



**Australian Government**

**Department of Sustainability, Environment,  
Water, Population and Communities**

# **Corner Inlet Ramsar site**

## **Ecological Character Description**

June 2011

Chapter 3

Other chapters can be downloaded from:

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### 3 CRITICAL COMPONENTS, PROCESSES AND SERVICES/BENEFITS

#### 3.1 Background

As wetlands are highly complex ecosystems, a complete inventory and assessment of the physical, chemical and biological components and processes for even the simplest of wetlands would be extensive and difficult to conceptualise. Of primary importance to wetland management is having an understanding of the key components that characterise the wetland and their initial state, and the basic rules that link the key components and cause changes in state.

A primary purpose of an ECD is to identify, describe and where possible, quantify the critical components, processes, benefits and services that together make up the ecological character of the site. These are the aspects of the wetland that if altered, would result in a change to the character of the wetland.

Figure 3-1 from the National ECD Framework document shows a generic conceptual model of the interaction between ecosystem components, processes and services/benefits for a wetland. In general terms, the model shows how wetland ecosystem processes interact with wetland components to generate a range of wetland services/benefits. These services/benefits can be broadly applicable to all wetlands ecosystems (such as primary productivity) or specific to a given site (for example, breeding habitat for an important avifauna species or population).

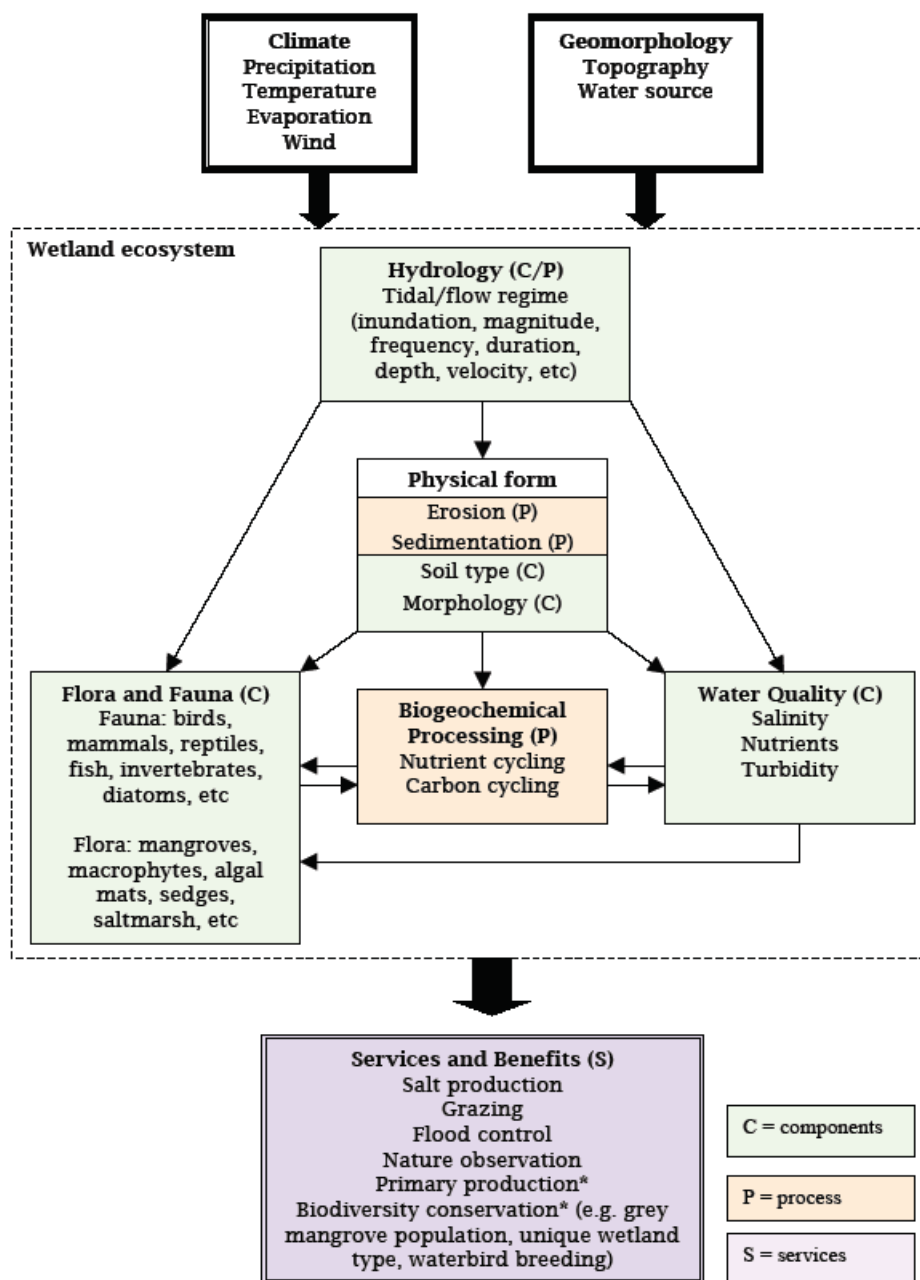
This section describes the critical components, processes and services/benefits that together make up the ecological character of the site. The method employed to identify critical components, processes and services/benefits is presented in Appendix A. Following the direction provided within the National ECD Framework (DEWHA 2008), the assignment of a given wetland component, process or service/benefit as critical was guided by the following considerations:

- the component, process or service/benefit is an important determinant of the unique character of the site, and/or
- the component, process or service/benefit is important for supporting one or more of the Ramsar Nomination Criteria under which the site was listed, and/or
- a change in a component, process or service/benefit is reasonably likely to occur over short or medium times scales (less than 100 years), and/or
- a change to the component, process or service/benefit will cause significant negative consequences.

Additionally, a second tier of 'supporting' components, processes and services/benefits have been identified. These 'supporting' components, processes and services/benefits, while important to wetland functioning, were in isolation not considered to directly address the criteria listed above.

For each of the critical components, processes and services/benefits (C, P, S/B), a brief description is provided for: (i) the rationale for inclusion as a critical; (ii) a description of the element and (iii) a description of patterns in variability over time. It should be noted that in nearly all cases, there was no actual baseline data-set describing the wetland indicator before or at the time of declaration of

the site in 1982. Therefore, in the following sections, both pre-listing and post-listing data have been used to describe patterns in variability in space or over time.



Note: Those marked with an \* may be considered as components or processes as well as ecosystem services or benefits

**Figure 3-1 Generic Conceptual Model Showing Interactions between Wetland Ecosystem Components, Processes and Services/Benefits (Source: DEWHA 2008)**

## **3.2 Overview of Critical Components, Processes and Services/Benefits**

A summary of the critical components, processes and services/benefits for the Corner Inlet Ramsar site as determined through the present study are shown in Table 3-1.

In summary, the following have been identified:

- two critical components and two supporting components
- one critical process and five supporting processes
- two critical services/benefits and two supporting services/benefits.

The justification for selection of each critical/supporting element and a more detailed discussion of each is described in Section 3.3 of this document.

The broad interaction of wetland services/benefits, processes and components at a whole-of-site level is shown in Figure 3-2. The figure shows that there are three broad processes identified (climate, geomorphology and regional-scale hydrodynamic and hydrological processes) that together have shaped the topography, marine and freshwater flow regime and other important aspects of the site. At the local habitat scale, there is a mix of physical and chemical processes as well as biological processes that control the wetland habitats and associated biota. The interaction of the wetland components with the wetland processes yields a range of wetland services/benefits (shown in the yellow box in Figure 3-2) that are characterised as supporting (ecosystem services) and cultural (relevant to providing a social or economic benefit to humans) using the terminology in the National ECD Framework.

Table 3-1 Summary of Critical Components, Processes and Services/Benefits

Critical Components	Critical Processes	Critical Services/Benefits
<p><b>C1.</b> Several key <b>wetland mega-habitat types</b> are present:</p> <ul style="list-style-type: none"> <li>• seagrass</li> <li>• intertidal sand or mud flats</li> <li>• mangroves</li> <li>• saltmarshes</li> <li>• permanent shallow marine water</li> </ul> <p><b>C2.</b> Abundance and diversity of <b>waterbirds</b></p>	<p><b>P1.</b> <b>Waterbird breeding</b> is a key life history function in the context of maintaining the ecological character of the site, with important sites found on the sand barrier islands</p>	<p><b>S1.</b> The site supports <b>nationally threatened fauna species</b> including:</p> <ul style="list-style-type: none"> <li>• orange-bellied parrot</li> <li>• growling grass frog</li> <li>• fairy tern</li> <li>• Australian grayling</li> </ul> <p><b>S2.</b> The site supports <b>outstanding fish habitat values</b> that contribute to the health and sustainability of the bioregion</p>
Supporting Components	Supporting Processes	Supporting Services/Benefits
<p>Important <b>geomorphological features</b> that control habitat extent and types include:</p> <ul style="list-style-type: none"> <li>• sand barrier island and associated tidal delta system</li> <li>• the extensive tidal channel network</li> <li>• mudflats and sandflats.</li> </ul> <p><b>Invertebrate megafauna</b> in seagrass beds and subtidal channels are important elements of biodiversity and control a range of ecosystem functions.</p> <p>The <b>diverse fish communities</b> underpin the biodiversity values of the site</p>	<p><b>Climate</b>, particularly patterns in temperature and rainfall, control a range of physical processes and ecosystem functions</p> <p>Important <b>hydraulic and hydrological processes</b> that support the ecological character of the site includes:</p> <ul style="list-style-type: none"> <li>• Fluvial hydrology. Patterns of inundation and freshwater flows to wetland systems</li> <li>• Physical coastal processes. Hydrodynamic controls and marine inflows that affect habitats through tides, currents, wind, erosion and accretion.</li> <li>• Groundwater. For those wetlands influenced by groundwater interaction, the level of the groundwater table and groundwater quality.</li> </ul> <p><b>Water quality</b> underpins aquatic ecosystem values within wetland habitats. The key water quality parameters for the site are salinity, turbidity, dissolved oxygen and nutrients</p> <p>Important <b>biological processes</b> include nutrient cycling and food webs.</p>	<p>The site supports <b>recreation and tourism values</b> (scenic values, boating, recreational fishing, camping, etc.) that have important flow-on economic effects for the region.</p> <p>The site provides a range of values important for <b>scientific research</b>, including a valuable reference site for future monitoring.</p>

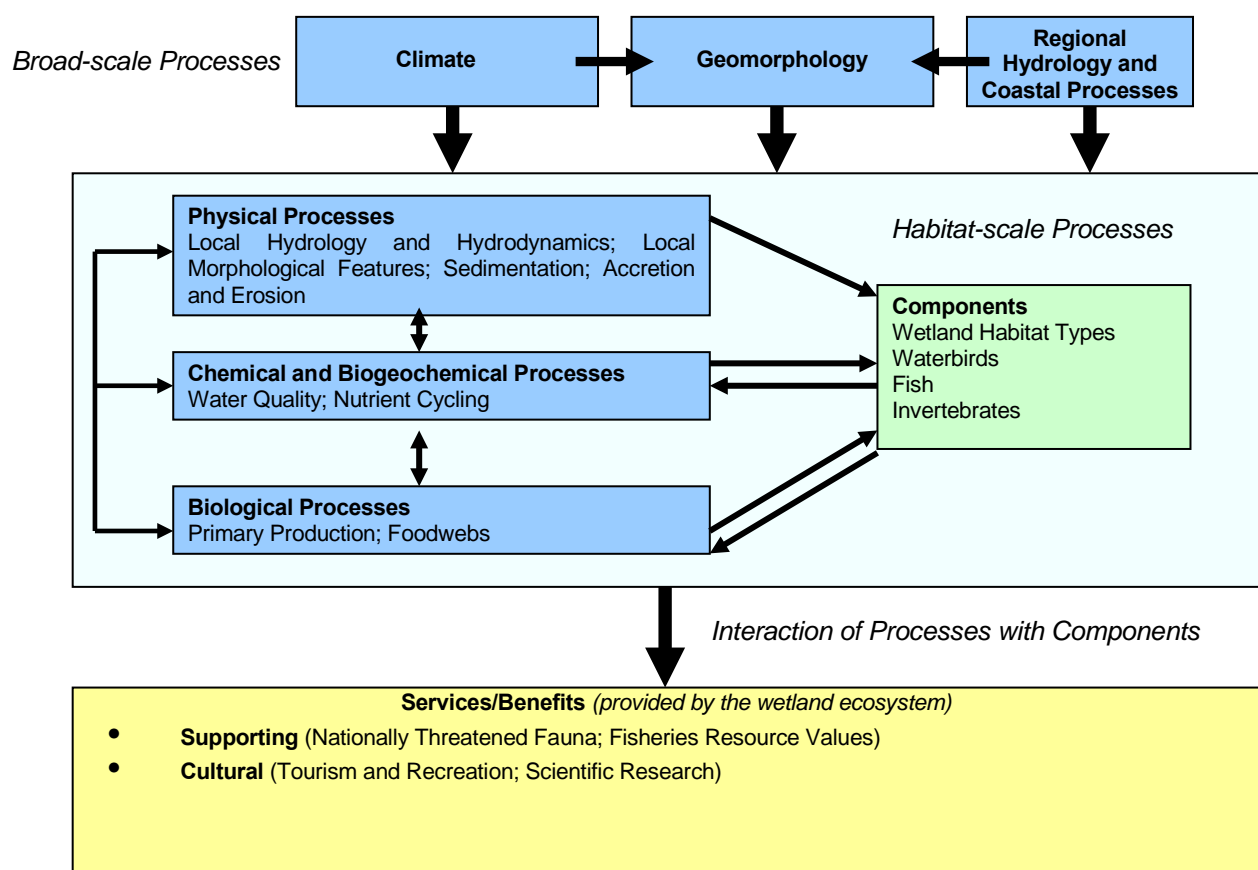


Figure 3-2 Conceptual Model Showing Interaction of Critical and Supporting Elements

### 3.3 Critical Components

As outlined in Section 2, a wide diversity of wetland types occurs within the site. These wetlands support a rich diversity of wildlife (from planktonic organisms to vertebrates), which together make up the ecosystem components of the wetland.

