting Lagoon. The swans feed on aquatic vegetation including the dominant seagrass *Ruppia* species and other vegetation within and adjacent to the central basin. In the more saline areas further downstream and in Great Swanport, the swans feed on the dominant seagrass *Zostera*. Their feeding behaviour in the seagrass beds can dislodge the tuberous roots of the plants and disturb sediments and benthic habitats. Habitat use in and around Moulting Lagoon is summarised in Table 6.

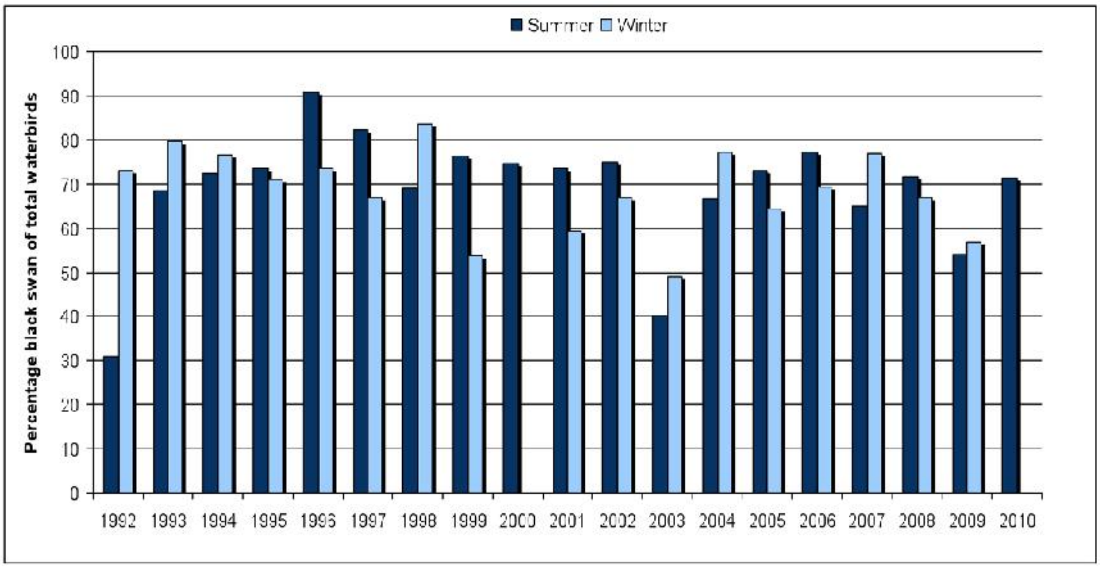


Figure 23: Percentage of black swan of total waterbirds at Moulting Lagoon Ramsar site 1992 to 2010 (S. Blackhall, unpublished data).

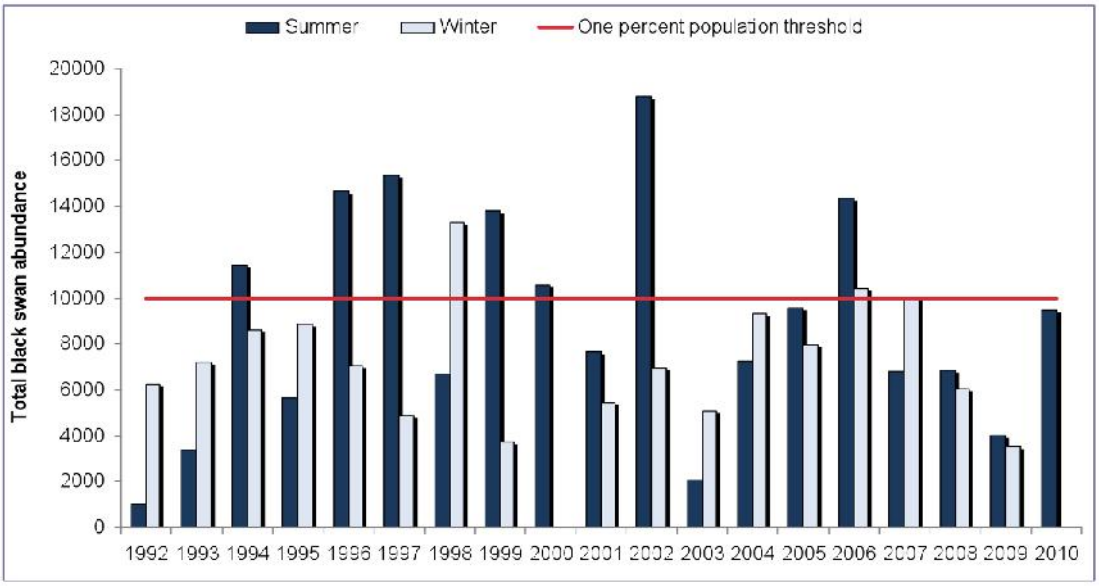


Figure 24: Numbers of black swan at Moulting Lagoon Ramsar site from 1992 to 2010 (S. Blackhall, unpublished data).

Table 6: Habitat use in the Moulting Lagoon Ramsar site by black swans (based on Guiler 1966).

Area	Features	Use by swans*
The Sanctuary	Very shallow open water	F, N, R
Apsley marshes	Freshwater marshes, densely vegetated	**F, N**
Moulting Lagoon	Shallow with some deeper channels, sandbanks and islands with saltbush	**N, R, F**
Sherbourne Bay	Shallow, Sabina Is	**N, F, R**
Watsons Bay	Shallow	**F, R**
Little Bay	Very shallow,	F, R
The Neck	Navigable depth, rocky shoreline	some F, R
King Bay	Shallow with sandbars	**F, R**
Pelican Bay	Shallow	F, R
Great Swanport estuary	3-5 m deep channel	F, R only in shallows along the edge

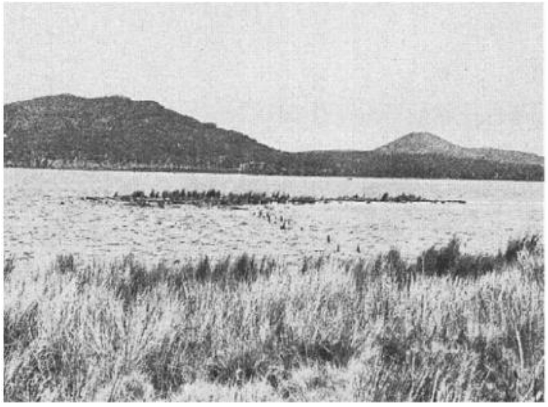
*F=feeding, N=nesting, R=roosting, **bold** = very important for

Moulting Lagoon provides suitable nesting areas for swans amongst low-lying vegetation largely isolated from human disturbance (Figure 25). The estuarine system also provides food resources for adult birds and freshwater necessary for drinking water for the cygnets. There are 11 islands in the lagoon, suitable shorelines with tussock or low scrub and shallow sandbars on which swans may build up so-called ‘lagoon’ nests from the seagrass and other vegetable material (Guiler 1966).

Swans also favour the adjacent Apsley Marshes on the northern edge of the eastern arm of the lagoon. During the breeding season many adults feed in the nearby bay. Within the Ramsar site, major breeding sites are around Sherbourne Bay and on Sabinas Island, the islands along the shoreline between Grassy Point and Cockatoo Islands and the southern area of the Lagoon in the bays near Long Point.

Rainfall and water levels in the central basin play a significant part in determining the pattern and success of breeding, which is largely confined to winter and spring with the peak months being August and September. The swans can delay nesting until suitable conditions occur and may extend the breeding season in favourable conditions (Hemsley 1973). The main onset of nesting activity is recorded as varying from late June to August. Hemsley (1973) observed that in the drier years of his study, the number of nests and eggs fell to levels one third to one quarter of normal, and that cygnet survival was ‘virtually nil’ (p6). Even in ‘good’ years, the survival of cygnets is dependent on post-hatching conditions, including availability of food sources and fresh water.

Table 7 illustrates the impact of dry seasons on breeding success. In the low rainfall years of 1968/9 and 1972/73, the mean number of eggs per nest was lower but the overall yield of cygnets was reduced to zero, with no broods reported surviving.



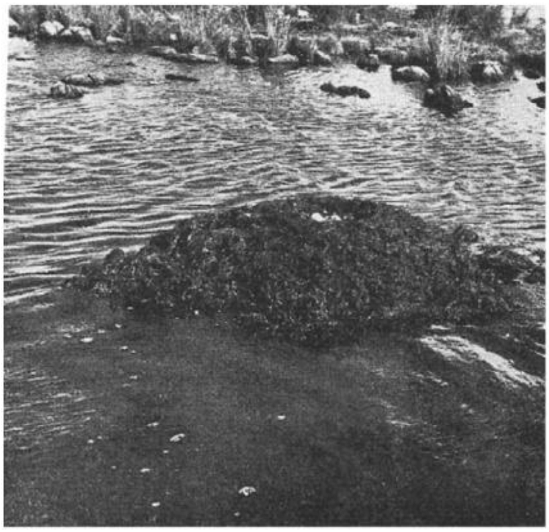


Figure 25: Swan nests in Moulting Lagoon (Guiler 1966).
Clockwise left to right:
Nesting areas viewed near Top Bank
Lagoon nest
Nests and markers on Pelican Island

Table 7: Breeding success of black swan at Moulting Lagoon (Hemsley 1973).

Year	Nests	Eggs	Mean eggs/nest	Broods	Cygnets	Mean cygnets/brood
1967/68	1930	8708	4.5	511	1582	3.1
1968/69	515	1914	3.7		Nil	
1969/70	1966	9655	4.9	671	2727	4.1
1970/71	2103	9340	4.4	443	1587	3.6
1971/72	2727	12 446	4.6	654	2057	3.1
1972/73	612	2120	3.5		Nil	

The Apsley River and small creeks feeding the central basin are subject to flash flooding. If the Lagoon is subject to a sudden large input of freshwater coupled with high tides and strong southerly winds, the central basin level rises rapidly, resulting in flooding of the nests. Nests can be washed away by floods, an event which occurred in 1960 (Guiler 1966).

The nature and condition of vegetation on islands favoured for nesting has an impact on the number of nests. Sabinas Island was a prime nesting area in the 1960s-early 1970s but had declined by 1984 (Blackhall 1986). Blackhall suggests that in comparison with photographs taken in 1970 the open understorey of tussock below a canopy of *Allocasuarina stricta* had changed to dense and impenetrable shrubs of exotic African boxthorn *Lycium ferocissimum*. The boxthorn shrubs have since been removed, but there has not yet been an increase in breeding activity possibly due to the many recent dry years. Change has also occurred to the prime nesting sites on Cockatoo and Top Bank Island where the tussock cover has declined and the islands 'are now nearly devoid of vegetation except for a few annual weeds' (Blackhall 1986). This may be a consequence of 'wear and tear' by the swan, though scouring by floods may have contributed.

Surrounding private land around Sherbourne Bay and the northern arm of the lagoon has largely been cleared of native vegetation, with the exception of the Apsley Marshes, and stock trample the foreshore, reducing the potential for suitable nesting sites for swans.

Other waterbirds
Sixteen species of waterbird were recorded in the early 1980s (Montague 1983) while current records (see Appendix 1) list 53 species. Australian shelduck (*Tadorna tadornoides*) and chestnut teal (*Anas castanea*) are the most numerous of the nine species of ducks. Grey teal (*Anas gracilis*) may occur in significant numbers from time-to-time: it is a highly nomadic species and breeding success varies from year to year (Montague 1983). This species may move to Tasmania from inland Australia in the summer months and in times of drought on mainland Australia. Pacific black duck (*Anas superciliosa*) often remain in the same location during the year and through their lifetime (Montague 1983). Pacific black ducks prefer relatively fresh, deep permanent water surrounded by heavy vegetation, hence are largely confined to particular sites on the eastern and northern shoreline. Grassy islands appear to be the favourite breeding habitat of chestnut teal (Montague 1983). Australian shelduck may be seen on the muddy shorelines but prefer to nest in thickly vegetated sites. Ducks use Moulting Lagoon primarily for feeding and resting (S. Blackhall, DPIPWE, personal communication 2009). Breeding is likely to occur in nearby marshland (Apsley Marshes), local waterways and woodlands.

The two sedentary species, black duck and chestnut teal, largely feed on seagrasses. Some 50 percent of the crop contents of the four main species of duck was found to be seagrass *Ruppia* spp.(Blackhall 1984). Other food sources from the central basin of Moulting Lagoon include algae and other aquatic flora, although for all duck species sampled this was supplemented by food sourced from nearby paddocks (Blackhall 1984).

Other common waterbirds at Moulting Lagoon include Eurasian coots (*Fulica atra*), white-faced herons (*Egretta novaehollandiae*), and great cormorant (*Phalacrocoras carbo*) and little pied cormorants (*P. melanoleucos*).

Gulls and seabirds
Silver gull (*Larus novaehollandiae*) and Pacific gull (*Larus pacificus*) are the dominant gulls, while crested terns (*Sterna bergii*) use the sandy beaches near the mouth of Great Swanport as roosting sites. Caspian terns (*Hydroprogne caspia*) occur in small numbers on a regular basis but counts do not exceed the one percent threshold of 1000 for the Australian population of this subspecies (Wetlands International 2006). Moulting Lagoon regularly supports more than one percent of the population of Pacific gulls, exceeding the threshold of 50 birds regularly (Figure 26).