Critical ecosystem components are considered here to represent the critical habitats, key species and wildlife populations that underpin the critical services/benefits described in Section 3.7. Thus, they include broadly, the 13 confirmed natural wetland habitat types presented by the site as outlined in Section 2, the populations of wetland species of national/international conservation significance, and populations of those wildlife groups that underpin Ramsar listing namely, waterbirds and fish.

#### 3.3.1 C1 - Marine and Estuarine Wetland Habitats

##### Reasons for Selection as 'Critical'

While the site supports a broad range of wetland habitat types, certain marine and estuarine habitats are considered to be particularly important in the context of maintaining fish, waterbird and other marine fauna assemblages. Furthermore, several of these wetland habitat types are considered to have high values in their own right, and are considered to be significant on a bioregional scale (see Criterion 1 – Section 2.2.2).

It is important to recognise that these habitat types do not represent discrete elements, but rather form a mosaic of habitat types that interact to maintain wetland functioning. Changes to functions in one habitat type are likely to have interactive and cumulative effects in other habitat types.

##### Description

As outlined in Section 2.1.2.2, the site supports a wide range of habitats, several of which are considered as critical components due to their roles in maintaining critical services discussed above. While all wetlands represent important components, the following are considered to be critical components in the context of the ecological character of the site including other critical components (fauna) and critical services/benefits:

##### *Marine subtidal aquatic beds*

Marine subtidal aquatic beds (analogous to Ramsar wetland type B) are characterised by seagrass meadows, although macroalgae (seaweed) also occurs through the site. Seagrass beds are considered critical components in the context of the following:

- *Posidonia* seagrass beds are the largest in the bioregion
- *Zostera* and *Heterozostera* beds are also significant in a bioregional context
- seagrass provides the basis of benthic food-webs at the site, particularly in the context of its role as a source of detritus for benthic invertebrates, and a source of epiphytic algae which represents a key food resource for commercially significant species (Nichols *et al.* 1985; Longmore 2007)

- seagrass, particularly *Posidonia* beds, provides important nursery habitat for stocks of fish and crustacean species of commercial and recreational fisheries value. Dense *Posidonia* and *Zostera*-dominated seagrass beds represent structurally diverse habitats that provide important nursery habitat for luderick (Jenkins *et al.* 1997), flathead and snapper (Plummer *et al.* 2003). The larval stages of several commercial species, such as blue rock whiting (*Haletta semifasciata*), six-spine leatherjacket (*Meuschenia freycineti*) and rough leatherjacket (*Scobinichthys granulatus*), settle directly on deeper, subtidal *Heterozostera* beds (Jenkins *et al.* 1997)
- other species (such as flounder), while favouring 'unvegetated' habitats, also benefit from organic enrichment of sediments by seagrass debris, which can increase food production in 'unvegetated' habitats (Jenkins *et al.* 1993 cited in Jenkins *et al.* 1997)
- associated with the above, anecdotal reports by commercial fishers suggest that long-term fish catches in the site are determined by changes in seagrass extent. An apparent decline in *Posidonia* extent in 1974 reportedly resulted in a decline in fish catches, to such an extent that several fishers took up other business (Corner Inlet Fisheries Habitat Association 2009)
- seagrass provides regulatory services through stabilisation of coastal sediments
- seagrasses are responsible for a significant portion of critical processes that underpin the health of the site, for example, primary production, sediment stabilisation, nutrient, carbon and energy cycling.

#### *Intertidal and shallow subtidal sand or mud flats*

These environments are notable in their role in the provision of:

- habitat for microphytobenthos (benthic micro-algae), which is a key driver of foodwebs supporting commercially significant species (Nichols *et al.* 1985; Longmore 2007)
- habitat for macroinvertebrates, which provide prey resources for a range of fish and wader birds, as well as a key role in nutrient cycling in the estuary (see Section 3.6.4)
- protection of the shoreline from erosion.

#### *Intertidal and fringing forested wetlands*

This habitat type is characterised by mangroves, intertidal marshes (saltmarsh) and fringing teatree communities and freshwater marshes (dominated by *Melaleuca* and *Leptospermum*). These habitats form an important linkage between terrestrial and marine-based ecosystems. They are notable in the context of their role in the provision of habitat for juvenile fish and other marine organisms, as well as roosting sites for birds, and function in protecting the shoreline from erosion. Mangroves within the site are also of biogeographical importance, forming the most southern distribution of white mangroves in the world. Forest areas also provide important bird roost sites and feeding areas, as well as potential fisheries habitats.

#### *Permanent shallow marine water*

Like intertidal flats (without seagrass), microphytobenthos represent the dominant primary producers in this habitat type. There are no available data describing patterns in biomass of microphytobenthos over time and space (among depths, different sections of the site etc.). This habitat type is characterised by invertebrate activity (Ecos unpublished), which like tidal flats,



provide important ecosystem functions in terms of nutrient cycling and maintenance of benthic foodwebs (see Section 3.6.4)

### **Patterns in Variability of Representative Wetland Types**

#### *Spatial and temporal variability in seagrasses*

Patterns in 'natural' variability in the distribution and extent of seagrass meadows are reasonably well known from seagrass mapping studies (see Roob *et al.* 1998; Hindell *et al.* 2007).

Several studies describe seagrass extent prior to site listing (that is, pre 1982). Poore (1978) estimated that *Posidonia* meadows in 1965 had a total area of 11 900 hectares. Roob *et al.* (1998) mapped seagrass and reported on changes in seagrass beds in Corner Inlet from 1969 to 1998. Large-scale (1:20 000 to 1:25 000) historical aerial photographs were available for six sites (Duck Point, Doughboy Island, Barry Point, Snake Island, Port Albert and Manns Beach) but not all years analysed (1969, 1972, 1976, 1980, 1981, 1988, 1989, 1991 and 1998) were available for each site. There were notable data limitations (primarily related to image quality) which preclude a definitive assessment of seagrass changes, however it is apparent that:

- the key temporal pattern of seagrass change was one of continual fluctuations in the level of seagrass cover
- there was generally good coverage of seagrass in 1969, a decline in the 1970's, a period of regrowth and regeneration in the 1980's, and a return to good coverage in 1998
- however, patterns in temporal change (that is, increase or decrease) were not consistent across all sites, with distinct differences between Corner Inlet, the Snake Island area and the Nooramunga.

Note that Roob *et al.* (1998) provided only qualitative descriptions of historical seagrass changes, largely due to poor image quality of many of the aerial photographs (as well as absence of ground-truthing). For this reason, the only quantitative data available prior to Ramsar site listing is Poore's estimate as of 1965 (11 900 hectares), which is known to have changed since this time and is therefore not indicative of conditions at the time of listing. This represents a critical information gap.

Based on the most comprehensive available data available to date (Roob *et al.* 1998), 14 895 hectares of seagrass was mapped in 1998, with mono-specific *Posidonia* meadows having an area of approximately 3196 hectares, monospecific *Zosteraceae* having an area of 10 999 hectares, and mixed *Posidonia/Zostera* and/or *Halophila* having a total area of approximately 696 hectares (Table 3-2). Roob *et al.*'s (1998) *Posidonia* cover estimate was therefore far lower than Poore's.

**Table 3-2 Summary of Total Areas of Various Seagrass Communities Mapped at Corner Inlet and Nooramunga by Roob et al. (1998) (surveyed in 1998)**

<b>Seagrass species and density</b>	<b>Area (hectares)</b>
Sparse <i>Zostera</i>	4179.3
Medium <i>Zostera</i>	1076.9
Dense <i>Zostera</i>	5743.0
Sparse <i>Posidonia</i>	109.3
Medium <i>Posidonia</i>	36.1
Dense <i>Posidonia</i>	3051.0
Sparse <i>Halophila</i>	5.1
Dense <i>Halophila</i>	15.9
Sparse Mixed <i>Zostera/Posidonia</i>	9.3562
Dense Mixed <i>Zostera/Posidonia</i>	173.0
Sparse Mixed <i>Zostera/Halophila</i>	455.4
Dense Mixed <i>Zostera/Halophila</i>	6.3
Sparse Mixed <i>Posidonia/Halophila</i>	30.3
Sparse Mixed <i>Zostera/Posidonia/Halophila</i>	1.2
Intertidal vegetation	3.7

#### *Spatial extent of other habitat types*

While there are some available data describing spatial patterns in the distribution and extent of mud flats, sand islands and mangroves, there is comparatively limited empirical data describing changes in these features at relevant (whole-of-site) spatial scales.

Figure 2-6 shows the present-day mapped extent of different vegetation communities (EVCs) within the site, which includes mangroves (2137 hectares) and saltmarsh (2613 hectares). These estimates are generally inconsistent with other mapping studies. For example, for mangroves, estimates include 1860 hectares (NLWRA 2001; see Table 3-3), 257 hectares (Australian Coastal Resource Atlas Online) and 3720 hectares (Bucher and Saenger 1989). All these studies were undertaken after Ramsar site declaration. For saltmarsh, NLWRA (2001) estimates that the area within Corner Inlet was 6550 hectares, which is far greater than the above EVC mapping estimates. It is likely that these differences were due to differences in mapping methodologies and study area extents.

NLWRA (2001) mapped the areas of mud flats, tidal sand banks and barrier/back barrier features in Corner Inlet (Table 3-3). Note that these data have limited spatial resolution and should therefore be considered as indicative only, and were also based on data collected well after Ramsar listing.

**Table 3-3 Mapped Area of Different Habitat Features in Corner Inlet (Source: NLWRA 2001)**

Feature	Area (hectares)
Barrier/Backbarrier	1071
Flood Ebb Delta	1081
Intertidal Flats	38 710
Mangrove	1859
Saltmarsh/Saltflat	6551
Tidal Sandbanks	689
Channel	16 349

*Temporal patterns in extent of other habitat types*

Denis (1994) provides estimates of temporal changes in mangroves at various stations in Corner Inlet between 1941 and 1987. The pattern of temporal change varied inconsistently among sites, with small changes noted at Millers Landing, losses recorded at Long Island, and increases recorded at Port Welshpool and Toora. Denis (1994) argued that most changes were associated with changes in climatic and coastal processes, as well as biological interactions with other vegetation types and existing mangroves. No studies have examined temporal changes in the extent of mangroves or saltmarsh at a whole of site scale, nor have any studies described changes in species composition in saltmarsh communities over time.

The sand barrier island system of Corner Inlet is known to be temporally dynamic, but no studies to date have quantified changes in distribution and extent over time. Similarly, there is little information describing changes in the extent of intertidal flats and shoals over time. These represent important information gaps in the context of this critical component.