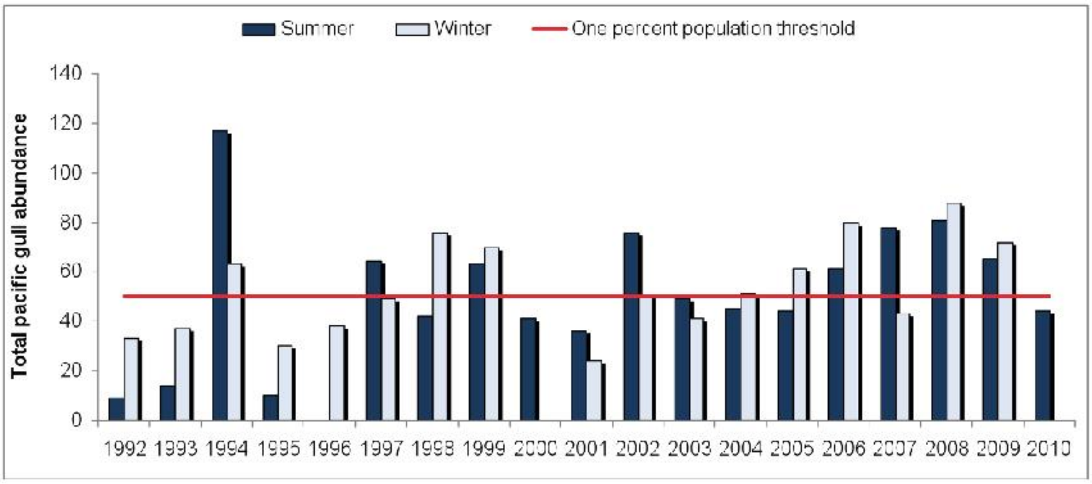


Figure 26: Numbers of Pacific gull at Moulting Lagoon Ramsar site from 1992 to 2010 (S. Blackhall, unpublished data).

Waders

Twenty two species of resident and migratory waders have been recorded at Moulting Lagoon (see Appendix 1.) It is an important location for pied oyster catchers and counts of this species have exceeded one percent of the Australian population threshold of 14 of the past 19 years (Wetlands International 2006) (Figure 27).

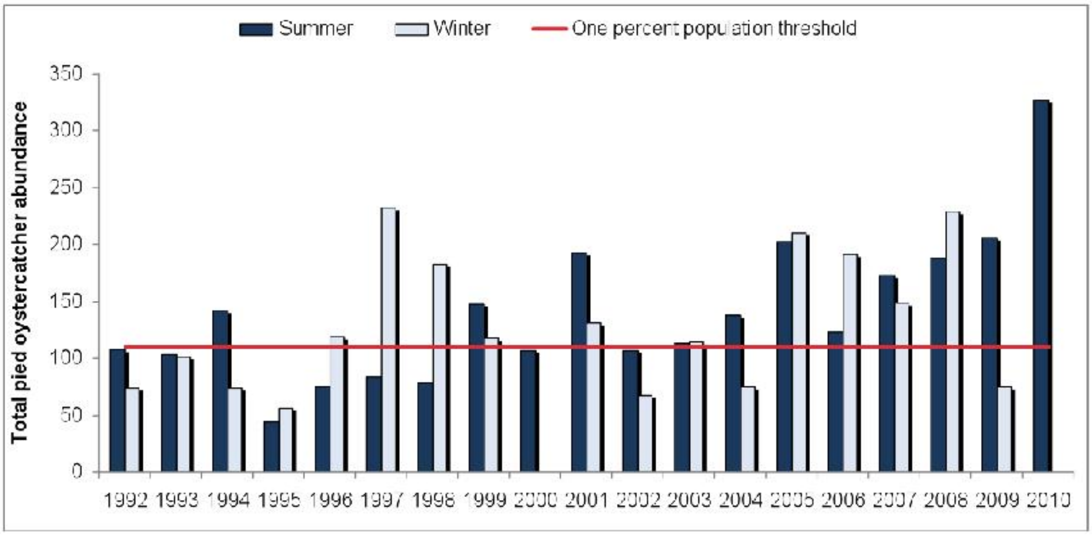


Figure 27: Numbers of pied oyster catcher at Moulting Lagoon Ramsar site from 1992 to 2010 (S. Blackhall, unpublished data).

Nine species of migratory waders use the area, particularly the lower estuary at King Bay and Pelican Bay along the intertidal mudflats (PWS 2007; Wakefield 1984; Schokman 1991). Numbers are not large, and systematic counts have only taken place since 1992. Six species only appear in these recent counts and of these six, curlew sandpiper and black-fronted plover only occur occasionally.

The double-banded plover (*Charadrius bicinctus*) breeds in New Zealand in spring and early summer, migrating to south-east Australia to over-winter. It is common around Moulting Lagoon between February and August. Most of the other migratory species use Moulting Lagoon as a stopover and feeding site during the summer, although small numbers of the eastern curlew and other species have been recorded during winter (Blackhall 1986). Moulting Lagoon and nearby areas are considered an important site for the greenshank, with the largest numbers in the state recorded at King Bay (Wakefield 1984).

The area in the delta of the Swan River in King Bay has an adequate food supply and undisturbed roost sites at all states of the tide, so it is the most important locality for waders (Wakefield 1984). It has a large exposure of mudflats and roosting spots on stakes in the river or dead trees nearby, once the tide covers the flats. This area is especially favoured by greenshank and eastern curlew. Curlew sandpiper and red-necked stint are more frequent around Little Bay and the nearby western bay of the main lagoon, sheltered from the prevailing wind. Pelican Bay is a shallow bay with extensive *Sarcocornia* flats interspersed with tidal pools. These attract sharp-tailed sandpiper and golden plover, while double-banded plovers feed among the saltmarsh (Wakefield 1984). Wakefield (1984) notes that records suggest that flocks of waders have also been observed between Middle Bank and Top Bank in the main lagoon, but he did not observe any in the years 1978 to 1983.

Other avian species of particular conservation significance
A number of avian species significant for conservation (Table 8) have been recorded at Moulting Lagoon and its immediate hinterland. Some are listed under legislation or international agreements; for others, the habitats of the site are of particular importance.

Table 8: Other avian species for which Moulting Lagoon is an important habitat.

Common Name	**Species**	**Status**
Eastern great egret	*Ardea modesta*	JAMBA/CAMBA
Cattle egret	*Ardea ibis*	JAMBA/CAMBA
Caspian tern	*Hydroprogne caspia*	JAMBA/CAMBA
Lesser sand plover	*Charadrius mongolus*	JAMBA/CAMBA/ROKAMBA
Wedge-tailed eagle*	*Aquila audax fleayi*	Vulnerable under TSPA Endangered under EPBC Act
Great-crested grebe	*Podiceps cristatus*	Vulnerable under TSPA
Grey-tailed tattler*	*Heteroscelus brevipes*	JAMBA/CAMBA /ROKAMBA
Pacific golden plover	*Pluvialis fulva*	JAMBA/CAMBA /ROKAMBA
Double banded plover	*Charadrius bicinctus*	Migratory species
Hooded plover	*Thinornis rubricollis*	Considered at risk, Tasmania a stronghold
White-bellied sea eagle	*Haliaeetus leucogaster*	Vulnerable under TSPA

* Not a waterbird or dependent on wetlands.

4. Benefits and Services

For the purposes of the Ramsar convention, ecosystem services are defined in accordance with the Millennium Ecosystem Assessment (MEA) definition of ecosystem services as 'the benefits that people receive from ecosystems' (Millennium Ecosystem Assessment 2005).

As noted in the ECD Framework document (DEWHA 2008), the economic, social and cultural benefits people receive from ecosystems rely on the underlying ecological components and processes that sustain the wetland. Ramsar values focus on ecological perspectives on 'services' and these are central to the ECD. The components and processes that support these services are also critical in supporting other types of services, such as cultural services. A summary of the benefits and services supplied by the Moulting Lagoon Ramsar site are presented in Table 9.

Table 9: Summary of benefits and services provided by Moulting Lagoon Ramsar site.

Provisioning services – products obtained from ecosystems.	
Wetland products.	Commercial oyster farming.
	Fish breeding area.
Regulating Services – benefits obtained from regulation within the ecosystem or as a result of ecosystem services.	
Pollution control and detoxification.	The Estuary forms an important sediment trap for the Swan and Apsley Rivers. Seagrass beds are likely to capture organic and inorganic chemicals carried in the flow of fresh water.
Cultural Services – non- material benefits that people obtain from the ecosystems through emotive and cognitive experiences and responses.	
Recreation.	Moulting Lagoon is a popular area for fishing, duck hunting and boating.
	Passive recreational activities such as bird watching and photography are very common uses of the reserve.
Tourism.	Moulting Lagoon is nearby to the Freycinet National Park and as such forms part of a major tourism destination for Tasmania.
	.
Spiritual and inspirational.	Moulting Lagoon plays an important role in defining the character of the East Coast of Tasmania. It features along with Freycinet and the Hazards in iconic scenery and symbolism of wilderness and freedom.
Scientific and educational.	Moulting Lagoon has been the site of considerable research over several decades, notably saltmarsh and seagrass ecology.
	Moulting Lagoon provides excellent opportunities for environmental education with schools in the district using it for excursions.
Aboriginal culture.	Moulting Lagoon is significant country for Aboriginal people, bearing extensive evidence of occupation and use.
Supporting services – Services that are necessary for the production of all other ecosystem services including sustaining biodiversity and habitats.	
Near natural wetland ecosystems.	The site contains a number of different wetland types which are relatively undisturbed by catchment development and water abstraction.
Nutrient cycling.	Moulting Lagoon plays a role in cycling and discharge of nutrients from the Swan and Apsley catchments
Sediment trapping, stabilisation and soil formation.	Tidal movement and freshwater flows re-suspend and recycle sediments and maintain sedimentary environments.

Physical habitat (for waterbirds).	Moulting Lagoon provides diversity of intertidal and sub tidal habitats for marine life and shorebirds. The site provides important resting feeding sites for populations of migratory birds and houses the largest populations of black swan in Tasmania. Large numbers of waterbirds are regularly recorded for the site.
Supports priority species.	Moulting Lagoon supports several migratory waders listed under bilateral agreements such as CAMBA/JAMBA/ROKAMBA.
Provides drought refuge.	In dry periods Moulting Lagoon supports significant numbers of waterbirds including species which migrate from the mainland, such as grey teal.
Supports threatened species.	Supports a number of nationally and locally threatened species.
Supports biodiversity.	Supports a range of ecological communities including fish, saltmarsh vegetation, seagrass beds, invertebrates, intertidal flats and benthic environments.
	Supports extensive and diverse areas of threatened communities - salt marsh.
Provides ecological connectivity.	Provides migration path on which fish species depend.

By applying the same guidelines for identifying critical components and processes as outlined in section 3, the following critical services are supported at the Ramsar site:

- supports near natural wetland types,
- provides physical habitat for waterbirds,
- provides drought refuge,
- supports biodiversity including threatened species; and
- provides ecological connectivity.

Several non critical services are briefly described in section 4.2 as these are not captured elsewhere in the ECD.

4.1 Critical services

4.1.1 Supports near-natural wetland types

Moulting Lagoon Ramsar Site is an extensive and complex estuarine ecosystem with relatively few anthropogenic disturbances. Its geomorphic history and origins, along with continuing change and renewal provided by tidal and riverine flows, creates a context for the development and maintenance of diverse geomorphic features and processes.These geomorphic features and process, together with the site's hydrology, create a suite of different habitats including benthic, intertidal, foreshore vegetation and pelagic (within the water column).". Key geomorphic elements within the site also have significance, such as Little Bay, which is a drowned deflation basin representative of a drier palaeoclimate. Significant areas of intertidal saltmarsh, tidal and subtidal sand banks, salt pans, beaches and dunes all contribute to the diversity of the site. Estuarine areas support significant stands of seagrass which in turn support numerous biota. Beds of *Zostera muelleri, Heterozostera tasmanica* and *Ruppia* spp. occur in the middle estuary and around the delta of the Swan River, with the main lagoon almost entirely dominated by *Ruppia* species. It is a near natural representative of the wetland type unaffected by urban development and upstream river abstractions (Edgar et al 1999, DPIWE 2005).

4.1.2 Provides physical habitat for waterbirds

Swan breeding area

Moulting Lagoon is considered the most important breeding site for black swan in Tasmania (Guiler 1966; PWS 2007). It has been estimated that about 85 percent of the swan breeding in Tasmania occurs at Moulting Lagoon (Hemsley 1973) and swan counts regularly exceed one percent of the Australian population (see section 3.2.4). The central basin and its environs provide extensive food sources and suitable low-lying nesting sites, mostly

inaccessible from human interference. Hemsley (1973) suggests that 'an adequate rainfall and buoyant lagoon levels have seemed necessary for optimal response' in determining breeding pattern and success. Initiation of breeding and nesting is dependent upon adequate water levels in the lagoon and availability of fresh water.
The swans use the resources of Moulting Lagoon for feeding and nesting. Vegetated shallow open water provides seagrasses and algae that supply their main food source, while nesting requires shrubby or grassy sites on islands and adjacent land.

Feeding and roosting sites for other waterbirds
Large numbers of ducks and other waterbirds use the food resources and roosting sites at Moulting Lagoon, (Blackhall, 1986; PWS, 2007).

Pelicans roost on Pelican Island (Schokman 1991) and find abundant supplies of fish in the estuary. Other piscivores are regularly recorded in the area, including cormorants (*Phalacrocrax carbo, P. melanoleucos*, and *P. fuscens*), white faced heron (*Ardea novaehollandiae*), crested tern (*Sterna bergii*) and Caspian tern (*Hydroprogne caspia*). Shorebirds include opportunistic feeders such as pied oystercatchers and silver gulls, which utilise food resources across the Ramsar site. Many of these species have been recorded as roosting around Moulting Lagoon amongst the saltmarshes or on the islands or headlands but there are few records of nesting within the boundaries.

The open intertidal flats and shallows of several locations around Moulting Lagoon provide a food source for nine species of migratory waders (Blackhall 1986; PWS 2007). Blackhall (1985) identified the preferred locations: Pelican Bay, King Bay, off the mouth of Little Bay, with occasional records around Grassy Point and Kitty's Mistake (S. Blackhall, DPIPWE, personal communication 2009). Adjacent saltmarshes are used as roosting sites by some species (Schokman 1991).

4.1.3 Provides drought refuge

Moulting Lagoon is known to support large number of waterbirds, particularly black swans (*Cygnus atratus*) and Australian shelducks (*Tadorna tadorniodes*), at key stages of their lifecycles. It provides year-round habitat for around 5000 to 10 000 black swans and is a critical late summer staging area for Australian shelducks, chestnut teal (*Anas castanea*) and several shorebird species. Grey teal (*Anas gracillis*) and other species are known to move from the mainland to Moulting Lagoon during dry periods.

There is evidence that Moulting Lagoon may be acting as a refuge when other waterbodies in the Tasmanian landscape are dry. Some speculation exists that the numbers of swans are excessive and unsustainable for Moulting Lagoon, with eutrophication of the water, damage to seagrass beds and insufficient nesting sites. It is not possible at this stage to ascertain the overall usage patterns by swans.

4.1.3 Supports biodiversity including threatened species

There are limited data or time series on the full extent of species, flora and faunal communities. Such data as exist – for fish in Great Swanport, birds and flora – indicate that Moulting Lagoon is an important area for the maintenance and conservation of biodiversity in the Tasmanian bioregion and the Freycinet IMCRA marine and coastal bioregion. The types of habitats in Moulting Lagoon are vulnerable to disturbance and hence loss of species.

4.1.4 Ecological connectivity

Moulting Lagoon (and the ocean) connects with the Apsley Marshes Ramsar site and inland freshwater environments acting as a migratory route for diadromous fish species. Most migrations are for feeding or breeding. Migratory fish supported by Moulting Lagoon (and the Apsley Marshes) are the Australian grayling, black bream and short-finned eel.

4.2 Cultural and provisioning, non-critical services

4.2.1 Importance to Aboriginal community

The following brief overview, taken from the Moulting Lagoon Game Reserve Management Plan (PWS 2007), presents an archaeological perspective of Aboriginal cultural resources in or near Moulting Lagoon.

Moulting Lagoon was part of the lands occupied by the Oyster Bay Tribe, which included most of the east coast from the Derwent estuary to the Fingal Valley and west inland to the Midlands. The tribe included at least 15 bands with a population of 600 to 800 people (Brown 1991 cited in PWS 2007). A key food resource provided by the site was black swan eggs which were harvested during the breeding season. As many as 80 people would use the lagoon during the swan breeding season and one band, the Linetemairrener, lived permanently at the site (Brown 1991; Ryan 1981; Hemsley 1973 cited in PWS 2007).

In the Moulting Lagoon area only eight sites have been registered on the Tasmanian Aboriginal Site Index, a reflection of low survey effort, and include isolated artefact scatters to middens and quarry sites. Most are located on private land with only one occurring within the boundary of the Ramsar site. Coastal camps were often located further inland in more protected, wooded, areas (Brown 1991 cited in PWS 2007) and as such it is likely that most sites of significance could lie on private lands adjacent to the Ramsar site.

Appropriate management and protection of Aboriginal cultural resources requires the full recognition of values held by the Tasmanian Aboriginal community concerning the Moulting Lagoon area, and the successful transfer of administration of management and protection of Aboriginal cultural resources to the Aboriginal community. Effective and appropriate management guidance of Aboriginal cultural resources in the Moulting Lagoon Ramsar site will be a product of ongoing consultation with the Aboriginal community.

4.2.2 Marine farms

The first leases for farming of oysters were granted in 1978 (DPIW, 1998). The scheduled marine farming zone covers a total area of approximately 583 hectares with a maximum leasable area of 85.68 hectares, all of which is leased and operational. The regulations restrict the species to be farmed to shellfish and seaweed, but only Pacific oysters are in production.

The marine farms are situated in the part of the estuary subject to regular tidal flows and high salinities. Some operators use these sites in conjunction with deeper water off-shore lease areas in Great Oyster Bay (DPIW, 1998). Alternatively, the area is used for nursery oyster production and the small stock is on-sold to other farmers to grow to market size (Blackhall, 1986).

Great Swanport provides a suitable environment for cultivation of oysters, ready access to the oyster racks and convenient on-shore facilities. The area is shallow with a high degree of flushing by tidal action, estimated at 40 percent exchange at neap tides and 80 percent at spring tides (DPIW, 1998). There is no evidence of adverse effects on sea life, birds or water quality (PWS, 2007).

Maintenance of the estuarine water quality is crucial for these marine farms. It has been reported by long-term local residents that unusually high sediment loads, attributed to logging operations in the upper catchment of the Apsley River, cloaked the oysters so badly that the racks had to be hosed down to remove the silt (A. Cole, personal communication, 2006).

The oyster farming provides local employment, a tourist attraction (one is open for visitors and direct sales) and a delicacy offered at local restaurants.

4.2.3 Recreational duck shooting and fishing

Hunting has a long history at the site, both as a recreational pastime and in earlier times as a source of food. Black swans were hunted legally until the last open season in 1971 (Hemsley 1973).

Moulting Lagoon is one of Tasmania's prime locations for recreational duck shooters. The shooting season and restrictions on species and bag limits are controlled under the provisions of the Wildlife Regulations 1999 of the *Nature Conservation Act 2002*, Tasmania.

Around 95 permanent shooting hides exist within the Ramsar site (S. Blackhall, DPIPWE, personal communication 2007). The hides are distributed in the central basin (but not within the 'Sanctuary') and in the Swan delta (King Bay) with a few in Pelican Bay. Approximately 150 shooters visit Moulting Lagoon each season (PWS 2007).

There is also a long history of recreational fishing at Moulting Lagoon, especially in the mouth of the Swan River and in the main estuary. Black bream are considered the most commonly caught sport fish (PWS 2007) and an estimated 2000 were taken in the Swansea fishing carnival in 1983 (Last 1983). This event is no longer held, so current data on bream numbers are unavailable. Other target species include mullet and flounder, the latter traditionally speared on the sandy unvegetated bottom. Hand netting of prettyfish and shrimp occurs in the shallows.

Commercial fishing for eels *Anguilla australis* and *A reinhardtii* is reported in the 1980s (Last 1983) but later declining demand saw this harvesting die out.

Much of the fishing occurs from boats launched at sites scattered around the lagoon, though early reports of the main lagoon being deep enough to travel across in a dinghy suggest that the depth of the main lagoon has become shallower since the early 1980s.

4.2.4 Tourism

The vistas around Moulting Lagoon and the opportunity for a variety of recreational pursuits have attracted visitors since the earliest days of settlement of the region. Fishing, bird-watching and other nature study, photography, walking, boating and camping are popular activities. Vehicle and pedestrian access is available at several locations around the perimeter of the central basin and Great Swanport, while formal and informal boat launching sites are present around the lagoon on both public and private land.

4.2.5 Sediment trapping

Protection of water quality discharging into Great Oyster Bay

The evidence of sediment deposition in Moulting Lagoon indicates that the estuary performs an important role as a sediment trap for discharges from the Apsley and Swan Rivers. The extensive seagrass beds and peripheral saltmarsh vegetation are likely to capture organic and inorganic chemicals carried in the flow of freshwater. Evidence of the high water quality of the Great Swanport estuary is provided in the choice of the site for marine farming (DPIWE 1998).

5. Limits of Acceptable Change

The aim of deriving limits of acceptable change is to make it easier to determine when the ecological character of a wetland is likely to change or when it has changed due to pollution or other human interference (DEWHA 2008).

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.*"

Hale and Butcher (2008) noted problems associated with using extreme measures of a selected parameter and then setting the limits outside those extremes. These include the possibility of missing shifts in character that stay within the extremes, including more frequent events, changes in seasonal patterns, and changes in central tendency (mean/median). As Moulting Lagoon was listed as a Ramsar site in 1982, this ECD describes the site as at that time where possible, and any changes since listing are noted. Much of the information about the site has been collected during the period since listing.

In accordance with the guidelines for preparing an ECD, the limits of acceptable change should refer to the ecological character of the site at the time of listing. That is, the baseline condition refers to the condition as in 1982, and limits of acceptable change are based on that reference condition or statistic. No data existed at the time of listing for some key parameters. In such cases, more recent information is assumed to provide an appropriate baseline when there is no evidence of change in these parameters between 1982 and 2010.

At Moulting Lagoon, some positive changes have occurred, notably the reduction in the numbers and extent of unregulated vehicle traffic and exclusion of grazing stock from several areas in the site. Where change is positive for the long-term maintenance of ecological character, present conditions provide a new baseline and limits of acceptable change must be considered against that benchmark.

It is important to recognise the difference between limits of acceptable change and management triggers. Limits of acceptable change incorporate natural variability (where appropriate) into a quantitative assessment (where possible) of the components that define the Ramsar site's unique character. Using data, expert judgment and the precautionary principle, limits of acceptable change set a quantitative limit which, if breached, will lead to a genuine change in the site's unique ecological character.

In contrast, management triggers represent smaller changes towards exceeding limits of acceptable change (or other resource management goals of the site). This is an important distinction, as management triggers should be set at a level that allows appropriate management responses well in advance of the limits of acceptable change being breached. It is not appropriate to provide management triggers in an ECD, as these must be derived as part of a detailed management plan. However, the information provided in an ECD should be used as part of the management planning process for a Ramsar site.

The following components and processes were identified (Section 3) as critical to the ecological character of the Moulting Lagoon ecosystem:

- wetland vegetation,
- hydrology,
- fish, and
- waterbirds.

The following services were identified (Section 4) as critical to the ecological character of the Moulting Lagoon ecosystem:

- supports near natural wetland types,
- provides physical habitat for waterbirds,
- provides drought refuge,
- supports biodiversity including threatened species, and
- provides ecological connectivity.

All critical components, processes, benefits and services require LAC. However, due to the interrelated nature of components, processes and services, LAC for a particular component may also account for other components, process and services. For example, LAC which address hydrology and vegetation are often suitable for many of the critical services at a site, such as supporting physical habitat, wetland types and many cultural services. If the hydrology or vegetation underwent a significant change, then these impacts would cascade through to other components and potentially lead to a loss of services. LAC for Moulting Lagoon are presented using a hierarchical approach, where LAC set for components are used for critical services where appropriate. The LAC for Moulting Lagoon are shown in Table 10 along with baseline information, and justification for how LAC were derived.

The confidence levels for the limits of acceptable change represent the degree to which the authors are confident that the LAC represents the point at which a change in character has occurred and follow the approach of Hale (2010):

> **High** – Quantitative site specific data; good understanding linking the indicator to the ecological character of the site; LAC is objectively measureable.
>
> **Medium** – Some site specific data or strong evidence for similar systems elsewhere derived from the scientific literature; or informed expert opinion; LAC is objectively measureable.
>
> **Low** – no site specific data or reliable evidence from the scientific literature or expert opinion, LAC may not be objectively measurable and / or the importance of the indicator to the ecological character of the site is unknown.

Additional explanatory notes for Limits of Acceptable Change

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

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

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

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

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

Table 10: Limits of Acceptable Change for the Moulting Lagoon Ramsar site.