### **3.3.2 C2 - Abundance and Diversity of Waterbirds**

#### **Reasons for Selection as 'Critical'**

The importance of Corner Inlet as a site of national and international significance for migratory shorebirds has been widely described (Martindale 1982; Mansergh and Norris 1982; Watkins 1993; ANCA 1996; Bell 1998; Minton et al. 2002; DSE 2003; Clemens et al. 2007; and Bamford et al. 2008). The site is also significant for non-migratory shorebirds (Mansergh and Norris 1982; Watkins 1993; Minton 1997; Taylor and Minton 2006; Clemens et al. 2007; Ecos unpublished) and waterbirds generally (Norman 1982; Peter 1991; ANCA 1996; Bell 1998; Ecos unpublished). Selection of waterbirds as a critical component supports Ramsar nomination criteria 2, 4, 5 and 6.

#### **Description**

A total of 95 waterbird species have been recorded within the site (Martindale 1982; DSE 2009; Birds Australia 2009c; see Appendix C) which represents 93 per cent of the waterbird diversity recorded in Victoria (Barrett et al. 2003). The site's waterbird assemblage includes 24 migratory shorebird species, 13 resident shorebird species and 14 species of gulls and terns.

Migratory shorebirds species that are listed under international bilateral agreements, and are known to occur within the site, are shown in Table 3-4.

**Table 3-4 Migratory Shorebirds within the Site that are Listed Under Bilateral Agreements**

Scientific name	Common name	CAMBA	JAMBA	ROKAMBA
<i>Actitis hypoleucos</i>	common sandpiper	x	x	x
<i>Ardea ibis</i>	cattle egret	x	x	
<i>Ardea modesta</i>	eastern great egret	x	x	
<i>Ardenna tenuirostris</i>	short-tailed shearwater		x	x
<i>Arenaria interpres</i>	ruddy turnstone	x	x	x
<i>Calidris acuminata</i>	sharp-tailed sandpiper	x	x	x
<i>Calidris alba</i>	sanderling	x	x	
<i>Calidris canutus</i>	red knot	x	x	x
<i>Calidris ferruginea</i>	curlew sandpiper	x	x	x
<i>Calidris melanotos</i>	pectoral sandpiper		x	x
<i>Calidris ruficollis</i>	red-necked stint	x	x	x
<i>Calidris tenuirostris</i>	great knot	x	x	x
<i>Charadrius leschenaultii</i>	greater sand plover	x	x	x
<i>Charadrius mongolus</i>	lesser sand plover	x	x	x
<i>Chlidonias leucopterus</i>	white-winged black tern	x	x	x
<i>Glarecola maldivarum</i>	oriental pratincole	x	x	x
<i>Gallinago hardwickii</i>	Latham's snipe	x	x	x
<i>Heteroscelus brevipes</i>	grey-tailed tattler	x		x
<i>Hydroprogne caspia</i>	caspian tern	x	x	
<i>Limosa lapponica</i>	bar-tailed godwit	x	x	x
<i>Limosa limosa</i>	black-tailed godwit	x	x	x
<i>Numenius madagascariensis</i>	eastern curlew	x	x	x
<i>Numenius phaeopus</i>	whimbrel	x	x	x
<i>Pluvialis fulva</i>	Pacific golden plover	x	x	x
<i>Pluvialis squatarola</i>	grey plover	x	x	x
<i>Sterna hirundo</i>	common tern	x	x	x
<i>Sternula albifrons</i>	little tern	x	x	x
<i>Sterna bengalensis</i>	lesser crested tern	x		
<i>Tringa glareola</i>	wood sandpiper	x	x	x
<i>Tringa nebularia</i>	common greenshank	x	x	x
<i>Tringa stagnatilis</i>	marsh sandpiper	x	x	x
<i>Xenus cinereus</i>	terek sandpiper	x	x	x

Analyses of shorebird monitoring data by Clemens *et al.* (2007) indicate that the barrier islands (eastern part of the site) and the south-eastern sector of the site represent areas of high shorebird abundance. In addition, areas with the greatest diversity were similar to the areas with the greatest

abundance, and south-eastern Corner Inlet has supported the most species (Clemens et al. 2007). Some areas such as Sandy Point (Figure 1-2) have relatively high abundance but low diversity, while other areas such as Camel Rocks reported relatively low abundance with high diversity (Clemens et al. 2007).

Species other than shorebirds also represent a large proportion of the overall waterbird assemblage (shorebirds and non-shorebirds). Non-shorebird species that are present in notable (potentially significant) abundance include black swan (*Cygnus atratus*), grey teal (*Anas gracilis*) and chestnut teal (*Anas castanea*) (Norman 1982; Peter 1991; Ecos unpublished; Norman and Chambers 2010).

Several factors contribute to the high abundances of shorebirds within the site, namely:

- the wide diversity of habitats in relatively close proximity
- the extensive areas of intertidal flats which represent the main feeding areas for shorebirds
- the relatively undisturbed nature of habitats
- low levels of human activity and associated disturbance.

### **Patterns in Variability**

With some notable exceptions (see discussion on ducks below), data for waterbirds is not as comprehensive as that for migratory shorebirds, and is generally insufficient to confidently enumerate the size of that part of the waterbird assemblage. Notwithstanding this, reviews of the available data indicate that both abundance and species richness of most non-migratory shorebirds have remained relatively stable in the long-term, but show great variability between years (Ecos unpublished, Norman and Chambers 2010).

Norman and Chambers (2010) analysed temporal patterns in the abundance of chestnut teal (*Anas castanea*), grey teal (*A. gracilis*), Pacific black duck (*A. superciliosa*) and Australian shelduck (*Tadorna tadornoides*) between 1977 and 2002 in western Corner Inlet. In summary they found:

- chestnut teal (mean count  $753.6 \pm 789.9$  S.D., range 0 to 3201,  $n = 279$ ) and grey teal (mean count  $356.2 \pm 464.9$ , range 0 to 2928,  $n = 928$ ) were the most abundant duck species, and Pacific black duck (mean count  $63.6 \pm 128.8$ , range 0 to 1003) and Australian shelduck (mean count  $3.4 \pm 12.1$ , range 0 to 104) were the least abundant
- the two teal species and Pacific black duck were most numerous in summer and autumn, and shelduck reached peak abundance earlier
- Pacific black duck showed strong positive associations with stream flows, chestnut teal showed few correlations to flow and Australian shelduck showed no association with rainfall. Some lags between rainfall and duck abundance were noted, varying among species
- Long term temporal patterns in abundance appeared to be largely determined by breeding conditions elsewhere.

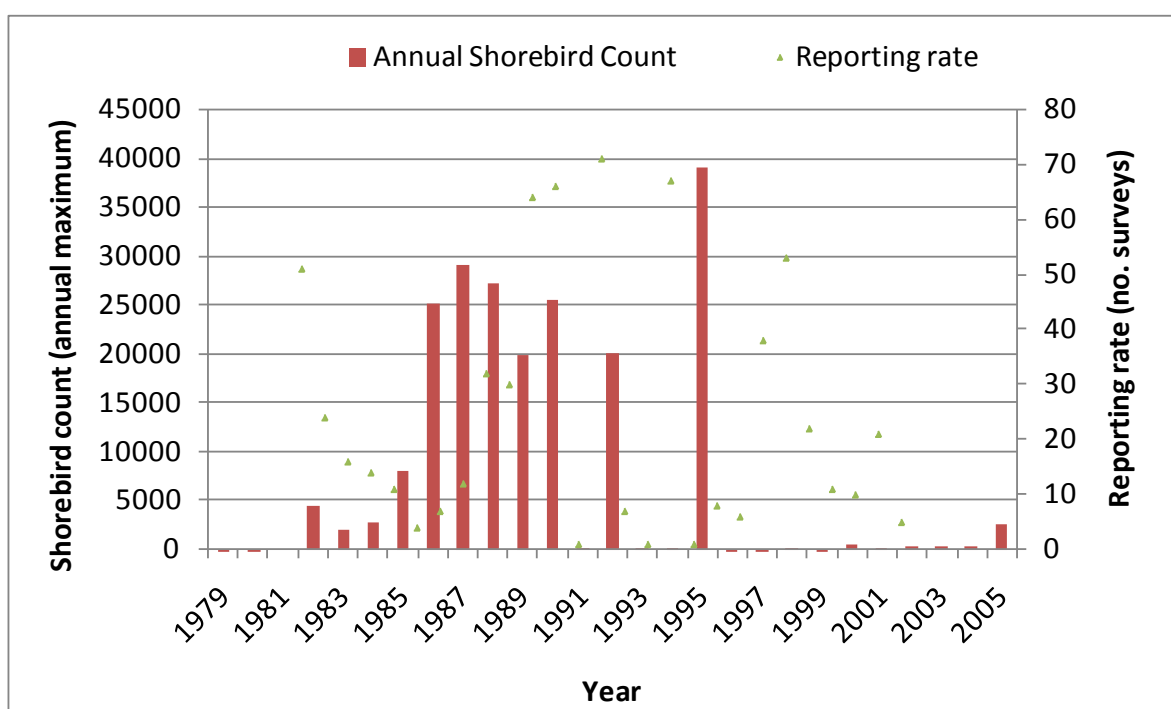
Approximately 25 percent of the waterbirds regularly occurring within the site are migratory shorebirds (24 species). These species utilise wetlands in the southern hemisphere during the austral summer, and while most return to the northern hemisphere in the austral winter, a small proportion may remain at the site. Populations of migratory species fluctuate over a range of time

scales, subject to local factors and conditions external to the site (that is, conditions along migratory routes and/or breeding grounds).

For migratory shorebird species, there is insufficient data to establish a baseline at the time of listing, as most quantitative bird count data were collected after 1982. Therefore, in the context of establishing a baseline to which LACs will apply, counts post listing were considered, particularly in the decade immediately after listing.

Figure 3-3 shows the maximum annual migratory shorebird counts and reporting rate (number of survey episodes and stations per year in which migratory shorebirds were reported) based on DSE Fauna Database Records for Corner Inlet (DSE 2009). The figure shows that for the period between 1986 and 1992, the maximum annual migratory shorebird count was typically (but not always) greater than 20 000 birds. Post-1995, the reported annual maximum migratory shorebird count was very low. The annual reporting rate was highly variable and did not show any consistent trends over time.

Table 3-5 shows the mean annual count for selected key waterbird species that have maximum annual counts that exceed the one per cent of the individuals within a population. Key trends are summarised for each species with the table. Refer also to Appendix D and Nomination Criteria 5 and 6 for discussion regarding trends in waterbird abundance over time. These data provide a reasonable baseline for developing limits of acceptable change (see Section 4).



**Figure 3-3 Maximum Annual Shorebird Counts and Reporting Rate (number of survey episodes and stations per year) based on DSE Fauna Database Records for Corner Inlet (DSE 2009)**

Table 3-5 Patterns in Abundant Waterbird Species at Corner Inlet

Species	One per cent threshold	Average annual count
curlew sandpiper ( <i>Calidris ferruginea</i> )	<p>The current flyway one per cent threshold is 1800 birds (Bamford et al. 2008)</p> <p>This threshold has been exceeded regularly since 1982 (Ecos unpublished; Birds Australia 2009c). This species has been recorded in numbers equivalent to 2.2 per cent of current flyway population estimates (Ecos unpublished).</p>	<p>Long term mean annual count = 2588 birds (Birds Australia 2009c)</p> <p>1987 to 1990, 1992 mean maximum annual bird count (DSE unpublished) = <math>886 \pm 374.9</math> S.E. (DSE 2009)</p>
bar tailed godwit ( <i>Limosa lapponica</i> )	<p>The current flyway one per cent threshold is 3250 (Bamford et al. 2008). This threshold has been exceeded regularly since 1982 (Ecos unpublished; Birds Australia 2009c), and on occasions, in numbers equivalent to 5.5 per cent of current flyway population estimates (Ecos unpublished).</p>	<p>Long term mean annual count = 9727 birds (Birds Australia 2009c)</p> <p>1987 to 1992 mean maximum annual bird count (DSE unpublished) = <math>3694 \pm 1678.5</math> S.E. (DSE 2009)</p>
eastern curlew ( <i>Numenius madagascariensis</i> )	<p>The current flyway one per cent threshold is 400 (Bamford et al. 2008). This threshold has been exceeded regularly since 1982 (Ecos unpublished; Birds Australia 2009c), and on occasions, in numbers equivalent to 3.3 per cent of current flyway population estimates (Ecos unpublished).</p>	<p>Long term mean annual count = 1971 birds (Birds Australia 2009c)</p> <p>1987 to 1990, 1992 mean maximum annual bird count (DSE unpublished) = <math>519 \pm 126.6</math> S.E. (DSE 2009)</p>
pied oystercatcher ( <i>Haematopus ostralegus</i> )	<p>The current flyway one per cent threshold is 110 (Wetlands International 2006). This threshold has been exceeded regularly since 1982 (data from Minton 1997; Taylor and Minton 2006; Birds Australia 2009c), and on occasions, in numbers equivalent to approximately eight per cent of current flyway population estimates (Ecos unpublished).</p>	<p>Long term mean annual count = 893 birds (Birds Australia 2009c)</p> <p>1987 to 1990, 1992 mean maximum annual bird count (DSE unpublished) = <math>370 \pm 130.3</math> S.E. (DSE 2009)</p> <p>Minton (1997) considers that the site may well support the largest breeding concentration in Australia (also supported by data in Taylor and Minton 2006). However, Taylor and Minton (2006) also suggest that predation by foxes may adversely affect breeding success of pied oystercatchers (see Section 5.1.10)</p>
sooty oystercatcher ( <i>Haematopus fuliginosus</i> )	<p>The current flyway one per cent threshold for <i>Haematopus fuliginosus fuliginosus</i> (of southern</p>	<p>Long term mean annual count = 285 birds (Birds Australia 2009c)</p>