Critical Component, Process or Service	Baseline Information and Justification	Limits of Acceptable change*	Confidence level
Hydrology	Moulting Lagoon receives freshwater inflows from the Swan and Apsley Rivers. DPIPWE monitor flow events into Moulting Lagoon at stream gauges located at Swansea Grange and Apsley upstream at Coles Bay Road. This information is stored and accessible via WIST (The Water Information System of Tasmania). There is a relatively high degree of inter annual variability in inflows. For example, from 1968 to 1992 average daily flow during winter ranged from less than 10 megalitres a day to over 5000 megalitres a day (data from State of Tasmania 2010). The tidal influence and estuarine conditions that prevail in the site are critical to the character of the site. However, there is limited information other than tide heights for this source of water. The site supports a range of estuarine wetland types including intertidal mud and sand flats, and sea grass beds. However mapping and other information is insufficient to determine extent and variability at the time of listing. In the absence of sufficient data LAC are based on no change in hydrological wetland types.	No change in wetland hydrological types present within the site. That is, the following hydrological wetland types are maintained: • Dominance of estuarine waters; • Presence of marine subtidal aquatic beds - seagrass beds; • Presence of sand bars, spits, dune systems; • Presence of intertidal mud, sand and salt flats; • Presence of intertidal saltmarsh and salt meadows; and • Presence of brackish to saline lagoons.	Medium
Wetland vegetation - saltmarsh	Some mapping of plant communities has been undertaken as part of the TASVEG program; however extent of saltmarsh vegetation within the Ramsar site is considered a knowledge gap. As such a quantitative LAC for this component cannot be set and will require revision should such information become available.	No less than 90 percent of the extent of saltmarsh communities within the Ramsar site.	Low

Critical Component, Process or Service	Baseline Information and Justification	Limits of Acceptable change*	Confidence level
Wetland vegetation – seagrass	Detailed mapping of seagrass was completed by Mount et al. (2005) (for the Great Swanport estuary part of the site) and Lucieer et al. (2009) for Moulting Lagoon. The combined figures from these studies indicate 2200 hectares of *Ruppia*; 940 hectares of seagrass (mixed *Heterozostera tasmanica* and *Zostera muelleri*) and 50 hectares of macroalgae. The mapping is a single snap shot in time and does not provide an indication in variability. The LAC has therefore been based on an arbitrary figure of 25 percent reduction from baseline mapping.	No less than 1650 hectares of *Ruppia* and 700 hectares of seagrass (*Heterozostera tasmanica* and *Zostera muelleri*).	High
Wetland vegetation – threatened species	The Management Plan for the Moulting Lagoon Game Reserve (PWS 2007), which covers a larger area than the Ramsar site, indicates that 13 plant species listed under the Tasmanian *Threatened Species Protection Act 1995* occur “in and around” the game reserve (Appendix 2). Moulting Lagoon is recognised as being important for the conservation of some of these species such as: large fruit sea tassel *Ruppia megacarpa* (rare) and the spreading watermat *Lepilaena patentifolia* (rare) both of which are marine angiosperms; southern swampgrass *Amphibromus neesii* (rare), which is found at Charlie Diglers Hole; and native broom *Viminaria juncea*, for which Moulting Lagoon is the only known Tasmanian population (DPIPWE 2010). However, how many of the 13 species occur within the Ramsar site and are important to the ecological character of the site remains unknown. The LAC is based on continued presence of those species currently known to occur in the site and for which the site has been recognised as important for their conservation.	Continued presence of the following species within the Ramsar site: *Ruppia megacarpa;* *Lepilaena patentifolia* *Amphibromus neesii* and *Viminaria juncea*	Medium
Fish	Last (1993) recorded 36 fish species from Great Swanport estuary. Last also described habitat preferences for these species.	No less than 28 of recorded fish species (Last 1983) are present at least once every 10 years.	High

Critical Component, Process or Service	Baseline Information and Justification	Limits of Acceptable change*	Confidence level
Waterbirds – abundance	Three waterbird species have greater than one percent of their population occuring at the site on a regular basis. These species are a major reason for the site's Ramsar listing. Further reductions in population numbers may be beyond site management control, but it is vital to the site's ecological character that it still retains the quality and quantity of habitat required by waterbirds for foraging and breeding. Long-term regional trends for these species can be used to underpin the LAC. If trends in species counts move opposite to regional trends, this may indicate issues at the site, and might be used as a management trigger for these LAC. The LAC for individual species are provided for the intrinsic value of the species but also in part as a surrogate for the waterbird community as a whole. For black swan the 20th percentile+ as a minima of the current data (1992 to 2009, S. Blackhall data) has been used to derive the LAC as the species move into and out of the site on a seasonal basis. For pied oystercatcher and Pacific gull the 80th percentile+ of the current data (1992 to 2009, S. Blackhall data) has been used to derive the LAC.	No less than 7000 black swan (*Cygnus atratus*) in eight out of 10 years.	High
		No less than 200 pied oystercatcher (*Haematopus longirostris*) in five out of 10 years.	High
		No less than 80 Pacific gull (*Larus pacificus*) in five out of 10 years.	High
Waterbirds – breeding	Of the waterbirds which breed at the site, the most significant in terms of occurrence and abundance is the black swan, which breeds annually within the site.	Presence of black swan (*Cygnus atratus*) breeding within the site on an annual basis.	High

Critical Component, Process or Service	Baseline Information and Justification	Limits of Acceptable change*	Confidence level
Supports near natural wetland types	Wetland types are maintained by hydrology and vegetation.	See LAC for hydrology and vegetation communities.	Not applicable
Physical habitat for waterbird (breeding, roosting and feeding).	Physical habitat for waterbirds is maintained through wetland types and can be indicated by the numbers of waterbirds supported by the site.	See LAC for hydrology, vegetation and waterbirds.	Not applicable
Provides drought refuge	Drought refuge is maintained by hydrology.	See LAC for hydrology.	Not applicable
Supports biodiversity including threatened species	Biodiversity values of the site lie predominantly with the high diversity of wetland flora, waterbirds and fish and can be indicated by the species richness of these groups.	See LAC for vegetation, fish and waterbirds.	Not applicable
Ecological connectivity	Connectivity for fish migration is maintained through hydrological connections from Moulting Lagoon to inland freshwater wetlands via the Aspley River. While the LAC for hydrology partially addresses this service, it is important that physical connectivity is also retained and that obstructions to water flow are not introduced to the site.	No barriers to hydrological connectivity between Moulting Lagoon and the Aspley River.	High

- Exceeding or not meeting a LAC does not necessarily indicate that there has been a change in ecological character.
- In the absence of sufficient data to develop quantitative LAC, qualitative LAC are proposed.

6. Threats to the Moulting Lagoon Ramsar Site

6.1 Climate change and water resource use

Factors external to the Ramsar site have been impacting upon the ecosystem since listing and are ongoing. Some of these factors are related, for example, to climate change – a decline in incidence and magnitude of rainfall events (and thus flushing events), accompanied by an increase in air temperature. Accompanying the decline in rainfall is a continuing demand for water from agricultural and horticultural industries within both the Swan and Apsley catchments. Further, an increase in demand for intercepted catchment and river water by urban, peri urban and rural domestic infrastructure, and consumption by tourism ventures, may have an impact on the site's ecological character. These extractions need to be assessed within the context of the hydrologic inputs presented in Section 3.1, in particular: the semi-arid zone equivalent mean annual runoff (MAR) for both the Apsley and Swan River catchments; the high variability in annual flow, with the greatest variability occurring in monthly flows, particularly in the low flows, and the high variability in annual peak flows and in low annual discharge, which is related to the mean annual catchment runoff (Hughes, 1987). Figure 15 showed a coincidence between the annual rainfall pattern for the 42 year period of recorded data and the annual river flows recorded at The Grange and Coles Bay Road, indicating a direct response to rainfall events.

The Sustainable Yields project in Tasmania (CSIRO 2009) provides a recent assessment of climate changes for the Derwent-South East region, which includes the Ramsar site. The climate for the Dewent South East region over the period 1997 to 2007 was drier than the previous 84 year period (historic climate), with declines in rainfall and run off (CSIRO 2009). Overall reductions in rainfall and run off were comparatively less in this region compared to the rest of the regions assessed. Generally, the mean monthly streamflow was lower than under the historical climate across the region, except for some catchments where streamflow was slightly higher in August to October. Under recent climatic conditions across the region as a whole, there was a 13 percent reduction in non-extracted water and a 3 percent reduction in extracted water (CSIRO 2009). CSIRO (2009) provide predictions of change under future wet and dry extremes of climate (2030) but state that whilst Moulting Lagoon would have been impacted by the recent climatic conditions, under future climate scenarios it is not likely to be impacted. Extracted and non-extracted shares of water for the Swan-Apsley catchment are shown in Figure 28. Future development, which is likely to include a 3 percent increase in plantation forests across the region, mainly on the east coast, is not predicted to have an impact on Moulting Lagoon (CSIRO 2009).

Changes to inflows in the Swan-Apsley catchment are predicted (under the median future climate) to be in the order of -0.7 percent and the reduction in extractions of -0.3 percent (CSIRO 2008). Groundwater extraction as a percentage of recharge in the Swansea-Nine Mile beach assessment area was 14 percent under the recent climate (1997 to 2007), which was similar to that of historical conditions (only slightly higher) (CSIRO 2009).

Significant ecosystem services of Moulting Lagoon are dependent upon, and triggered by, rainfall pattern and events. The impacts of these factors on the health, structure and robustness of biotic components are not presently quantifiable due to lack of baseline information at the time of listing, limited understanding of the communities and their interrelationships and absence of recent survey data.

Sea level rise associated with climate change poses a potential threat to the ecological character of the Ramsar site. Moulting Lagoon is considered to be representative of one of the more sensitive coastal landforms in Tasmania (DTAE 2007), having Tertiary sediment shorelines. Several distinct types of sediments, which are susceptible to erosion, occur within Moulting Lagoon. These include muddy shorelines in the northern part of the site and soft-clayey-gravel shores (Sharples 2006). The soft clayey-gravel sediments are semi-lithified with a clayey texture and whilst coherent are prone to progressive ongoing erosional retreat (Sharples 2006). Sea level rise would accelerate this erosion. Sea level rise will cause salt water to penetrate further into the site and potentially have significant impacts on the saltmarsh communities.

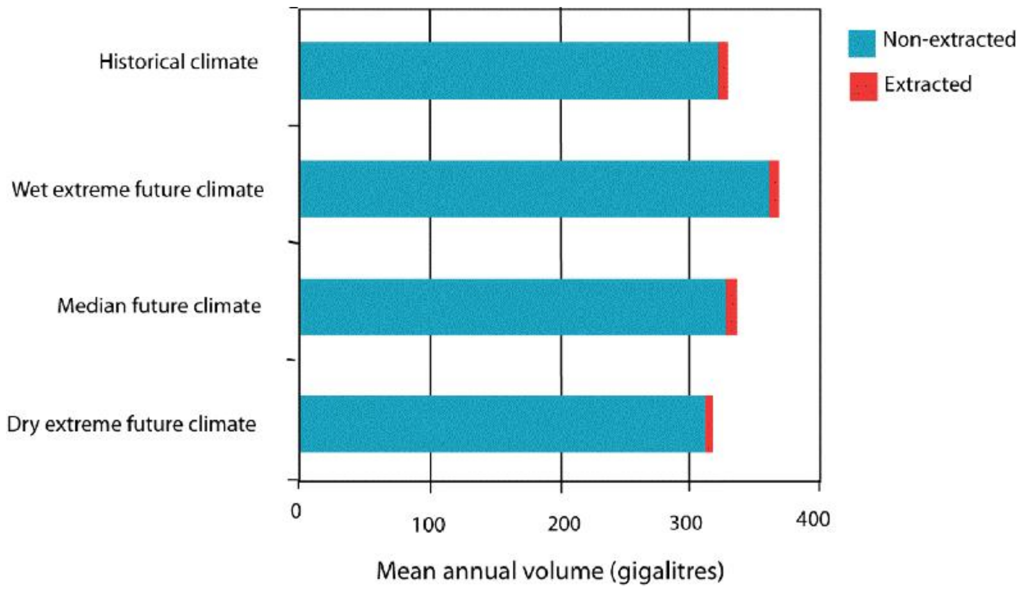


Figure 28: Extracted and non-extracted shares of water for the Swan-Apsley catchment under historical and future climate (modified from CSIRO 2009).

6.2 Catchment landuse – sedimentation and grazing

Land clearance and on-going agricultural/horticultural practices generate sediment loads that are deposited into the central basin and the Swan delta, arguably resulting in vertical accumulation of sediment. Lateral expansion of flats may be as significant as vertical accumulation. To date, verbal reports indicate that within the preceding 40 years accumulation of sediment in the basin has resulted in shallower basin water, higher water temperatures and hypersalinity during extended periods of higher air temperatures. These events may be linked with a decline in the magnitude and incidence of flushing by fresh flows. The relatively rapid accumulation or infilling by sediment in the central basin is consistent with the results of Heap et al. (2004).

Since listing of the Ramsar site there has been a reported loss of habitat for flounder, a response to 'muddy' sediment deposition on white beach sands, and saline waters have penetrated up stream on the Swan River (P. Last personal communication 2006).

Grazing has a serious impact on saltmarsh vegetation as a consequence of both browsing and trampling. *Tecticornia arbuscula* is especially vulnerable to browsing and can be lost in areas of saltmarsh where stock have access (Figure 29). Farmers may be reluctant to fence stock out of the marshes as they believe salt can be beneficial to the diet of their stock. Some areas adjacent to the central basin have now been fenced, including at Top Bank, Sherbourne Bay and around Little Bay. It is estimated (Col Dyke personal communication 2007) that it takes around 20 years for *Tecticornia arbuscula* to re-establish in suitable locations following exclusion of stock. The presence of isolated *Tecticornia arbuscula* shrubs around much of the shoreline, interspersed within *Sacrocornia* species patches, may be indicative of previous grazing, or may be a response to past or current tidal or aeolian influences.

Figure 29: Impact of stock grazing on succulent saltmarsh with *Tecticornia arbuscula* destroyed on grazed area, with *Sarcocornia spp*. obliterated by trampling along the fenceline. (Blackhall 1986).

6.3 Acid sulphate soils

Mapping has been undertaken for Moulting Lagoon by the Tasmanian Acid Sulphate Soils Information Project (Moreton et al. in prep) to demonstrate the extent and location of potential acid sulphate soils (PASS) within the Ramsar reserve boundary. Mapping is available on the Tasmanian Land Information System (theLIST) together with summarised site and soil data for field sites which were sampled and tested during project fieldwork. (www.thelist.tas.gov.au).

Mapping and site data both indicate significant areas of land (500 hectares) and subaqueous sediments (2825 hectares) that have the potential to contain PASS sediments - this is confirmed by the sulfide concentrations within the field reference sites (13 sites were sampled, 10 of which had sediments that exceeded trigger levels for PASS). A total of 3323 hectares of land with potential to contain PASS has been identified. Most landforms with a high potential to contain PASS occur within the supratidal and extratidal tidal flats and within the subaqueous and intertidal wetland areas. Those classified as having low and extremely low classification occur mainly within the sandplain and supratidal landforms as well as within other areas characterised by Hydrosol soil types.

The PASS hazard generally occurs within one metre of the soil surface for all but one of the field reference sites. Whilst risk of disturbance of these sites through development are currently low due to its reserved status, impacts from surrounding agricultural land such as stock trampling/pugging, water diversion and land drainage are the main threats that have potential to expose these sediments to oxidation. Recreational impacts from vehicles are also of significance. A full description of sites and the methods used to determine map boundaries are described in Moreton et al. (in prep).