Species	One per cent threshold	Average annual count
	Australia) is 40 (Wetlands International 2006). This threshold has been exceeded regularly since 1982 (Ecos unpublished; Birds Australia 2009c), and on occasions, in numbers equivalent to 4.3 per cent of current flyway population estimates (Ecos unpublished).	1987 to 1990, 1992 mean maximum annual bird count (DSE unpublished) = $31 \pm 5.2$ S.E. (DSE 2009)
double-banded plover ( <i>Charadrius bicinctus</i> )	The current flyway one per cent threshold is 500 (Bamford et al. 2008). This threshold has been exceeded regularly since 1982 (see data in Birds Australia 2009c).	Long term mean annual count = 523 birds (Birds Australia 2009c)  1987 to 1990, 1992 mean maximum annual bird count (DSE unpublished) = $518 \pm 126.6$ S.E. (DSE 2009)  Ecos (unpublished) data analysis indicates that numbers fluctuate between about 500 to 950 birds
fairy tern ( <i>Sterna nereis nereis</i> )	The one per cent population threshold for <i>Sterna nereis nereis</i> (of south-eastern Australia) is 25 birds (Wetlands International 2006). This threshold has been exceeded regularly since 1982 (Ecos unpublished), and on occasions, in numbers equivalent to 3.3 per cent of current flyway population estimates (Ecos unpublished).	Insufficient data to determine trends and average number
Pacific gull ( <i>Larus Pacificus</i> )	The one per cent population threshold for <i>Larus Pacificus Pacificus</i> (of Tasmania and Victoria) is 50 birds (Wetlands International 2006). This threshold has been exceeded regularly since 1982 (Ecos unpublished), and on occasions, in numbers equivalent to eight per cent of current flyway population estimates (Ecos unpublished).	Ecos (unpublished) notes that numbers have increased with counts of about 100 in 1982, to almost 400 in 1994, and having remained relatively constant since  Long term average abundance (1965 to 2005) = 7 birds $\pm 2$ S.E. (DSE 2009). For the period 1977 to 1979, maximum annual bird counts were 60, 100, 70 birds, and similar high variability recorded in 2003 to 2005 (172, 20, 23 birds)



## 3.4 Supporting Components

The supporting components outlined below are considered to be important or noteworthy in the context of maintaining the character of the site, but are not considered to represent a critical component in the context of the considerations outlined in Section 3.1 of this report.

### 3.4.1 Geomorphological Features

#### Reasons for Selection

Geomorphological features are important determinants of the configuration, extent and structure of both unvegetated (that is, tidal flats, sandy beaches etc.) and vegetated habitats within the site. Furthermore, the site supports a range of nationally significant geomorphological features that are considered important from a geological perspective.

#### Description

##### *Geomorphological Setting*

The catchment area of Corner Inlet Ramsar site is 2100 square kilometres and the water body comprising Corner Inlet has an area of approximately 600 square kilometres (CSIRO 2005). Corner Inlet is bound to the west and north by the South Gippsland coastline, in the south-east by a series of barrier islands and sandy spits lying end to end and separated by narrow entrances, and to the south by the hills of Wilsons Promontory (Casanelia 1999). The western half of Corner Inlet is a large open basin approximately 25 kilometres in diameter, which has a two kilometre opening between Wilsons Promontory and Snake Island. The eastern half of the site is located almost entirely within Nooramunga Marine and Coastal Park, and is comprised of numerous low lying islands and the outer barrier islands. There are five permanent entrances, which allow exchange of water with Bass Strait (CSIRO 2005).

Corner Inlet is a large submerged plain covered by subtidal and intertidal sand and mud flats, which are intersected by a network of radiating channels. Water depth in the channels is three to 10 metres deep in the northern and western areas of the site, and up to 40 metres deep near the centre and entrance of the site (Plummer et al. 2003; CSIRO 2005; Ecos unpublished). Flow velocities in the channels of Corner Inlet are quite high (greater than one metre per second), facilitating a large exchange of water, yet most of the area is shallow and drains and fills slowly.

A group of low, predominantly sandy islands that are an extension of the Ninety Mile Beach and Gippsland Lakes region occurs east of Corner Inlet between Barry Beach and McLoughlins Beach (DPI 2007b). There are five major islands (Snake, Little Snake, Sunday, Saint Margaret and Clonmel Islands) and over 20 smaller islands, which are comprised of late Pleistocene and Holocene marine sediments (DPI 2007b). Shorelines and tidal flats that border the islands are typically sandy, with the ocean beaches consisting of medium to coarse sand and shells, while finer sands and occasionally mud are the dominant materials of the intertidal areas (Ecos unpublished).

##### *Sites of Geological and Geomorphological Significance*

Sites of geological and/or geomorphological significance within Corner Inlet Ramsar site were mapped by the Victorian DPI (2007a, b and c) and described in the 1999 RIS (Casanelia 1999),

based on information in Rosengren et al. (1981) and Rosengren (1984; 1989). The dates of the original assessments by Rosengren and others suggest that the descriptions apply to the condition of the sites at the time of Ramsar listing in 1982.

Corner Inlet lacks sites of National Significance, but has numerous sites of State, Regional and Local Significance. At Nooramunga, two outer islands and the tidal entrances and tidal deltas have been assigned National Significance, and there are a number of sites of State, Regional and Local Significance. Significant sites at a national scale include (see Figure 1-2 and 1-3; Rosengren 1984; 1989):

- Snake Island
- Clonmel Island
- Shallow Inlet to Reeves Beach (Outer Barrier)
- Port Albert Entrance – Outer Barrier
- Kate Kearney Entrance – Tidal Entrances and Tidal Delta
- Shallow Inlet - Tidal Entrances and Tidal Delta
- New Entrance - Tidal Entrances and Tidal Delta.

Casanelia (1999) suggests that the chain of barrier islands are a westward extension of the Ninety Mile Beach and are of complex form and origin, providing an outstanding example of the processes involved in barrier island formation including the development of multiple beach ridges, lagoons and swamps, tidal creeks, tidal deltas, and tidal washovers. As well as providing localities for the monitoring of sediment dynamics associated with marine and aeolian processes, Ecos (unpublished) suggested that they are of critical importance in the analysis of the evolution of the entire coastal barrier system between Wilsons Promontory and Lakes Entrance (Casanelia 1999).

In the context of maintaining the ecological character of the site, the most important morphological features of the site are considered to be:

- The extensive sand barrier island and associated tidal delta system located on the eastern side of the site. The sand barrier island system partially encloses the site, and protects the site from wave attack due to oceanic swells and seas. This has allowed the development of the extensive network of shoals and channels, which provide habitat for a range of marine/estuarine flora and fauna, as well as shorebirds
- The extensive tidal channel network, which allows very high tidal exchange rates and tidal mixing within the site. The high rates of flushing are a key determinant of the physio-chemical properties of waters and sediments within the site, and the maintenance of relatively good water quality conditions
- Mudflats and sandflats (refer to critical components section for further information).

### **3.4.2 Invertebrate Megafauna**

#### **Reasons for Selection**

Invertebrate megafauna are the large, conspicuous species commonly found in seagrass beds, mudflats and sandflats. These species all contribute to the maintenance of foodchains and

ecosystem functions that underpin the general biodiversity values of the site (underpinning services 1 and 2).

### **Description**

The site supports diverse and abundant invertebrate megafauna assemblages. Surveys by O'Hara *et al.* (2002) noted that seagrass meadows of Corner Inlet effectively support a single benthic community. Representative species include:

- seastars (*Parvulatra exigua* and *Meridiastra calcar*), which are important detritivores that feed on plant and animal debris. Less common are the large eleven-armed seastar (*Coscinasterias muricata*) which preys on molluscs and the seven-armed Southern sand star (*Luidia australiae*)
- turban shells (*Thalotia conica* and *Astraliium aureum*), which feed on epiphytes that grow on seagrass, and therefore are important in the maintenance of seagrass health
- crabs, including red swimmer crab (*Nectocarcinus integrifrons*) and the long-limbed decorator crab (*Naxia aurita*).

The deep channels that drain the seagrass beds support a different invertebrate megafauna community (O'Hara *et al.* 2002). Conspicuous species include:

- planktivorous brittle-star species (*Amphiura elandiformis* and *Ophiocentrus pilosa*), which form extensive colonies along the edge of the channels
- sponges and sea-squirt colonies form 'mini-reefs' at the base of channels (five to 20 metres depth). The sea-squirt *Pyura stolonifera* is a common species which can attach itself to dead oyster shells, and then form micro-habitats for other sedentary species such as sponges (*Dendrilla rosea*), encrusting ascidians, soft-corals, fragile lace-corals, large orange anemones, some red seaweeds and various hydroids, as well as a range of mobile species such as brittle stars, sea cucumbers and seastars.

## **3.4.3 Fish Species Richness**

### **Reasons for Selection**

This supporting component underpins Critical Service 2. Furthermore, fish communities also represent an important driver in maintaining foodwebs within Corner Inlet (see Section 3.6.4), and represent important biodiversity components in their own right.

### **Description**

Approximately 171 fish species have been recorded at the site to date (Ecos unpublished). This represents a high proportion (just under a third) of the total number of marine fish species known to occur in southern temperate waters, although as discussed in Section 2.2.2 (Criterion 7), there is insufficient information to determine the level of diversity relative to other estuaries and embayments in the bioregion.

The high diversity of fish assemblages reflects in part the wide diversity and interconnectivity of habitats present (fresh to marine-estuarine waters) and the large size of the site. Furthermore, the key processes that ultimately control the diversity of habitats (as outlined in Section 3.3) are also likely to maintain fish biodiversity values.

As outlined in Ecos (unpublished), it is thought that marine ‘stragglers’ (occasional visitors to the site) currently comprise just under half the total number of species previously recorded in the site, whereas estuarine – marine opportunists make up approximately one-third of the total number of species within the site.

There are no available data describing natural variability in fish species richness at smaller spatial scales, for example, within and among habitat types; stations within habitat types. The only long-term data describing fish assemblages within the site is commercial fish catch data (that is, catch per unit effort for selected species). These data are not suitable for assessing patterns in species richness. Systematic monitoring would be required to assess patterns in natural variability.

Fish populations within the site contribute to its ecological character but have been addressed as a critical service/benefit (refer Critical Service 2; see Section 3.7.2), focussing on those species and groups that are of commercial and recreational value. Overall, there are significant knowledge and information gaps about broader fish species abundance, distribution and diversity across the site.

## **3.5 Critical Processes**

### **3.5.1 P1 - Waterbird Breeding**

#### **Reasons for Selection as ‘Critical’**

Underpinning the abundance of waterbirds at Corner Inlet (see Critical Component 2; Section 3.3.2), the site supports habitat and conditions that are important to maintaining critical life cycle stages of a variety of wetland-dependent waterbird species (for example, breeding, overwintering, moulting), such that if interrupted or prevented from occurring, may threaten long-term conservation of those species. Of these life cycle functions, breeding is considered to be the most prominent and therefore critical.

Breeding is a critical life stage of species (as reflected in Criterion 4) that is essential in order to ensure the long-term persistence of waterbird populations.

#### **Description and Patterns in Variability**

Site values with respect to waterbird breeding habitat include the following (refer to Figure 1-2 and 1-3 for map of the locations outlined below):

- pied oystercatcher (*Haematopus longirostris*) - over 400 pairs comprising 402 pairs within Nooramunga Marine and Coastal Park (mainly islands, especially Sunday Island) and 44 pairs within Corner Inlet Marine and Coastal Park (mainly mainland coast) (Taylor and Minton 2006); 250 pairs recorded in 1996 considered an underestimate (Minton 1997). Considered to be a breeding (and non-breeding) site of national importance for this species (Taylor and Minton 2006)
- fairy tern (*Sterna nereis nereis*) - Clonmel Island (30 pairs); Boxbank Island (20 pairs); and Dream Island (up to 70 pairs) (Minton in Bell 1998; Ecos unpublished). Barrier islands in the Nooramunga area regularly supports 20 to 40 pairs of Fairy Tern, which is estimated to be 10 to 20 per cent of Victorian breeding population (Ecos unpublished)

- hooded plover (*Thinornis rubricollis*) - up to 20 pairs at sites including Dream Island, Box Bank, Clonmel and Snake Islands (C. Minton in Bell 1998; Ecos unpublished). A review by Clemens *et al.* (2007) suggests that most of the ocean sandy beaches in the region offer good habitat that has been used for breeding by the hooded plover
- Caspian tern (*Sterna caspia*) - up to 55 pairs, one of the largest breeding colonies in Australia (Ecos unpublished), with up to 90 pairs at/on Clonmel Island at port Albert Entrance in late 1990s (Minton in Bell 1998; Ecos unpublished)
- crested tern (*Sterna bergii*) - approximately 400 pairs at McLoughlins Entrance and Dream Island in early 1990's with most breeding effort centred on Clonmel Island at Port Albert Entrance in late 1990s (Minton in Bell 1998; Ecos unpublished).

In terms of temporal patterns, the key breeding times of each species are well understood, however few studies have sought to examine temporal patterns and trends in waterbird breeding success within the site. This represents a key gap in the context of this critical process.

### **3.6 Supporting Processes**

A broad range of ecosystem processes are occurring within Corner Inlet. Those ecosystem processes that are considered to most strongly influence the ecological character of the site have been described below.

Not all ecosystem processes will be relevant across all waterbodies/wetlands of the site, noting the diversity of habitat types and the natural variability of the site to key parameters such as freshwater flows, salinity and nutrient enrichment. Ecosystem processes can also be highly interlinked, for example, the relationship between increased rainfall, hydrological processes and the resultant runoff affecting water quality.

The following sections identify critical processes underpinning critical services/benefits within the site.

#### **3.6.1 Regional Climate Patterns and Processes**

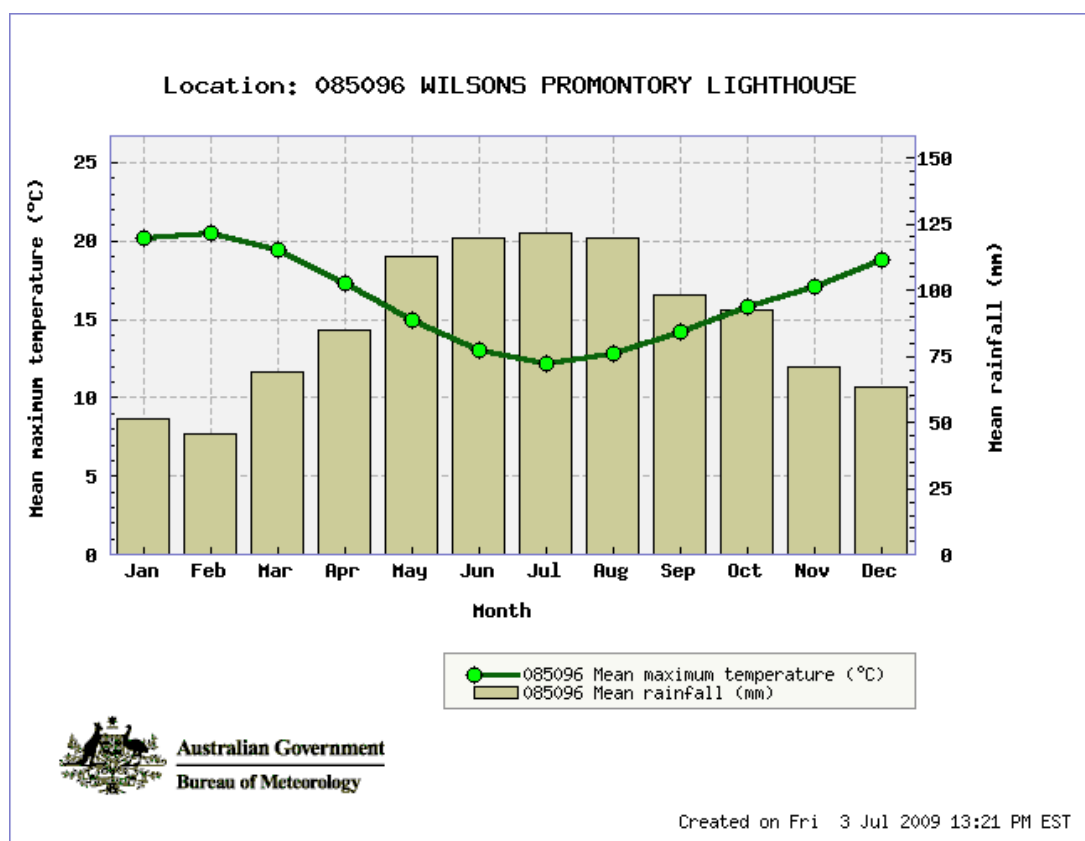
##### **Reasons for Selection**

Key climatic processes that underpin the wetland values of the Corner Inlet Ramsar site include temperature, rainfall, and evaporation. These climatic processes influence the volume, timing and duration of water flows into the site from the major tributaries as well as water levels and inundation regimes within wetland environments.

## Description

Based on Bureau of Meteorology data for Wilsons Promontory Lighthouse (1872 to 2009), the average maximum air temperature in summer is approximately 20 degrees Celsius and the minimum is approximately 14 degrees Celsius. The average maximum temperature in winter is approximately 12 degrees Celsius and the minimum average is approximately eight degrees Celsius (BOM 2009).

Rainfall in the Corner Inlet catchment varies slightly from east to west but significantly north to south. This is due to the presence of the Strzelecki and Hoddle Ranges to the north of the inlet, with much higher rainfalls occurring along the ranges (Ecos unpublished). Rainfall at Wilsons Promontory Lighthouse (Figure 3-4) varies between 46 and 122 millimetres per month (approximately 1049 millimetres annually), but higher average annual rainfalls occur along the mountain ranges situated north of the site (Wonyip station = 1250 millimetres annually). Set against the average annual rainfall, the observed daily rainfall across the catchment can be highly variable in response to weather patterns (southwest fronts, east coast lows) and the resulting stream hydrology is also highly variable (Ecos unpublished). It is expected that climate change will result in an increase in extreme events and altered rainfall and temperature patterns (see Section 5.1.8).



**Figure 3-4 Mean Maximum Temperature and Mean Rainfall at Wilsons Promontory Lighthouse between 1872 and 2009 (source: BOM 2009)**

As climate changes, the climate of Victoria is expected to become warmer, water availability will reduce and extreme storm events are likely to increase in frequency (State of Victoria 2008). In terms of water inflows and wetlands, a significant implication of climate change will be that while

there will continue to be large flow events, the frequency of flooding, flows and duration of inundation is likely to reduce. Further discussion about potential threats to the Ramsar site from climate change are discussed in Section 5.1.8 of this report.

### **3.6.2 Hydrodynamic Regime**

#### **Reasons for Selection**

The Corner Inlet Ramsar site's hydrological regime can be separated into:

- surface freshwater inflows (fluvial hydrology)
- marine in-flows (coastal hydrodynamic processes)
- groundwater inflows and influences.

Each of these aspects of the hydrological regime are considered to be supporting processes that affect the ecological character of the site through their effect on water levels, inundation of soils and the distribution and condition of wetland vegetation communities and the wetland fauna that inhabit them.

#### **Description**

##### *Fluvial Hydrology*

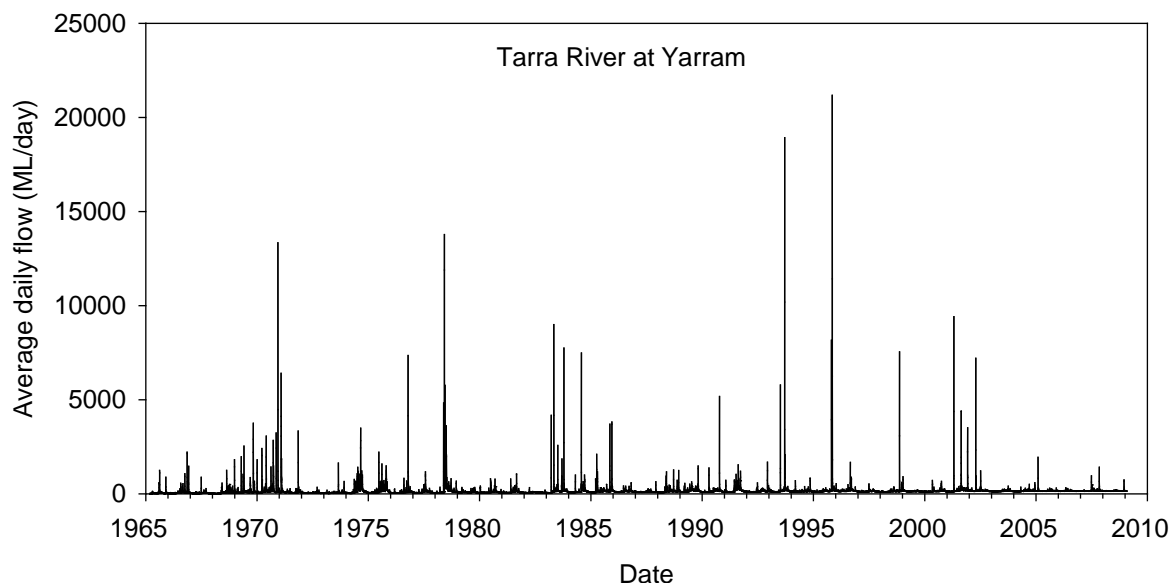
The catchment to water ratio for Corner Inlet is approximately 4:1 with a catchment area of 2100 square kilometres and the Inlet area of about 600 square kilometres. This is comparable to Port Phillip Bay and Western Port (5:1) but much smaller than that of the Gippsland Lakes, which have a ratio of 50:1 (CSIRO 2005). The largest streams entering Corner Inlet are the Franklin, Agnes, Albert, Jack and Tarra Rivers, as well as Bruthen Creek (Figure 3-6).

Due to the relative shortness of these river systems and the small catchments they drain, significant rain events create large flows with higher concentrations of contaminants than during normal dry weather flows (CSIRO 2005). However, daily rainfall can be highly variable across the Corner Inlet catchment and the resulting stream flows are therefore also highly variable (WGCMA 2007). Generally, significant seasonal trends can be observed with higher flows during winter-spring (August to September) and lower flows in summer, but highly variable inter-annual flow is also apparent (WGCMA 2007).

Occurrence of high flow events is infrequent (Figure 3-5) and flows generally revert to their normal dry weather flow within a week. Furthermore, analysis of streamflow occurrence frequencies for several rivers discharging into Corner Inlet showed that flows can range between three to six orders of magnitude (one to 99 percentile flow). However, flows vary only within one order of magnitude for most of the time (15 to 85 percentile flow) indicating that rivers flow consistently for most of the time but may exhibit short events of very small or large flows (WGCMA 2007).

High flow events may lead to a complete flushing of the estuarine reaches of the rivers and make them completely fresh, although these events occur only for short periods (days). The resulting introduction of large volumes of sediment and nutrients may play an important role as lifecycle

triggers for various species, for example, by facilitating fish migration by a flood that acts as a breeding trigger (Ecos unpublished).



**Figure 3-5 Average Daily Flow (Calculated) for Tarra River at Yarram from 1965 to 2009.**  
Data Sourced from Victorian Water Resources Data Warehouse

#### *Coastal Hydrodynamic Processes*

A significant proportion of the Corner Inlet Ramsar area (approximately 630 square kilometres) comprises water and intertidal flats (540 square kilometres) with the remainder being barrier islands and fringing wetlands. Five permanent entrances allow exchange of water with Bass Strait (CSIRO 2005).