6.4 Recreational activities

6.4.1 Recreational duck shooting

A study in the lagoon (Smith et al. 1995) demonstrated that lead shot used by hunters could remain within the lagoon sediments as a source of contamination to the ecosystem and move into the food chain. Following such moves in other countries and a national agreement in 1996, the use of lead shot in public wetlands in Tasmania was banned from the 2005 season (Game Management Liaison Committee) with a change to the Wildlife Regulations 1999.

Some 130 duck hides were in place across Moulting Lagoon at the time of listing. Duck hunting continued as a permitted use within the scheduled Game Reserve but continued to be prohibited in the northern area set aside as a Conservation Area. Duck hides were unregulated and could be installed as the hunters chose.

In 1997 regulations were introduced requiring hides to be registered with the managing agency, and for these hides to be maintained. A stock take of hides led to the removal of some thirty unused or dilapidated hides. The total number of registered hides is now about 95 limited to specific areas of the Ramsar site (PWS, 2007). Most are located in the area of Top, Middle and Bottom Banks of the central basin where they can be accessed by wading. Another concentration is in Watsons Bay, and a few are sited in Little Bay, near Sabina's Island and the Swan river delta at King Bay. Some owners have more than one hide and all owners have been encouraged to have hides that may be removed each season. Concerns remain about litter emanating from duck hides and for the visual impact (S. Blackhall, personal communication 2007). The reduction in use of duck hides is unlikely to have any major impacts on the ecological character of the site.

6.4.2 Fishing

A major recreational activity within the Ramsar site is fishing. In the past, an annual fishing carnival occurred in the region and the Ramsar site was popular with fishers. At the peak of the event as many as 1500 people took part. The carnival is no longer an annual event, occurring on an irregular basis, but the site remains popular with local fishers. One of the most popular areas for fishing is in and upstream of the mouth of the Swan River. Limited data on catch is available, however anecdotal evidence suggests the flounder catch has declined throughout the site and shrimps have declined in the area near Apsley Marshes and Sherbourne Bay. The bream catch is reported as being fairly stable (PWS 2007). Impacts from recreational fishing on the ecological character of the site are not known.

6.4.3 Vehicle access

Access to the lagoon foreshore at the time of listing in 1982 was uncontrolled. This led to extensive vehicle tracks through saltmarshes, compacting soils and destroying the vegetation, which contributed to the formation of deflating salt pans (Figure 30). With the declaration in 1988 of the area as a Game Reserve under the *National Parks and Wildlife Act 1970,* it became possible to control access. Now there are defined areas for launching boats and 4WDs are limited to small, contained areas of the shoreline. Elsewhere, the foreshore is clearly signed as closed to vehicles, with a high degree of compliance, and the saltmarsh is slowly recovering (Figure 30). Over time this has the potential to change the extent of saltmarsh communities, but in a positive manner and as such is unlikely to lead to a negative change in the ecological character of the site.

6.5 Invasive species

Overall, invasive species are not considered a major problem within the Ramsar site, although some invasive weeds are impacting on habitat values in some areas of the site. Invasive plant species within the site include South African boxthorn (*Lycium ferocissimum*), which is established on Sabinas Island. This species outcompetes the native *A. verticilata* overstorey and reduces the nesting habitat available to black swans (PWS 2007). Bulrush (*Typha latifolia*), blackberry (*Rubus fruticosis*), and gorse (*Ulex europaeus*) are other invasive plant species of concern for the Ramsar site (PWS 2007).

A number of serious declared weeds occur within the catchment and have the potential to move into the site. These include: bridle creeper and Paterson's curse, both recorded at Swansea: Spanish heath (Bicheno): pampas grass (Swan River): and serrated tussock (Swansea). The serious environmental weed *Spartina anglic*a occurs at Little Swanport.

This raises an additional issue of weed and disease hygiene, and the threat of weeds and diseases being introduced by vehicles (tourists, recreational, agricultural) accessing adjacent areas of Moulting Lagoon.

Animal pest species of concern include the toxic dinoflagellate *Gymnodinium catanatum*, the North Pacific seastar (*Asterias amurensis*), and the European shore crab (*Carcinus meanusl*) (PWS 2007). Feral cats are recorded within the site, however the impacts on wildlife, in particular waterbirds, is not known (PWS 2007) and remains a knowledge gap for the site.

PWS (2007) states that root-rot fungus *Phytophthora cinnamomi* that causes dieback and/or death of a wide range of native plant species, most likely occurs within the Ramsar site. The fungus occurs throughout the east coast and has been recorded in nearby Freycinet Peninsula and Schouten Island (PWS 2007).

From left to right
a) At time of listing (soutce Blackhall 1982).
b) On eastern shoreline where fishers are permitted access (2007).
c) Area closed to fishers showing evidence of regeneraton (2007).

Figure 30: Vehicle track damage and regeneration.

6.6 Fire

Wildfire and control burns have the potential to impact on the site through increased nutrient and sediments loads, and fragmentation through direct loss of habitat. Large fires have the capacity to influence biodiversity values, hydrology and geomorphology – the latter through the deposition of sediment. Information on fire history within the site has not been sourced, however wildfire can have catastrophic impacts and the potential to change the character of the site is noteworthy.

6.5 Summary of threats

Although a risk assessment is beyond the scope of an ECD, the DEWHA (2008) framework states that an indication of the impacts of threats to ecological character, likelihood and timing of threats should be included. The major threats considered above are summarised in Table 11.

Table 11: Summary of actual or potential threats to Moulting Lagoon.

Threat	Potential impacts to wetland component or service	Critical CPS Impacted	Likelihood[1]	Time frame[2]
Climate change	Reduced inflows, rainfall and evaporation rates. Increased air temperatures. Reduced intervals of significant rainfall events with associated flushing pulses. Penetration of saline water upstream. Prolonged periods of increased salinity. Changes in freshwater input regimes (seasonality, occurrences of flushing events). Changes in seasonal air temperature averages and solar radiation incidence with resulting potential changes in water temperatures and evaporation rates. Increased chance of occurrence of destructive stochastic events (unusually high tides, storm surges) resulting in increased erosion of saltmarsh margins. Accelerated progressive erosion of sediments associated with sea level rise.	All critical CPS	Certain.	Current (in particular recent climatic conditions of 1997 to 2007) and future climate 20-50 years.
Water resource use	Lowering of water table, resulting in less habitat diversity (spatial and temporal), less water to support ecosystem. Reduced frequency and size of flushing flows. Reduced base flow.	All critical CPS	Low.	Current.
Catchment land use – sedimentation and grazing	*General* Increased nutrient concentrations (and increased algal growth). Hydrological changes. Increased turbidity. Inundation by suspended sediment. Erosion of Apsley River channel and reworked fluvial saltmarsh flats infilling *Central Basin.* Exposure or disturbance of Passive Acid Sulphate Soils in Moulting Lagoon.	All critical CPS.	Medium.	Five to 20 years.

[1] Indicates the likelihood that the identified threat will have an impact on the ecological character of the site.
[2] Indicates the timeframe in which the threat is likely to occur (regardless of the potential for impact on ecological character).

Threat	Potential impacts to wetland component or service	Critical CPS Impacted	Likelihood[1]	Time frame[2]
	Sedimentation Loss of seagrass beds leading to algal dominated systems. Loss of habitat for flounder due to sediment overlaying white sand areas. Changed hydrological systems and channel form. Changed habitat for marine and aquatic species.	All critical CPS	Medium.	Current.
	Grazing Destruction of natural vegetation leading to hard surfaces and exposure to wind erosion. Compaction. Channelisation along walking tracks. Exposure or disturbance of Passive Acid Sulphate Soils in Moulting Lagoon.	Hydrology Wetland vegetation types Waterbirds Physical habitat	Low.	Current (but reducing).
	Vegetation clearance (surrounding land) Geomorphic instability. Infilling of basins in the lagoon. Hydrological changes. Increased turbidity.	All critical CPS	Certain.	<10 years (commenceme nt).
Acid sulphate soils	Acidification of water and soils. Loss of biodiversity.	Wetland vegetation Fish Waterbirds Physical habitat Near natural wetland type	Low	Current (potentially)
Recreational activities	*Vehicle access* Lake bank/shore damage and erosion. Reduced water quality. Exposure or disturbance of Passive Acid Sulphate Soils in Moulting Lagoon.	Hydrology Wetland vegetation Near natural wetland type Physical habitat	Certain.	Current.
	Duck hunting Overshooting, illegal hunting. Lead shot poisoning of benthic feeders.	Waterbirds	Low.	Current (diminishing).

Threat	Potential impacts to wetland component or service	Critical CPS Impacted	Likelihood[1]	Time frame[2]
Invasive species	Invasion of wetlands, reducing habitat availability for other species. Predation and displacement of native species. Predation on plant and animal biomass.	Wetland vegetation Waterbirds Fish Biodiversity	Certain.	Current (for example. African boxthorn, gorse, feral cat,). Potential (pacific sea star, toxic dinoflagellate).
Fire	Changes to vegetation communities. Changes to geomorphology via erosion. Changes to hydrology via infiltration and landform.	Hydrology Wetland vegetation types Waterbirds	Medium.	Current.

7. Current Ecological Character and Changes Since Designation

7.1 Site changes since listing

The declaration of the area as a Game Reserve in 1988 brought this parcel of Crown Land under the jurisdiction of the Parks and Wildlife Service and enabled progress towards management for conservation. Under the *National Parks and Wildlife Act 1970*, the agency was able to enforce closure of some tracks and to negotiate fencing of some sections adjacent to grazing land.

A number of other threatening processes have had the stressors reduced or removed, including a banning of the use of lead shot in 2005, removal of some duck hides and improved maintenance of duck hides. As it is unlikely that these changes would result in a change in ecological character, they are not discussed further here (see section 6 for details).

7.2 Current assessment of ecological character

An assessment of current conditions, with respect to LAC, is provided in Table 12. This highlights the lack of available data for several critical components. However, despite being unable to assess several LAC, it would appear that the site has not undergone significant change since listing in 1982 and that it continues to meet criteria 1, 3, 4, 6 and 8 (see section 2.4).

Table 12: Assessment of current conditions against LAC for the Moulting Lagoon Ramsar site.

Critical component / process	Limit of Acceptable Change	Current conditions	Confidence that LAC is met.
Hydrology	No change in wetland hydrological types present within the site. That is, the following hydrological wetland types are maintained: • Dominance of estuarine waters. • Presence of marine subtidal aquatic beds - seagrass beds. • Presence of sand bars, spits, dune systems. • Presence of intertidal mud, sand and salt flats. • Presence of intertidal saltmarsh and salt meadows. • Presence of brackish to saline lagoons.	Direct observations in 2010 indicated that all wetland types described are still present within the site.	High.
Wetland vegetation - saltmarsh	No less than 90 percent of the extent of saltmarsh communities within the Ramsar site.	In the absence of fires and no change in hydrology it is likely that all major communities remain present within the site.	High

Wetland vegetation - seagrass	No less than 1650 hectares of *Ruppia* and 700 hectares of seagrass (*Heterozostera tasmanica* and *Zostera muelleri*).	Only data is that which was used to develop the LAC (Mount et al. 2005 and Lucieer et al. 2009), so it is not possible to assess any change.	Not applicable.
	Three key species found throughout the site recorded over any five year period: Central basin of Moulting Lagoon dominated by *Ruppia megacarpa*. Presence of *Heterozostera tasmanica* in subtidal zones. Presence of *Zostera muelleri* in tidal areas.	Species were recorded in 2005 from Great Swanport estuary (Mount et al. 2005), but no additional surveys have been conducted. In the absence of changes to hydrology it is considered likely this LAC is met.	High.
Wetland vegetation - threatened species	Continued presence of the following species within the Ramsar site: *Ruppia megacarpa;* *Lepilaena patentifolia;* *Amphibromus neesii;* and *Viminaria juncea.*	*Ruppia megacarpa* is assumed to still be the dominant seagrass species in the central basin. The presence of the remaining three species is not known. This LAC is most likely met, but survey data is required to ascertain this.	Low
Fish	No less than 28 of recorded fish species (Last 1983) are present at least once every 10 years.	Data insufficient at this time.	Not applicable.
Waterbirds - abundance	No less than 7000 black swan (*Cygnus atratus*) in eight out of 10 years.	Data from 1992 to 2010 show this LAC is met.	High
	No less than 200 pied oystercatcher (*Haematopus longirostris*) in five out of 10 years.	Moulting Lagoon supported more than 200 pied oystercatchers for 74 percent of years from 1992 to 2010. This LAC is met.	High
	No less than 80 Pacific gull (*Larus pacificus*) in five out of 10 years.	Moulting Lagoon supported more than 80 pacific gulls for 63 percent of years from 1992 to 2010. This LAC is met.	High
Waterbirds – breeding	Presence of black swan (*Cygnus atratus*) breeding within the site on an annual basis.	This LAC is met.	High

8. Knowledge Gaps

While it is tempting to produce an infinite list of research and monitoring needs, 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. As such, there is only a handful of knowledge gaps required to be addressed to fully describe the ecological character of this site and enable rigorous and defensible limits of acceptable change to be met; these are presented in Table 13.

Table 13: Knowledge gaps relevant to the functioning of Moulting Lagoon Ramsar site.