The extensive intertidal area within Corner Inlet (approximately 390 square kilometres) is dissected by a network of channels that drain and fill from the entrance in the east. The three main channels include the Franklin, Middle and Bennison channels, which are three to 10 metres deep and become shallower towards the western and northern areas of the Inlet. The main entrance channel is approximately 40 metres deep.

According to NLWRA (2001), Corner Inlet is a tide dominated estuary. Tides at Port Welshpool are classed as mixed with two high tides per day with a pronounced inequality between them (CSIRO 2005). Maximum tidal range can reach up to 2.5 metres during the equinoxes, while average daily tidal range is about 2.0 m (CSIRO 2005). Tidal variations are complicated by changes in wind speed and direction, high and low pressure systems, wave action and storm surges, which may lead to large variations in the width of the intertidal zone (Parks Victoria 2005).

While numerical modelling indicates that tidal currents can exceed 1.2 metres per second in the channels, tidal velocities on the tidal flats are generally quite low with less than 0.25 metres per second (WGCMA 2007). Tidal information for Corner Inlet indicates a slight amplification of the tidal signature as it propagates from Bass Strait into Corner Inlet. While the tidal range in Bass Strait is about 1.8 metres, the tidal range amplifies within Corner Inlet to about 2.0 metres, corresponding to approximately 10 per cent increase in tidal range (WGCMA 2007).



Based on modelling assessments by WGCMA (2007), it is predicted that more than 40 per cent of Corner Inlet is exposed during a typical low spring tide (–1.0 metres AHD at Port Welshpool), corresponding to an area of approximately 220 square kilometres. However, owing to the relatively flat slope of the intertidal flats and due to frictional effects, there is insufficient time for the water to drain completely off the tidal flats prior to the next incoming tide. This means that not all of the tidal flats are exposed during low tide.

The reasonably large tidal range in Bass Strait and the extensive shallow areas in Corner Inlet mean that more than 60 per cent of the inlet volume is exchanged over an average tidal cycle (WGCMA 2007). While the majority of the water within the system is likely to be exchanged within only a few tidal cycles within Corner Inlet, the extensive network of channels and islands in Nooramunga leads to longer residence times of approximately one week (WGCMA 2007). Accordingly, impacts from runoff from the catchment are likely not as severe as might be observed for other less well flushed inlets.

#### *Groundwater*

The Seacombe Groundwater Management Area (GMA) extending from near Welshpool to Bairnsdale partly covers the Corner Inlet catchment. Seacombe GMA's primary groundwater extractions are for urban/industrial uses including domestic, industrial, mining, power and commercial uses. Rural extractions include stock activities and irrigation of agricultural areas (CSIRO 2005).

Groundwater may be discharged across the sea floor to the coastal ocean. This submarine groundwater discharge is primarily driven by hydraulic gradient (gravity) due to the difference in water level between the groundwater table and seawater level (Burnett *et al.* 2006). Hindell *et al.* (2007) suggested that submarine groundwater discharge may also be of significance for Corner Inlet. The authors noted high concentrations of ammonia and nitrate/nitrite in Corner Inlet at Yanakie and concluded that local contaminated groundwater inflows were the underlying cause for the exceptionally high nutrient concentrations rather than riverine discharges.

Water Technology (2008) undertook follow-up investigations to assess Hindell *et al.*'s (2007) hypothesis that groundwater was a key source of localised nutrient contamination. Water Technology (2008) found that only a minor percentage of flow was in the form of groundwater recharge in comparison to stream flow. With the exception of ammonia, all water quality parameters measured had lower concentrations in groundwater than the natural surface water course (Golden Creek). On this basis, groundwater was considered by Water Technology (2008) to represent a relatively minor contaminant source.

### **3.6.3 Water Quality**

#### **Reasons for Selection**

Water quality is a key driver of aquatic ecosystem health within Corner Inlet. In particular, the generally low levels of turbidity and nutrients are required to maintain the health of seagrass meadows (and associated biodiversity and fisheries values) within the site. The high degree of tidal flushing strongly influences water quality within the site (see Section 3.6.2).

## **Description**

### *Catchment Loads to Corner Inlet*

The main rivers discharging into Corner Inlet are relatively short and drain small catchments, which leads to a rapid response to significant rain events and ensuing high concentrations of nutrients and sediment loads (CSIRO 2005). The important impact of rainfall events on water quality is generally reflected in higher total and reactive phosphorus concentrations and increased turbidity levels in catchment streams during years with above average rainfalls, such as occurred in 2001 (CSIRO 2005, NCI 2007).

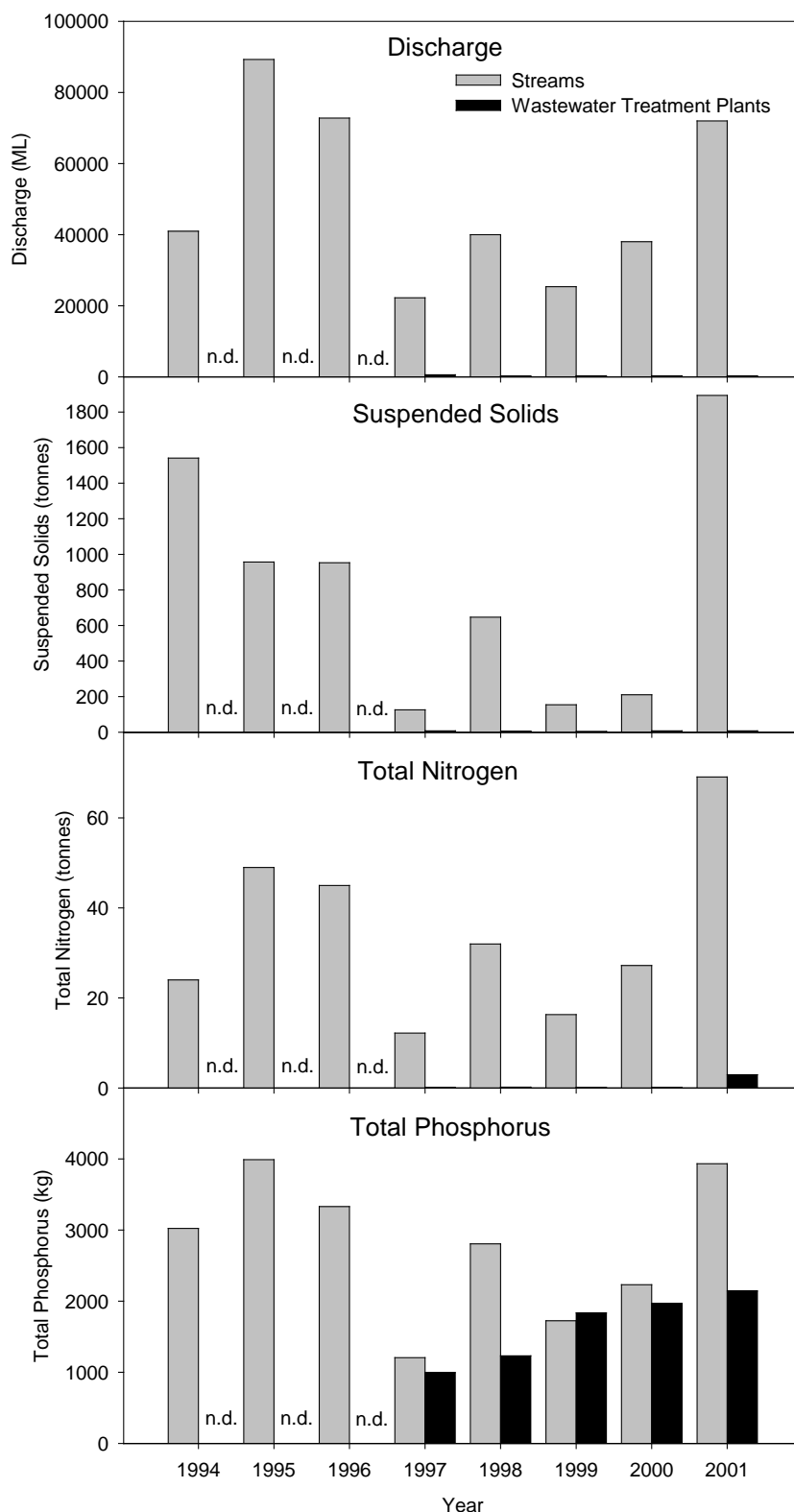
Of the major streams in the catchment, the Tarra River (refer Figure 3-6) is normally the largest contributor for loads entering Corner Inlet. However, other rivers such as the Franklin, Agnes, Albert and Jack River can produce greater loads when flood events have been isolated to their catchment (CSIRO 2005). While the Agnes River contributed more nutrients than the Franklin River, the Franklin was a higher contributor of suspended sediment (South Gippsland Water 2002). Deep Creek supplied a significantly higher proportion of reactive (biologically available) phosphorus to Corner Inlet than the other rivers.

Overall, the main streams entering Corner Inlet exhibited moderate to good water quality, while many of the smaller streams were characterised by poor water quality (South Gippsland Water 2002). However, the actual impact of these smaller streams on water quality in Corner Inlet is largely unknown as no flow data exists and loads cannot be adequately estimated. Similarly, the impact of urban stormwater drains is largely unknown because of the lack of information on water quality and quantity (CSIRO 2005).

The impact of wastewater treatment plants (WWTP) (see Figure 3-6 for locations) on water quality in Corner Inlet has been assessed by South Gippsland Water (2002). Figure 3-7 presents annual discharge volumes and loads of suspended solids and nutrients for major streams and wastewater treatment plants discharging into Corner Inlet. Discharge volumes for the wastewater treatment plants were much lower than for the rivers and typically contributed only around one per cent of the total annual discharge. Correspondingly, annual loads of suspended solids and total nitrogen from the WWTP's were minor compared to the respective river loads. However, total phosphorus loads from the WWTP's were sometimes as high as those from the major streams (refer Figure 3-7). Loads of reactive phosphorus (directly available for plant growth) from the WWTP's were of similar magnitude or higher than those contributed by the major streams in 2000 and 2001 (South Gippsland Water 2002).



**Figure 3-6 Corner Inlet Ramsar Site (red outline) with Locations of Waterwatch Sampling Sites (red stars) and Outfall Locations for Foster, Toora and Port Welshpool Wastewater Treatment Plants (black squares)**



**Figure 3-7 Discharge and Summed Annual Loads of Suspended Solids, TN and TP for Major Streams Discharging into Corner Inlet (Franklin River, Agnes River, Deep Creek) and Wastewater Treatment Plants (Toora, Foster, Port Welshpool). No Data Exists for the WWTP between 1994 and 1996. Annual Loads Based on Calculations in South Gippsland Water (2002)**

*Ambient Water Quality in Corner Inlet*

Water quality data are not available from sites within the Corner Inlet Ramsar boundary from the time of listing (1982). The Waterwatch Victoria volunteer monitoring program has closed this information gap since 2001 with regular sampling of water quality data from sites along the boundaries of the Corner Inlet Ramsar wetlands (refer Figure 3-6). Accordingly, the recent Waterwatch data represents a current description of Corner Inlet and inferences whether the water quality in Corner Inlet has deteriorated or improved since the time of listing cannot be made.

Table 3-6 presents the Waterwatch water quality data for ten sites within the Ramsar boundary and comparison with ANZECC/ARMCANZ (2000) guideline values. It should be noted that the purpose of this comparison to guideline values is to determine whether there are any key contaminants of concern that could have an effect on ecosystem health. Due to the lack of data from around the time of listing, it is uncertain whether either the guideline values or monitoring data reflect water quality conditions at the time of listing.

Reactive phosphorus concentrations exceeded the guideline values for all stations. It should be noted, however, that the values for six of the sites were at the lowest limit of measurement resolution rendered possible by Waterwatch analysis methods. Notable exceedances of the guideline trigger limits include sampling sites ESC010 and BCK020, which exceed trigger limits for reactive phosphorus 20 to 48 fold, total phosphorus six to 10 fold and turbidity by about 3.5 fold (Table 3-6). These two sites are located close to the outfalls of the Foster and Toora WWTP's, which were shown to discharge significant loads of phosphorus into Corner Inlet (South Gippsland Water 2002). Water quality parameters generally met the guidelines at site EPW010, which is located close to Port Welshpool WWTP. South Gippsland Water (2002) noted that phosphorus loads for this WWTP were typically 10 times lower than for the Foster and Toora WWTP's. They also observed that phosphorus loads contributed by Deep Creek were significantly higher than for the other rivers, which is reflected in elevated reactive and total phosphorus concentrations at site EFR010 located close to the mouth of Deep Creek (refer Figure 3-6 and Figure 3-6).