Component, process or service	Identified knowledge gap	Recommended data collection or other action to address the gap.	Priority
Hydrology	Flow requirements for Moulting Lagoon, including groundwater and near-surface discharge. Determine the role of seasonal flushing flows in maintaining biotic communities and species. Mapping of freshwater habitats within the site.	Extent of marine inflow – halocline location. Mapping of inundation cycles either from aerial imagery time series or from hydrological modelling to provide clear information on cycles of inundation.	High
Sedimentation processes	Rates and dynamics of sediment inflows to Moulting Lagoon. Data required includes information on volume of tidal prism and factors affecting tidal range (for example astronomical, barometric, wind setup, fresh inflow); mixing of saline and fresh water (affecting flocculation); wave resuspension and redistribution.	Sediment budgeting for Swan and Apsley catchments. Shoreline profiles applying GPS kinematics. Map and characterise the sediment types and volume in each basin. Define sediment loads, sediment accumulation in basins and extent of flushing from the system.	High
Climate change	Quantify likely impacts of climate change on Moulting Lagoon.	Model likely erosion, sedimentation, water salinity, tidal variation under predicted sea level rise scenarios.	Medium
Water quality	Baseline water chemistry information for geomorphic features within Moulting Lagoon.	Update Hughes (1987) assessments (major water quality parameters, pH, turbidity, salinity, nutrient loads, chlorophyll A, conductivity, coliform bacteria, heavy metals). Organic carbon. Locate and quantify likely sources of nutrient inputs, for example swan excreta, urban runoff, septic tanks, farming practices, natural processes. Verify indicative salinity profiles of each geomorphic feature.	Low
Invertebrates	Baseline species assemblages of invertebrates for specific habitat types. Determine the role of seasonal	Survey abundance and species diversity of benthic and pelagic invertebrate communities of key habitats	Low

Component, process or service	Identified knowledge gap	Recommended data collection or other action to address the gap.	Priority
	flushing flows in maintaining biotic communities and species.	and Ramsar wetland types, for example, intertidal flats, seagrass beds, main lagoon, Great Swanport.	
Wetland vegetation – threatened species	Need to set baseline of presence, distribution and extent for threatened flora species.	Survey and map presence, distribution and abundance of threatened floral species. Establishment of monitoring program of key species.	High
Wetland vegetation habitat types	Mapping of current and projected 1982 extent of wetland vegetation communities. TASVEG 2.0 maps saltmarsh communities within the site, however the accuracy is currently very low with large areas mapped as saltmarsh (undifferentiated). Extensive areas (100s of hectares) of the northern end of the site are mapped as water when they would be better mapped as Saline Aquatic herbland (AHS).	Detailed mapping of saltmarsh communities including geomorphic contexts, zonation, indicator species. Baseline mapping of seagrass distribution and channels, including high resolution, ground-truthed vegetation mapping.	High
Waterbirds	Adequate data exists for management of waterbirds on the site.	Continue present program of bird counts and other monitoring.	Medium
Fish	Population dynamics. Limited information on diversity, abundance and the importance of the site as a migratory route.	Update fish population studies undertaken by Last (1983). Establish a program of periodic monitoring of distribution and abundance of key fish species, migration routes and breeding cycles.	High
Recreational fishing	Inventory of recreational fishery activity and impacts of this fishery.	Monitoring of recreational fishing activities. Establishment of limits on the scale of recreational fishing in Moulting Lagoon.	Low
Provides drought refuge	Develop understanding of relative importance of the site as a drought refuge for waterbirds in the bioregion (Tasmania).	Survey and comparison of waterbird numbers in dry and wet periods.	High
Invasive species	Limited information on the extent and abundance of invasive species and the potential impact of ecological character.	Weed and pest control/monitoring programs be implemented.	Medium

9. Key Site Monitoring Needs

The Ramsar Convention (1999) proposes a Risk Assessment Framework for monitoring and assessing change in ecological character. The flow chart (Figure 31) summarises the steps involved in identifying risk, management response and monitoring effectiveness (Ramsar 1999).

The model assumes data exist to adequately describe the ecological character and the effects of perceived risks. These links can only be inferred from the available data on Moulting Lagoon, together with known types of risk and their consequences. Where key elements are poorly known or understood, establishing baselines is an important component of monitoring changes in ecological character.

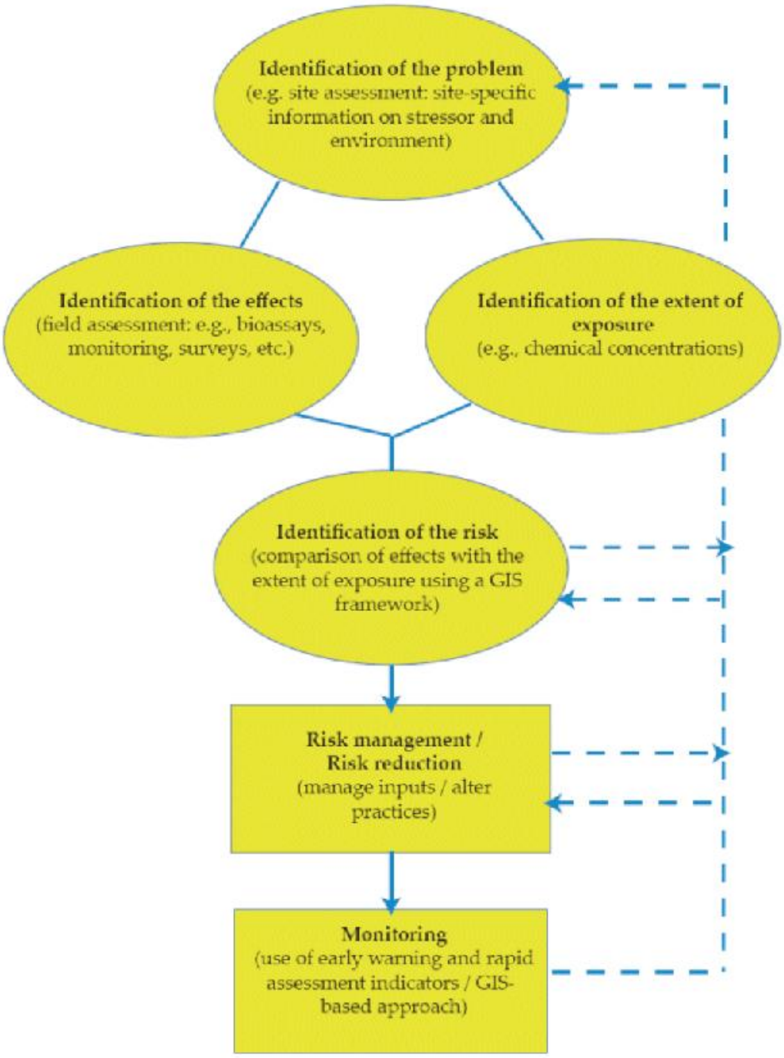


Figure 31: Suggested model of wetland risk assessment.

Recommendations for benchmarking and monitoring

This ECD provides an identification of monitoring needs required to both set baselines for critical components, processes and services to assess against limits of acceptable change. It should be noted that the focus of the monitoring recommended in an ECD is an assessment against LAC and determination of any changes in ecological character. This monitoring is not designed as an early warning system whereby trends in data are assessed to detect changes in components and processes prior to a change in ecological character of the site. This shouldt be included in a management plan for the site.

The recommended monitoring needs to meet obligations under the Ramsar Convention and the EPBC Act with respect to Moulting Lagoon are provided in Table 14.

Table 14: Key monitoring needs for Moulting Lagoon Ramsar site.

Component, process, or threat	**Purpose**	**Key Indicator(s)**	**Monitoring needs (type and frequency)**	**Priority**
Hydrology	Assessment against LAC.	Flow in the Swan and Apsley Rivers, including flushing events. Wetland extent.	Flow data, river levels using continuous data loggers. Map extent of Ramsar wetland types – once off.	High
Sedimentation processes	Threat indicator, knowledge gap.	Sediment rates and patterns of deposition. Sediment sources.	Map and monitor sediment patterns and rates.	High
Water quality	Threat indicator, knowledge gap.	Changes in salinity, penetration of marine waters, phases of hypersalinity and stratification of water bodies.	Establishment of baseline water chemistry standards for Moulting Lagoon. Water samples at selected georeferenced sites, including stratified depth samples.	Medium
Wetland vegetation	Assessment against LAC, setting of baseline and threat indicator.	Abundance, health, and distribution of seagrass species. Spatial extent, composition and condition of saltmarsh communities.	Collection of baseline flora species and community data via establishment of permanent transects across hydrological gradients. Use resulting data to identify the ecological communities which will then be mapped using low level aerial photography taken in November /December. Future monitoring requirements are to repeat low level aerial photography taken in November /December every five years in conjunction with re-surveying of permanent transects.	High

Component, process, or threat	Purpose	Key Indicator(s)	Monitoring needs (type and frequency)	Priority
Wetland vegetation - Threatened species	Assessment against LAC and setting of baseline.	Extent and condition	Periodic assessment of fixed (geo-referenced) monitoring points (suggested frequency of every three to five years).	High
Waterbirds	Assessment against LAC.	Use of Moulting Lagoon by waterbirds and waders. Swan breeding success rates	Seasonal and annual numbers of waterbird and wader species. Include areas used by different species. Annual breeding data including numbers of nests and survival rates (As per Guiler, 1966). Review historic waterbird data in terms of its adequacy to detect change relevant to management.	High
Invertebrates	Establishment of baseline and condition assessment.	Invertebrate species diversity and population	Number of general species of invertebrates resident at Moulting Lagoon. Seasonal abundance of key food species for fish and bird species. Critical habitat requirements for key invertebrate species.	Low
Fish	Assessment against LAC.	Fish communities distribution and health	Annual assessment of change in distribution and abundance of fish communities according to tolerance of estuarine conditions. (As per Last (1983)	High

10 Communication, Education and Public Awareness (CEPA) Messages

10.1 Current CEPA activities

Moulting Lagoon is located in close proximity to Freycinet National Park and as such forms part of an important tourism and recreational area for locals and visitors. Moulting Lagoon is an important recreational fishery and is used regularly by amateur birdwatchers and others participating in nature based tourism.

Visitor figures for Freycinet National Park were 198000 in 2003/2004. Visitation rates to the region have increased by an average of seven percent per year since the beginning of the 1990s; this is the highest rate of all Tasmania's National Parks. Moulting Lagoon has recently been included in the ecotourism program based at Freycinet Lodge and a sea kayak business also visits the Lagoon area.

To date, interpretive signage and displays relevant to the Ramsar site are limited to four simple signs describing the Ramsar Convention on Wetlands of International Importance at strategic locations in the local vicinity.

10.2 Proposed CEPA messages

Key messages for Moulting Lagoon should focus on the significance of the site and key features that have justified its listing as a Ramsar site. There is a need to improve the present interpretive signage at the site, in particular improved maps and signage that shows safe access points and walking tracks.

A high standard interpretive centre is maintained by PWS at Freycinet National Park. This centre enjoys high visitation and accordingly a separate interpretive centre at Moulting Lagoon would be duplicative. It may be preferable to improve the profile of Moulting Lagoon at the current PWS interpretive centre. This, augmented by improved signage at key points within and near Moulting Lagoon, would improve community awareness of the significance of the site.

Key CEPA messages for Moulting Lagoon Ramsar site arising from this ECD, which should be promoted, include:

- Moulting Lagoon is listed as a Wetland of International Importance under the Ramsar convention. At the time of listing in 1982, it met five of the nine Ramsar Nomination criteria.
- The Ramsar values of the site and the importance of the site as a habitat for shorebirds and waterfowl to meet different needs in their lifecycles.
- The significance of geomorphic features and the processes forming the lagoon itself.
- Waterbird species and the importance of the site for migratory species and as a breeding site for black swan, amongst other species. The site is critical as a breeding site for black swan, and periodically provides drought refuge for a number of waterbirds and other aquatic species.
- The site regularly supports more than one percent of the population of black swan, pied oystercatcher and Pacific gull.
- The importance of seagrass in the healthy functioning of wetlands.
- Saltmarsh vegetation communities and the threats they face from human disturbance.
- Importance of the site to Aboriginal Traditional Owners, including information on present values and interactions with the site.
- Moulting Lagoon is hydrologically and ecologically connected to the privately owned Apsley Marshes Ramsar site.
- Climate change has the potential to exacerbate the impacts of upstream water use through increased temperature and evaporation. However, these effects may have limited impacts on the site.

11 Glossary

Abiotic	Not living. Deposition of suspended sediments on floodplains is an abiotic process (Brinson 1993).
Acceptable change	The variation that is considered 'acceptable' in a particular measure or feature of the ecological character of a wetland. Acceptable variation is that variation that will sustain the component or process to which it refers (Phillips 2006). See "Limits of Acceptable Change".
Accretion	Vertical accumulation of sediments or organic matter (Brinson 1993).
Aerobic	Occurring in the presence of free molecular oxygen (Brinson 1993)
Alluvial	Pertaining to alluvium, or material transported by flowing water (Brinson 1993).
Benthic	Pertaining to the seafloor (or bottom) of a river, coastal waterway (Brinson 1993).
Baseline	Condition at a starting point, usually the time of listing.
Basin	Shallow depression in landscape (Brinson 1993).
Biogeographic region (Criteria 1 and 3)	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 (Criteria 3 and 7)	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).
Biotic	Refers to living processes or entities. (Brinson 1993).
Brackish	Water containing salt. Normally a mixture of fresh water and sea water (Brinson 1993).
Catchment	The total area draining into a river, reservoir, or other body of water.
Change in ecological character	Defined as the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service (Ramsar Convention 2005).
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.
Community Composition	All the types of taxa present in a community.
Catchment	The area of land which collects and transfers rainwater into a waterway.
Critical stage (Criterion 4)	Meaning stage of the life cycle of wetland-dependent species. Critical stages being those activities (breeding, migration stopovers etc.) which if interrupted or prevented from occurring may threaten long-term conservation of the species. For some species (Anatidae for example), areas where moulting occurs are vitally important. (Ramsar Convention 2005).
Deposition	The dropping of material which has been picked up and transported by wind, water, or other processes (Ryan et al. 2003).
Discharge	The volume of flow per unit time, such as m^3/sec (Brinson 1993).

Dissolved oxygen (DO)	The amount of oxygen that is dissolved in water. This term also refers to a measure of the amount of oxygen available for biochemical activity in a waterbody and is an indicator of the quality of that water (WARSSS 2007).
Ebb tide	A falling tide - the phase of the tide between high water and the succeeding low water (Ryan et al. 2003).
Ecological character	Is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. Within this context, ecosystem benefits are defined in accordance with the MA definition of ecosystem services as "the benefits that people receive from ecosystems" (Ramsar Convention 2005). The phrase "at a given point in time" refers to Resolution VI.1 paragraph 2.1, which states that "It is essential that the ecological character of a site be described by the Contracting Party concerned at the time of designation for the Ramsar List, by completion of the Information Sheet on Ramsar Wetlands (as adopted by Recommendation IV. 7).
Ecological communities (Criterion 2)	Any naturally occurring group of species inhabiting a common environment, interacting with each other especially through food relationships and relatively independent of other groups. Ecological communities may be of varying sizes, and larger ones may contain smaller ones (Ramsar Convention 2005).
Ecological function	Potentially impacted by changes in channel morphology, stream hydrology, water quality, and habitat structure. Ecological function can be measured by fish diversity, macroinvertebrate diversity, biological integrity (WARSSS 2007).
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).
Ecosystem Components	Include the physical, chemical and biological parts of a wetland (from large scale to very small scale, for example habitat, species and genes).
Ecosystem Processes	Are the changes or reactions which occur naturally within wetland systems. They may be physical, chemical or biological. (Ramsar Convention 1996).
Ecosystem services	Are the benefits that people receive or obtain from an ecosystem.
Evapotranspiration	The combination of evaporation and transpiration expressed in the same units as precipitation (Brinson 1993).
Flocculation	The process by which suspended colloidal or very fine particles are assembled into larger masses or floccules that eventually settle out of suspension (WARSSS 2007).
Flood tide	A rising tide - the phase of the tide between low water and the next high tide (Ryan et al. 2003).
Flushing	Exchange of water between an estuary and the ocean (Ryan et al. 2003).
Fluvial geomorphology	The study of running water-shaped landforms.
Forcing functions	External empirical formulation used to provide input describing a number of processes. Forcing functions, or perturbations to the System, are triggering events, representing an energy input to which the system may respond. Typical forcing functions include parameters such as changes in air and water temperature, salinity, solar radiation, peak and low fresh water flows, increased variability of hydrological conditions, storms, relative sea

	level rise, sediment supply. For saltmarsh hydoperiod and ground water inputs, surface and sub-surface drainage and ground water level, salinity, erosion, physical location can determine exposure to wave action, tidal currents. Human activity can also be a forcing function for example water pollutants, land use changes, climate change. Climate changes may also increase the frequency or severity of storms and wave action. Time scales are important in the context of inputs and triggering events. (Woodroffe 2003; WARSSS 2007).
Freshwater Water	Typically derived from inland or rainfall, with less than 0.03 percent ionic content (Ryan et al. 2003).
Functional capacity:	The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem the surrounding landscape (Brinson 1993).
Function (ecosystem):	Processes necessary for the self-maintenance of an ecosystem such as primary production, nutrient cycling, decomposition, etc. The term is used primarily as a distinction from values. The term “values” is associated with society’s perception of ecosystem functions. Functions occur in ecosystems regardless of whether or not they have values (Brinson 1993). The function of an estuary is how it acquires the materials and energy needed, processes its waste products, and interacts with adjacent waters and the surrounding landscape (Ryan et al. 2003).
Functions of wetlands	The activities or actions which occur naturally in wetlands as a product of interactions between the ecosystem structure and processes. Functions include flood water control; nutrient, sediment and contaminant retention; food web support; shoreline stablization and erosion controls; storm protection; and stabilization of local climatic conditions, particularly rainfall and temperature (Ramsar Convention 1996).
Geomorphology/Geomorphic	A term that refers to the shape of the land surface (Brinson 1993). The study of the nature and history of landforms and the processes which create them (Ryan et al. 2003). The study of Earth’s surface and its development (Brinson 1993).
Geomorphic setting	The location in a landscape, such as valley bottom depression, coastal position (Brinson 1993).
Halophytic	Salt-tolerant vegetation (Ryan et al. 2003)
Hypersaline	Water with a high concentration of salt (Ryan et al. 2003) greater than 40 ppt (Brinson 1993).
Indicators (of function)	Water chemistry, species composition, soil characteristics, or some other feature that allows one to infer or predict certain ecosystem functions or other conditions (Brinson 1993).
Indicator species	Species whose status provides information on the overall condition of the ecosystem and of other species in that ecosystem; taxa that are sensitive to environmental conditions and which can therefore be used to assess environmental quality (Ramsar Convention 2005).
Intertidal	The environment between the level of high tide and low tide (Ryan et al. 2003).
Inundation	The condition of water occurring above the surface (Brinson 1993).

Introduced (non-native) species	A species that does not originate or occur naturally in a particular country (Ramsar Convention 2005).
Landscape	Gross features of the land surface, including but not limited to slope, aspect, topographic variation, and position relative to other land forms. (Brinson 1993).
Limits of Acceptable Change	The variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland without indicating change in ecological character which may lead to a reduction or loss of the values for which the site was Ramsar listed (DEWHA 2006).
Model	Wetland conceptual models express ideas about components and processes deemed important for wetland ecosystems.
Monitoring	The 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 (Ramsar Convention 2009).
Mouth	The entrance of the coastal waterway, or the place where the sea meets or enters the coastal waterway. (Ryan et al. 2003).
Periphery or fringe wetland	A wetland that is located near a large body of water, most typically the ocean, and receives frequent and regular two-way flow from astronomic tides or wind-driven water-level fluctuations. (Brinson, 1993).
pH	The negative log of the hydrogen (hydronium) ion concentration. (Brinson 1993).
ppt	Parts per thousand, units generally used for expressing salinity. (Brinson 1993).
Prograde	The outward building of a sedimentary deposit, such as the seaward advance of a delta or shoreline (Ryan et al. 2003).
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" www.ramsar.org
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* is the official name of the Ramsar Convention; 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. Also known as the “Ramsar Information Sheet”.
Ramsar site	Wetland 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 [http://www.ramsar.org/about/about_glossary.htm].
Resuspension	Process in which sediment particles on the substrate are brought back into water column suspension by waves, tides,

	or wind (Ryan et al. 2003).
Sand	Grains with diameters between 0.06 mm to 2 mm. (Ryan et al. 2003).
Salt-wedge	An intrusion of sea water into a coastal waterway in the form of a wedge along the seabed. The lighter fresh water from riverine sources overrides the denser salt water (Ryan et al. 2003).
Saltmarsh	A wetland with emergent, herbaceous vegetation.
Seagrass	Marine flowering plants which generally attach to the substrate with roots. (Ryan et al. 2003).
Spring Tide/King Tide	Tide greater than the mean tidal range. Occurs about every two weeks, when the Moon is full or new (Ryan et al. 2003).
Stratification	Physical layering of the water column resulting from differences in density caused by salinity or temperature variation (Ryan et al. 2003).
Sub-tidal	Permanently below the level of low tide, an underwater environment (Ryan et al. 2003).
Supra-tidal	Above the level of high tide, a terrestrial environment (Ryan et al. 2003).
Surface Runoff	The flow across the land surface of water that accumulates on the surface when the rainfall rate exceeds the infiltration capacity of the soil (Ryan et al. 2003).
Suspended Sediment	Sedimentary material subject to transport by flowing water (for example currents) that is carried in suspension. Typically comprises relatively fine particles that settle at a lower rate than the upward velocity of water eddies (Ryan et al. 2003).
Threatened species	Species listed under either the Tasmanian *Threatened Species Protection Act 1995* or Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*
Tidal amplitude	The elevational difference between high and low tide. (Brinson, 1993).
Turbidity	The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration (Ryan et al. 2003).
Vertical Accretion	Accumulation of sediments or other material resulting in the building-up or infilling of an area in a vertical direction (Ryan et al. 2003).
Wave-dominated	Estuary coastal waterway in which waves are the principal factor in shaping the overall geomorphology. Characterised by a sandy barrier (partially constricting the entrance) that is backed a broad central basin and a fluvial delta, where the river enters the basin (Ryan et al. 2003).
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	Those areas that are inundated or saturated at a frequency to support, and which normally do support, plants adapted to saturated and/or inundated conditions. They normally include swamps, bogs, marshes, and peatlands (Brinson 1993).
Wetland types (Criterion 1)	As defined by the Ramsar Convention's wetland classification system.

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Appendix 1: Waterbird Species

Waterbirds recorded within the Moulting Lagoon Game Reserve (PWS 2007; Blackhall 1985, Schokman 1987, Schokman 1991).

r, v, e = listed in the schedules of the *Threatened Species Protection Act 1995* as rare, vulnerable or endangered respectively
E = Endangered under the *Environment Protection and Biodiversity Conservation Act 1999*
M = listed as migratory or marine under the EPBC Act
J = listed on the Japan–Australia Migratory Bird Agreement (JAMBA)
C = listed on the China–Australia Migratory Bird Agreement (CAMBA)
R = listed on the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)
CE = Critically endangered under IUCN Red List.

Common name	**Species name**	**Status**
Australasian bittern	*Botaurus poiciloptilus*	CE, E
Australasian grebe	*Tachypaptus novaehollandiae*	
Australasian shoveler	*Anas rhynchotis*	M
Australian pelican	*Pellecanus conspicillatus*	M
Australian shelduck	*Tadorna tadornoides*	M
Bar-tailed godwit	*Limosa lapponica*	M,J,C,R
Black duck	*Anas superciliosa*	M
Black swan	*Cygnus atratus*	M
Black-faced cormorant	*Leucocarbo fuscescens*	
Black-fronted dotterel	*Elseyornis melanops*	
Blue-billed duck	*Oxyura australis*	M
Caspian tern	*Hydroprogne caspia*	M,J,C
Cattle egret	*Ardea ibis*	M,J,C
Chestnut teal	*Anas castanea*	M
Common greenshank	*Tringa nebularia*	M,J,C,R
Crested tern	*Sterna bergii*	M
Curlew sandpiper	*Calidris ferruginea*	M,J,C,R
Double-banded dotterel	*Charadrius bicinctus*	M
Eastern curlew	*Numenius madagascariensis*	M,J,C,R, e
Eurasian coot	*Fulica atra*	
Great cormorant	*Phalacrocorax carbo*	
Great crested grebe	*Podiceps cristatus*	v
Great egret	*Ardea alba*	M,J,C
Grey teal	*Anas gracilis*	M
Grey-tailed tattler	*Heteroscelus brevipes*	M
Hardhead	*Aythya australis*	M
Hoary-headed grebe	*Poliocephalus poliocephalus*	
Hooded plover	*Charadrius cucullatus*	
Latham's snipe	*Gallinago hardwickii*	M,J,C ,R
Lesser sand plover	*Charadrius mongolus*	M,J,C,R
Little black cormorant	*Phalocrocorax sulcirostris*	
Little egret	*Egretta garzetta*	M
Little pied cormorant	*Phalacrocorax melanoleucos*	
Long-toed stint	*Calidris subminuta*	M,J,C,R
Marsh sandpiper	*Tringa stagnatilis*	M,J,C,R
Masked lapwing	*Vanellus miles*	
Musk duck	*Biziura lobata*	M

Common name	**Species name**	**Status**
Pacific golden plover	*Pluvialis fulva*	M
Pacific gull	*Larus pacificus*	M
Pied oystercatcher	*Haematopus ostralegus*	
Purple swamphen	*Porphyrio porphyrio*	M
Red knot	*Calidris canutus*	M,J,C,R
Red-capped dotterel	*Charadrius ruficapillus*	
Red-necked stint	*Calidris ruficollis*	M,J,C,R
Ruddy turnstone	*Arenaria interpres*	M,J,C,R
Sharp-tailed sandpiper	*Calidris acuminata*	M,J,C,R
Silver gull	*Larus novaehollandiae*	M,J,C
Sooty oystercatcher	*Haematopus fuliginpsus*	
Swamp harrier	*Circus approximans*	M
Tasmanian native hen	*Gallinula mortierii*	
Whimbrel	*Numenius phaeopus*	M,J,C,R
White-bellied sea-eagle	*Haliaeetus leucogaster*	v, M
White-faced heron	*Egretta novaehollandiae*	

Appendix 2: Plant Species

Plants recorded in or around Moulting Lagoon Game Reserve (PWS 2007).
i = introduced to Tasmania
e = endemic to Tasmania
T = within Australia, occurs only in Tasmania
r = listed in the schedules of the Threatened Species Protection Act 1995 (TSPA) as rare
v = listed in the schedules of TSPA as vulnerable
en = listed in the schedules of TSPA as endangered
EN = listed in the schedules of EPBC Act as endangered