Hindell *et al.* (2007) recorded water quality data from six sites within Corner Inlet as part of an investigation into seagrass health between March 2005 and August 2006. Salinity within Corner Inlet was generally oceanic but could exceed oceanic levels during summer due to evaporation. Dissolved oxygen levels were well in excess of saturation during summer, indicating significant oxygen production through algae and seagrass photosynthesis. A significant overnight oxygen sag was hypothesised due to respiration of algae and seagrass. Hindell *et al.* (2007) noted elevated dissolved inorganic nitrogen concentrations (ammonium and nitrate/nitrite) but found that reactive phosphorus (phosphate) concentrations were typically quite low. The authors proposed that the source of the elevated nitrogen concentrations was both river discharge as well as groundwater influx.

**Table 3-6 Waterwatch data of stations within the Ramsar site (refer to Figure 3-6). The data were calculated to give the 80<sup>th</sup> Percentile (20<sup>th</sup> and 80<sup>th</sup> Percentiles for pH) and Compared against the ANZECC/ARMCANZ (2000) for Southeast Australian Estuaries where applicable\***

Location	Station	Data period	Water Temp (°C)	EC (µS/cm)	pH	Reactive P (mg/L)	Total P (mg/L)	Turbidity (NTU)
	ANZECC Estuarine				20 <sup>th</sup> –80 <sup>th</sup> percentile 7.0–8.5			Default 0.5–10
	SEPP WoV Estuarine					75 <sup>th</sup> percentile ≤ 0.005	75 <sup>th</sup> percentile ≤ 0.030	
NW Corner Inlet – Near-shore	BCK020	2004, 2006–2008, n=74	17.1	42 320	7.00–7.55	0.240	0.318	34.1
	EAG010	2001–2009, n=299	19.1	56 800	7.83–8.15	0.010	0.030	7.0
	EAL010	2002–2008, n=238	18.0	55 900	7.56–8.05	0.020	0.050	16.6
	EFR010	2001–2009, n=243	22.1	54 900	7.66–8.04	0.029	0.056	12.4
	ESC010	2001–2003, n=32	18.0	52 700	7.34–7.86	0.100	0.195	35.2
Main Entrance	EEN010	2001–2009, n=269	18.0	55 724	7.88–8.14	0.010	0.020	2.4
Port Welshpool	EPW010	2001–2009, n=274	19.0	56 200	7.84–8.13	0.010	0.020	2.9
Port Albert	ETB010	2001–2006, n=201	21.0	57 784	7.76–8.03	0.010	0.020	6.7
	ETR010	2008–2009, n=13	21.1	55 540	8.12–8.28	0.007	0.028	7.2
McLoughlins	MCL010	2001–2002, n=51	20.0	61 536	7.91–8.30	0.010	0.060	6.8

\* The 75th percentile has been calculated for reactive and total phosphorus to be compared against the SEPP Waters of Victoria guideline. Orange and red shading indicate exceedance of guideline values up to a factor of 2 or more than a factor of 2, respectively.

### 3.6.4 Nutrient Cycling and Foodwebs

#### Reasons for Selection

Biological processes describe any process occurring within, or by, an organism, and can operate at the genetic, cellular, individual, population, community or ecosystem levels. There is a vast range of biological processes that, together with physical (abiotic) processes described above, are important to the maintenance of wetland ecosystem functioning. Of particular note in the context of the biological processes that maintain the ecological character of the site are nutrient cycling and foodwebs.

#### Description

##### *Marine and Estuarine Nutrient Cycling*

As vegetative and animal matter begins to senesce and die, microbes invade the tissues and transform the organic material into more bio-available forms of carbon and other nutrients. While microalgae, marshes and seagrasses are mainly responsible for primary productivity within estuarine and marine waters of the site, microbial breakdown is a key pathway for plant material entering the food-web in these ecosystems (Alongi 1990). This is especially true for marine and freshwater macrophytes (seagrass, mangroves, saltmarsh, freshwater marshes), which with few notable exceptions (for example, by some invertebrates fish and birds) are generally not directly grazed, but instead enter food-webs following microbial conversion of organic matter (Day *et al.* 1989).

Nutrient cycling processes are controlled by tidal exchange (flushing and dilution of nutrients), and the relative influence of different nutrient sources and sinks. Due to the relatively large tidal range in Bass Strait, over 60 per cent of the Corner Inlet volume is exchanged over an average tidal cycle (see Section 3.6.2). Although high nutrient concentrations were noted close to wastewater treatment plant outfalls, the rapid dilution through high flushing rates means that impacts are likely localised (CSIRO 2005; see Section 3.6.3).

Corner Inlet is characterised by its extensive areas of intertidal sand- and mudflats (approximately 390 square kilometres) as well as large areas covered by seagrass (approximately 150 square kilometres) (NLWRA 2001). Due to their wide extent, these habitats potentially play a very important role for nutrient cycling within Corner Inlet.

##### *Productivity and Foodwebs*

The main primary producers within the site include phytoplankton, benthic microalgae (microphytobenthos) and seagrass. Saltmarsh and mangroves, while having high productivity rates, are not likely to represent dominant primary producers at a whole of site scale due to their limited spatial coverage. The relative contribution of each of these components to total primary productivity will vary from place to place and across a range of spatial (and possibly temporal) scales.

Case studies elsewhere demonstrate that seagrass, mangroves and saltmarshes represent particularly productive communities (on a 'productivity per unit area' basis). When taking into

account the large total area of phytoplankton habitat (open water), phytoplankton may represent a major proportion of total primary productivity of the wetland.

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

The direct consumption of macrophytes by grazers also represents a pathway for energy flow through the ecosystem. Macrophytes generally form a direct food source for only a limited number of species, including sea urchins, some amphipods, gastropod snails, some fish species (for example, garfish, luderick and leatherjackets), together with black swan, ducks and geese (Day *et al.* 1989; Colwell 2010). From an energy flow perspective, perhaps the most important linkage between macrophytes and higher trophic levels is through the decomposition of dead plant material by bacteria and fungi (see discussion on nutrient cycling above). This is likely to be particularly the case in detritus-based foodwebs that characterise saltmarsh, seagrass and mangrove wetland habitats.

Recent studies at Corner Inlet using stable isotope analysis indicate that the nutrition of three fish species of recreational and commercial importance (King George whiting, southern sea garfish and yelloweye mullet) was mainly obtained from foodwebs derived from seagrass and seagrass-associated epiphytes (micro-algae). Mangroves and saltmarsh did not contribute significantly to foodwebs supporting these species. While these fish do not generally graze on seagrass and epiphytes, the organisms that form their prey rely on these plants for nutrition (Longmore 2007). Stable isotope analysis of fish in Port Phillip Bay also indicated that seagrass underpin the foodwebs supporting several piscivorous fish species (Hindell 2008). These results indicate that seagrass is important to the maintenance of foodwebs supporting commercially significant species within the site.

The diet of waterbird species differs between species, and also within species, depending on food availability (Colwell 2010). While many waterbirds feed on freshwater and estuarine/marine benthic macroinvertebrates on intertidal flats, there are also a number of herbivores (species that feed directly on submerged aquatic macrophytes, such as black swan) and piscivores (species that feed on fish, such as cormorants and pelicans). No studies to date have examined the relative contribution of different primary producers to foodwebs supporting bird assemblages within the site.

## **3.7 Critical Services/Benefits**

### **3.7.1 S1 – Presence of Threatened Species**

#### **Reasons for Selection as ‘Critical’**

Biological diversity, or biodiversity, is the variety of all life forms, the genes they contain and the ecosystem processes of which they form a part. The term biodiversity can therefore incorporate most of the critical and supporting components outlined in the previous sections. However, in the



context of how the Ramsar site provides a critical role in maintaining global biodiversity, the site supports critical habitat for globally and nationally threatened wetland-dependent species.

Key services provided by the site in regards to threatened fauna complies with Ramsar Nomination criteria 2 in that the site supports nationally threatened fauna including:

- orange-bellied parrot (*Neophema chrysogaster*) – Critically Endangered under the EPBC Act and Endangered under IUCN Red List (IUCN 2010)
- growling grass frog (*Litoria raniformis*) - Vulnerable under the EPBC Act and Endangered under IUCN Red List (IUCN 2010)
- fairy tern (*Sterna nereis nereis*) - Vulnerable under the IUCN Red List (IUCN 2010)
- Australian grayling (*Prototroctes maraena*) - this species is listed as Vulnerable under the EPBC Act and Near Threatened under the IUCN Red List (IUCN 2010).

Ramsar Nomination criteria 4 is also relevant in that the site supports habitat for critical stages in the life cycles of these nationally threatened fauna.

### Description

#### Orange-bellied parrot

*Neophema chrysogaster* is listed as critically endangered under the EPBC Act and IUCN Red List (IUCN 2010). The current total wild population of orange-bellied parrots is unlikely to exceed 150 individuals (OBPRT 2006). The orange-bellied parrot is endemic to south-eastern Australia and migrates from breeding grounds within coastal south-western Tasmania to non-breeding grounds within coastal areas of southern Australia (about east from the Murray River mouth to South Gippsland) (Higgins 1999; OBPRT 2006). Birds generally arrive on the mainland during March/April and depart September/November (OBPRT 2006; Birds Australia 2009b).

In Victoria, orange-bellied parrots are found mostly within three kilometres of the coast where they forage within coastal saltmarsh vegetation associated with sheltered coastal areas such as bays, estuaries and lagoons (Emison et al. 1987; Birds Australia 2009b). Within these habitats, known key food plants include beaded glasswort (*Sarcocornia quinqueflora*), shrubby glasswort (*Sclerostegia arbuscula*), sea-blite (*Suaeda australis*) and other low herbaceous plants (Higgins 1999; BA 2009b). Current data indicates that a significant proportion of the known orange-bellied parrot population congregates at three sites in Victoria (around Port Phillip Bay and the Bellarine Peninsula) (Birds Australia 2009b).

In the Gippsland area, there are sporadic records at Jack Smith Lake, the fringes of Corner Inlet and several islands within, Andersons Inlet, and from the Powlett River mouth (DEWHA 2009b; Birds Australia 2009b). There are seven records for the Ramsar site (1983–1988; DSE 2003 and 2009), the most recent being 2004 (Ecos unpublished). Records were associated with the Port Albert area and Mangrove Root, Barry, Long and Mangrove Islands in western Corner Inlet.

The main current threat to the orange-bellied parrot is the loss and fragmentation of its non-breeding saltmarsh habitat due to: drainage of wetlands for grazing; alteration and destruction of saltmarsh for industrial and urban development; grazing of native vegetation; vegetation clearance

for agricultural purposes; changes to land use practices; and recreational activities (Garnett and Crowley 2000; OBPRT 2006).

### Growling grass frog

*Litoria raniformis* is found mostly amongst emergent vegetation (for example, bullrush *Typha* spp., sedges, and reeds, for example, *Phragmites* sp. and *Eleocharis* spp.), in or at the edges of still or slow-flowing water bodies such as lagoons, swamps, lakes, ponds and farm dams (DEWHA 2009a). Approximately 1405 hectares of this vegetation type is present within the site on Snake Island (refer Section 2.1.2), although the exact proportion of this that is used by growling grass frog is not known. This species is dependent upon permanent freshwater lagoons for breeding where shallow still or slow moving water (up to approximately 1.5 metres) supports a generally complex vegetation structure of emergent or submergent vegetation (for example, Heard et al. 2004; Clemann and Gillespie 2004; Hamer and Organ 2006). The following are regarded as threats to the growling grass frog: habitat loss and fragmentation, habitat degradation, altered flooding regimes, predation by introduced fish (especially *Gambusia holbrooki*), chemical pollutions of water bodies (herbicides, insecticides, biocides), salinisation, and disease (chytrid fungus) (NSW DEC 2005a, DEWHA 2009a).