Species Name	Common Name	Status
ANGIOSPERMAE: DICOTYLEDONAE		
Acacia dealbata	silver wattle	
Acacia genistifolia	spreading, early wattle	
Acacia mearnsii	black wattle	
Acacia melanoxylon	blackwood	
Acacia sophorae	coast wattle,	
Acacia suaveolens	sweet wattle	
Acacia terminalis	sunshine wattle	
Acacia verticillata	prickly Moses	
Acaena echinata	sheep’s burr	
Acaena novae-zelandia	buzzy, biddy-widdy	
Acetosella vulgaris	sheep’s sorrel	
Acrotriche serrulata	ant’s delight	
Allocasuarina monilifera	necklace she-oak	e
Allocasuarina littoralis	black she-oak, bulloak	
Allocasuarina verticillata	she-oak, drooping she-oak	
Amperea xiphoclada	broom spurge	
Anagallis arvensis	scarlet pimpernel	i
Angianthus preissianus	salt cup flower	
Aotus ericoides	golden pea, common aotus	
Apium prostratum	sea parsley	
Astroloma humifusum	native cranberry	
Astroloma pinifolium	soft cranberry heath	
Atriplex prostrata	saltbush	
Banksia marginata	silver banksia, honeysuckle	
Bedfordia salicina	Tasmanian blanket leaf	e
Boronia parviflora	swamp boronia	
Bossiaea cinerea	showy bossiaea	
Bossiaea prostrata	creeping bossiaea	
Brachyloma ciliatum	ciliate brachyloma	
Brachyscome aculeata	hill or coarse daisy	
Brachyscome cardiocarpa	swamp daisy	
Bursaria spinosa	prickly box, blackthorn	
Callistemon viridiflorus	prickly bottlebrush	
Carpobrotus rossii	native pigface	
Cassinia aculeata	dolly bush	
Cassytha pubescens	hairy dodder-laurel	
Centaurium erythraea	common centaury	i
Centella cordifolia	centella	
Centipeda minima	spreading sneezeweed	
Chenopodium pale	goosefoot	
Chrysocephalum apiculatum	common everlasting, yellow buttons	
Cirsium vulgare	spear thistle, black thistle	i
Clematis gentianoides	gentian clematis	e
Comesperma volubile	blue love creeper	

Correa reflexa	native fuschia	
Cotula coronopifolia	water buttons	
Crassula decumbens	creeping crassula	
Crassula helmsii	swamp stonecrop	
Crassula sieberiana	Australian stonecrop	
Dampiera stricta	blue dampiera	
Daviesia ulicifolia	native gorse, bitter gorse	
Dichondra repens	kidney-weed	
Dillwynia cinerascens	grey parrot pea	
Dillwynia glaberrima	smooth parrot pea	
Disphyma crassifolium	round-leaved pigface	
Dodonaea viscosa	native or broad-leaved hop-bush	
Drosera peltata	pale sundew	
Drosera pygmaea	dwarf sundew	
Elatine gratioloides	waterwort	
Epacris impressa	common heath	
Epacris lanuginosa	swamp heath, woolly-style	
Epacris obtusifolia	blunt-leafed heath	
Epilobium billardierianum	common willowherb	
Eryngium vesiculosum	prickfoot	
Eucalyptus amygdalina	black peppermint	e
Eucalyptus barberi	Barbers gum	r, e
Eucalyptus globulus	Tasmanian blue gum	
Eucalyptus ovata	swamp, black or marrawah gum	
Eucalyptus viminalis	manna or white gum	
Exocarpos cupressiformis	native cherry	
Geranium potentilloides	mountain geranium	
Gnaphalium cudweed		
Gompholobium bladder-pea,	pale wedge-pea, karella	
Gonocarpus micranthus ssp. micranthus	common or creeping raspwort	
Goodenia lanata	native primrose	
Goodenia ovata	parrot’s food, hop goodenia	
Gratiola nana	matted brookline	
Grevillea australis	southern grevillea	e
Hakea teretifolia	dagger hakea	
Helichrysum (or	Xerochysum) bicolor curling everlasting	r
Hemichroa trailing	hemichroa	
Hibbertia prostrata	prostrate guinea-flower	
Hibbertia riparia	erect guinea-flower	
Hovea linearis	common hovea	
Hydrocotyle muscosa	mossy pennywort	
Hypericum gramineum	small St Johns wort	
Hypericum japonicum	matted St Johns wort	
Hypochoeris glabra	smooth catsear	
Kennedia prostrata	running postman	
Kunzea ambigua	white kunzea, tick-bush	
Lasiopetalum micranthum	Tasmanian velvet bush	e
Lawrencia spicata	salt lawrencia	
Leontodon taraxacoides	hairy hawkbit	I
Leptinella longipes	long cotula	
Leptomeria drupacea	currant bush	
Leptorhynchos squamatus	scaly buttons	
Leptospermum lanigerum	woolly tea-tree	
Leptospermum scoparium	manuka	
Leucopogon ericoides	pink beard-heath	
Lilaeopsis polyantha	Australian lilaeopsis	
Limosella australis	mudwort	

Linum marginale	wild or native flax	
Lobelia alata	angled lobelia	
Lomatia tinctoria	guitar plant	e
Mazus pumilio	swamp mazus	
Melaleuca ericifolia	swamp paperbark	
Melaleuca gibbosa	small-leaved melaleuca	
Melaleuca pustulata	Cranbrook paperbark	e, r
Mimulus repens	creeping monkey flower	
Monotoca elliptica	tree broom-heath	
Myriophyllum brackish	water-milfoil	
Odixia angusta	thin odixia	e
Olearia ciliata	fringed daisy bush	
Olearia ericoides	heathy daisy bush	e
Oxalis perennans	native oxalis	
Pelargonium sp.	pelargonium, geranium	i
Pimelea humilis	common or dwarf rice-flower	
Pimelea flava	yellow rice flower	r
Plantago coronopus	plantain, buck's horn	i
Platylobium obtusangulum	common flat-pea	
Platylobium triangulare	ivy flat-pea	
Pomaderris apetala	dogwood, native hazel	
Pomaderris elliptica	yellow dogwood	
Pomaderris pilifera	hairy yellow dogwood	
Poranthera microphylla	small poranthera	
Pratia irrigua	salt pratia	
Pultenaea dentata	button pea	
Pultenaea pedunculata	matted bush-pea	
Ranunculus water	buttercup	
Rhytidosporum procumbens	marys flower	
Ricinocarpos pinifolius	wedding bush	
Sagina sp.		
Samolus repens	creeping brookweed	
Sarcocornia blackiana	marsh samphire	
Sarcocornia quinqueflora	beaded glasswort or samphire	
Scaevola aemula	fairy fan-flower	
Scaevola hookeri	creeping fan-flower	
Scleranthus biflorus	knawel, twin-flower knawel	
Sclerostegia shrubby	glasswort	
Sclerostegia arbuscula	shrubby glasswort	
Sebaea albidiflora	white sebaea	
Selliera radicans	swamp-weed	
Senecio hispidulus	hill fireweed	
Senecio quadridentatus	cotton fireweed	
Spergularia media	coastal sand-spurry	
Stenanthemum pimeleoides	spreading stenanthemum	e, v, EN
Stylidium graminifolium	common trigger plant	
Styphelia adscendens	golden heath	
Suaeda australis	seablite	
Trifolium sp.	subterranean clover, clover	i
Ulex europaeus	common gorse, furze	i
Utricularia dichotoma	bladderwort, fairies' aprons	
Vellereophyton white	cudweed, cudweed	i
Villarsia reniformis	yellow or running marsh-flower	
Viminaria juncea	golden spray or native broom	en
Viola hederacea	ivy-leaf violet	
Wahlenbergia sp.		
Wilsonia backhousei	narrow-leaf wilsonia	
Wilsonia humilus	round-leaf wilsonia	

Xanthosia pilosa	woolly xanthosia	
ANGIOSPERMAE: MONOCOTYLEDONAE		
Agrostis aemula	blown grass	r
Agrostis avenacea	blown grass	
Agrostis billardierei	coast blown grass	e
Agrostis capillaris	bent grass	i
Aira caryophyllea	silver hair grass	i
Amphibromus neesii	southern swampgrass	r
Amphibromus recurvatus	dark swamp wallaby-grass	
Austrodanthonia caespitosa	common wallaby-grass	
Austrodanthonia laevis	wallaby-grass	
Austrodanthonia racemosa	wallaby-grass	
Austrodanthonia setacea	bristly or mulga wallaby-grass	
Austrodanthonia tenuior	fine wallaby-grass	
Austrostipa mollis	soft spear-grass	
Austrostipa nodosa	spear grass	
Austrostipa pubinodis	tall spear-grass	
Austrostipa rudis	australis Austral spear-grass	
Austrostipa stipoides	coastal spear-grass	
Austrostipa stuposa	corkscrew grass	
Baumea acuta	pale twig-rush	
Baumea arthrophylla	articulate twig-rush	
Baumea juncea	bare twig-rush	
Bolboschoenus caldwellii	sea club-rush	r
Burchardia umbellata	milkmaids, star-of-Bethlehem	
Caladenia alata	winged caladenia	
Caladenia fuscata	dusky caladenia	
Caladenia gracilis	musky caladenia	
Carex appressa	tall sedge	
Carex breviculmis	sedge	
Caustis pentandra	thick twist-rush	
Centrolepis fascicularis	tufted centrolepis	
Centrolepis polygyna	wiry centrolepis	
Chorizandra australis	heron thistle-rush	
Dactylis glomerata	cocksfoot, orchard-grass	i
Deyeuxia monticola	bent grass	
Deyeuxia quadriseta	reed bent grass	
Dianella revoluta	spreading or black-anther flax-lily	
Dianella tasmanica	blue berry, tasman flax-lily	
Dichelachne crinita	long-hair plume grass	
Dichelachne rara	scarce plume-grass	
Diplarrena moraea	white flag iris, butterfly iris	
Distichlis distichophylla	Australian salt-grass	
Ehrharta distichophylla	hairy rice-grass	
Ehrharta stipoides	weeping grass	
Eleocharis pusilla	small spike-rush	
Eleocharis sphacelata	tall spike-rush	
Elymus scaber	rough wheat-grass	
Eriochilus cucullatus	pink autumn orchid	
Eurychorda complanata	flat cord-rush	
Festuca arundinacea	fescue, tall fescue	i
Gahnia filum	chaffy saw-edge, thready saw-edge	
Gahnia radula	thatch saw-edge	
Gahnia trifida	coast saw-sedge	
Genoplesium tasmanicum	Tasmanian midge orchid	
Hemarthria uncinata	matt grass	
Holcus lanatus	velvet grass, Yorkshire fog	i
Holcus mollis	velvet grass	i

Hypolaena fastigiata	tassel rope-rush	
Hypoxis hygrometrica	golden weather-glass	
Imperata cylindrica	blady grass	
Isolepis cernua	nodding, low or grassy club-rush	
Isolepis fluitans	floating club-rush	
Isolepis inundata	swamp club-rush	
Isolepis nodosa	knobby or knotty club-rush	
Isolepis producta	club-rush	
Juncus articulatus	rush, jointed rush	i
Juncus australis	Austral rush	
Juncus bufonius	toad rush	
Juncus kraussii	sea rush	
Juncus pallidus	pale rush	
Juncus planifolius	broad-leaf rush	
Juncus procerus	great rush	
Juncus revolutus	creeping rush	
Lepidosperma concavum	sand or hill sword-sedge	
Lepidosperma gunnii	little or narrow sword-sedge	
Lepidosperma inops	fan sedge	e
Lepidosperma longitudinale	pithy or common sword-sedge	
Lepilaena cylindrocarpa	long-fruited water-mat	
Lepilaena patentifolia	spreading water-mat	r
Leptocarpus brownii	coarse twine-rush	
Leptocarpus tenax	slender twine-rush	
Lepyrodia muelleri	common or erect scale-rush	
Lomandra longifolia	sagg, long or spiny-headed mat-rush	
Lomandra nana	pale mat-rush	
Microtis unifolia	common onion orchid	
Notodanthonia gracilis	graceful wallabygrass	T
Patersonia fragilis	blue iris, short purple-flag	
Poa clelandii	Cleland’s poa grass	
Poa labillardierei	tussock grass	
Poa poiformis	blue tussock grass	
Poa sieberiana	tussock or snow grass	
Polypogon annual	beardgrass	i
Potamogeton australiensis	thin pondweed	
Potamogeton ochreatus	blunt pondweed	
Pterostylis aff.	cycnocephala swan greenhood en	
Puccinellia stricta	saltmarsh grass	
Ruppia megacarpa	ruppia	r
Ruppia polycarpa	ruppia	
Schoenus fluitans	floating bog-rush	
Schoenus maschalinus	leafy or dwarf bog-rush	
Schoenus nitens	shiny bog-rush	
Schoenus tesquorum	bog-rush	
Spiranthes australis	pink spiral orchid	
Sporobolus virginicus	salt couch	r
Tetraria capillaris	hair-sedge, bristle twig-rush	
Thelymitra carnea	tiny sun orchid	
Themeda triandra	kangaroo grass	
Triglochin procerum	water-ribbons	
Triglochin striatum	streaked arrow-grass	
Wurmbea uniflora	early Nancy, harbinger-of-spring	
Xanthorrhoea australis	Austral grass-tree, black-boy	
Zostera muelleri	dwarf grass-wrack	
Zoysia macrantha	prickly couch	
GYMNOSPERMA		
Callitris rhomboidea	Oyster Bay pine	

Callitris sp. aff. oblonga	south esk pine	
Pinus radiata	radiata pine	i
PTERIDOPHYTA		
Pteridium esculentum	bracken, Austral bracken	
Selaginella uliginosa	swamp selaginella	