### Fairy tern

Fairy tern (*Sterna nereis nereis*) is listed as vulnerable under the IUCN Red List (IUCN 2010). This small tern mainly occupies sheltered coastlines (rarely found out of sight of land), favouring estuaries, embayments, inlets, and along ocean beaches and near-shore environments (Hill et al. 1988; Higgins and Davies 1996). Fairy terns are colonial nesters and prefer to nest on near-shore islands, small islands in archipelagos, and on open sandy beaches inside estuaries. Breeding habitat within the Ramsar site includes Clonmel, Boxbank and Dream Islands (Figure 1-2), and barrier islands in the Nooramunga area (Minton in Bell 1998; Ecos unpublished).

In the context of all of these species, the dominant process required for the maintenance of suitable habitat conditions are natural patterns of freshwater inundation to freshwater wetlands, natural patterns of tidal inundation and freshwater flows to intertidal and supralittoral wetland systems; and natural vegetation patterns, extent, health, and habitat interconnectivity.

### Australian grayling

The Australian grayling (*Prototroctes maraena*) is considered almost certain to occur in the Ramsar site. Confirmed records for this species exist for all major river basins that drain directly into the site (Agnes, Albert, Franklin and Tarra Rivers; Backhouse et al. 2008). This species spends most of its life-cycle in freshwaters (McDowall 1996). Australian grayling spawns in freshwaters, and their larvae are subsequently transported into estuarine and marine waters (which are represented in the Ramsar site) by river flows. Given the apparent obligatory oceanic habitat requirement of juveniles, it is almost certain that this species relies on the Ramsar site to complete its life-cycle.

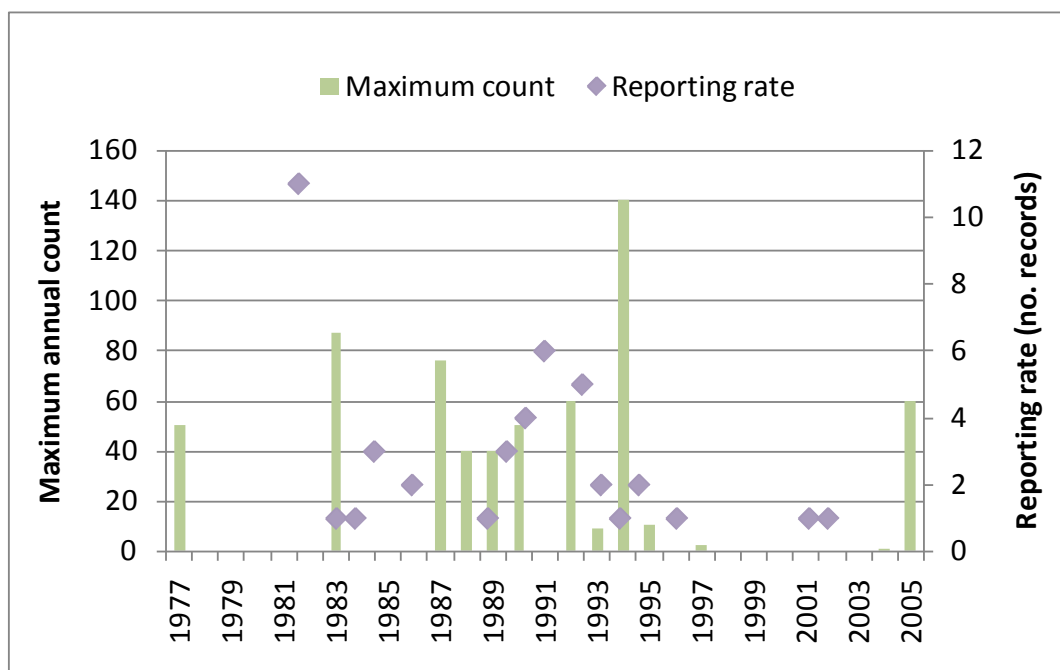
### **Patterns in Variability**

There are presently too few data describing patterns in the abundance of any of these species. In summary, available data show:

- orange-bellied parrot - there are seven records for the site (Birds Australia = one record in 2004; DSE 2003 and 2009 = six records between 1983–1988). Records were associated with

the Port Albert area (Mangrove Root Island, Barry Island, Long and Mangrove Islands). There are too few data to determine patterns in the abundance of this species within the Ramsar site

- growling grass frog – there are 39 records for the site (two individuals in 1977 and 37 individuals in 1995, based on DSE 2009 data). There are insufficient data to determine patterns in the abundance of this species within the Ramsar site
- fairy tern – Figure 4-2 shows the maximum annual count of fairy terns recorded at the site based on DSE Fauna Database records. Unfortunately there are few data available for the site at the time of site listing, therefore baseline conditions needs to be considered in the context of data collected post-listing. These data show that the maximum count in the period 1983 to 1994 was generally greater than 10 birds, with a peak in 1994. Since 1994 the counts were generally less than 10 birds, except in 2003 when 60 birds were recorded. The Birds Australia database has only a few records of this species at the site, and only one record contained count data (eight individuals)
- Australian grayling – there are no data describing the occurrence and abundance of this species within the site. South Gippsland Water monitors fish abundance at stations located throughout the Tarra and Agnes River catchments, however none of the stations are located within the Ramsar site. This represents an important information gap in the context of this critical service.



**Figure 3-8 Maximum Annual Count and Reporting Rate (Number of Episodes and Stations) for Fairy Tern Abundance (Total Records in each Year) at Corner Inlet Ramsar Site**  
(Data source: DSE fauna database)

### 3.7.2 S2 – Fisheries Resource Values

#### Reasons for Selection as ‘Critical’

As discussed in the context of the justification for meeting criterion 8 of the Convention, the site provides important habitats, feeding areas, recruitment areas, dispersal and migratory pathways, and spawning sites for numerous fish species of direct and indirect fisheries significance. These fish have important fisheries resource values both within and external to the site.

This service/benefit is based on fisheries habitat and fish abundance, and excludes fishing activities. It was selected on the basis of being an important determinant of the site’s unique character and the importance of fisheries values with respect to support of other services/benefits including recreation and tourism (supporting service).

#### Description

The Corner Inlet commercial fishery is based mostly on King George whiting (*Sillaginodes punctatus*), Australian salmon (*Arripis* spp.), greenback flounder (*Rhombosolea tapirina*), southern garfish (*Hyporhamphus melanochir*), yellow eye mullet (*Aldrichetta forsteri*), silver trevally (*Pseudocaranx dentex*), flatheads (several species) and school shark (*Galeorhinus galeus*) (DPI 2007c; 2010). According to habitat/life-history classifications of Ecos (unpublished), these fish are either estuarine dependent, marine estuarine opportunists or marine straggler species. The fishery also includes southern calamari, which is considered a “marine straggler” invertebrate species (Ecos unpublished).

Table 3-7 shows that important fisheries species commonly found within the Ramsar site are not found exclusively in any one habitat type during any part of their life-cycle. Rather, these species have relatively plastic habitat requirements, and are typically found in a variety of habitat types. In general terms, most of the species listed in the table below spend their juvenile stages in shallow protected waters, particularly around seagrass and mangroves, whereas most species tend to spawn in coastal and marine waters. Adults of most species tend to utilise a variety of habitats.

There are exceptions to these general patterns. Corner Inlet is recognised as an important pupping area for school shark (AFMA 2009). Shallow sheltered bays, estuaries and littoral areas such as mangrove lined creeks are of particular importance in this regard (Olsen 1954; Walker *et al.* 2005). Furthermore dusky flathead (*Platycephalus fuscus*) and river garfish (*Hyporhamphus regularis*) spawn in estuaries near seagrass and/or shoals, whereas black bream (*Acanthopagrus butcheri*) is thought to spawn in upper estuaries near the fresh and brackish water interface (Ramm 1986).

#### Patterns in Variability

Relative abundance data can be broadly determined based on commercial fish catch data (see long term trends in Figure 3-9) and catch-per unit effort data (Table 3-8). Data are available for a small number of years prior to site listing (four years), which is insufficient for developing an appropriate ‘pre-listing’ baseline incorporating the range of inter-annual variability. For this reason, baseline values are defined as the 11 year period leading up to and immediately following site declaration (1978/79 to 1988/89). Note that these commercial catch data have a number of limitations, including a strong bias towards adults, are not based on systematic standardised catch methods and have

limited spatial resolution. There are also no suitable fisheries independent catch data to validate trends in commercial catch data.

These data show that commercial catch varies greatly over time, partly in response to changes in fishing effort. Changes in commercial catch are discussed further in Section 5.2.1 in the context of whether there is any evidence of changes in ecological character.

**Table 3-7 Key Fisheries Species present in the Corner Inlet Ramsar site, and their Primary Habitats at Different Stages of their Life-cycle (Data: Kailoa et al. 1993)**

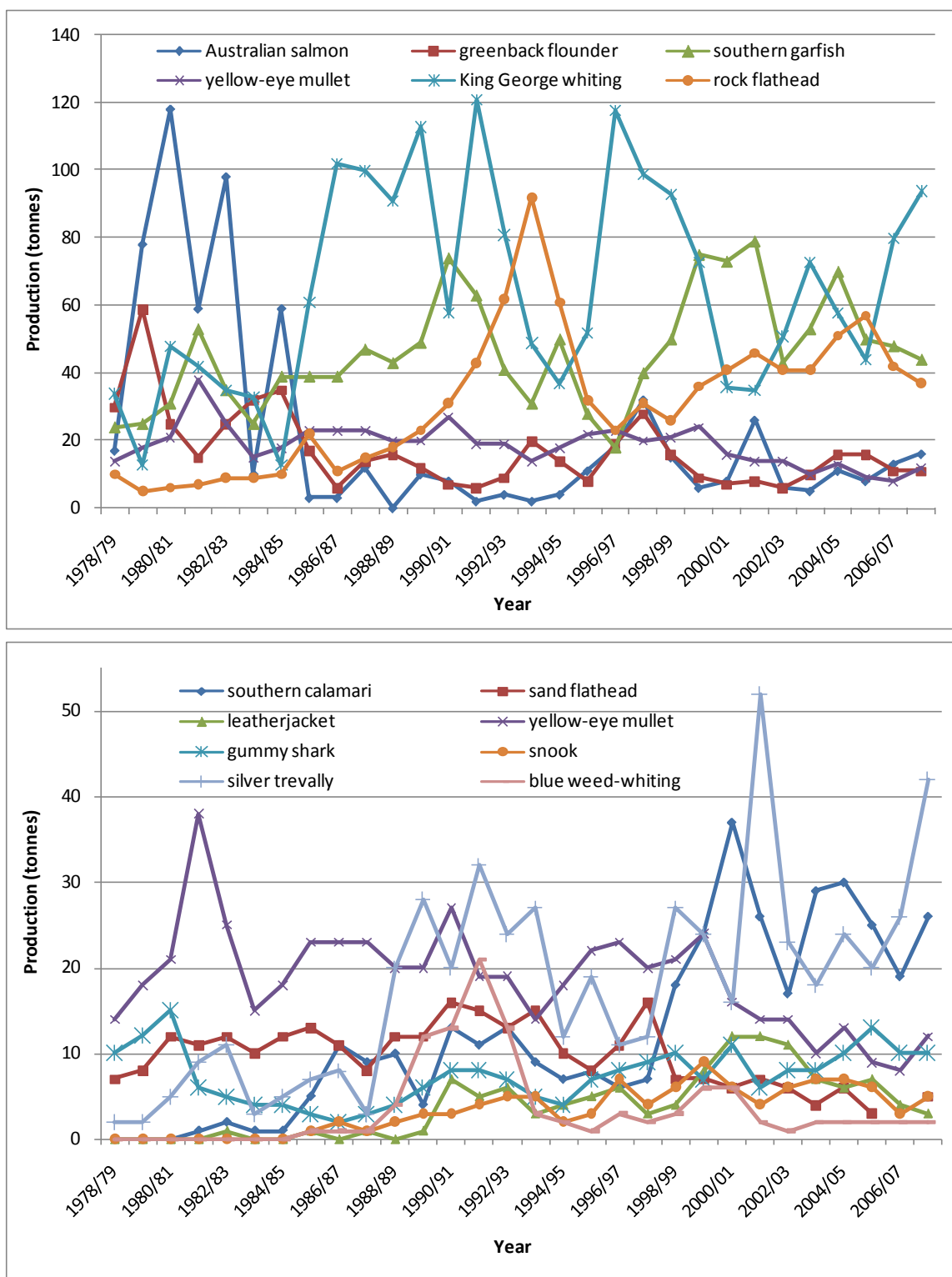
Species	Estuary/Freshwater					Coastal/Oceanic			
	Mangroves*	Seagrass*	Shoals*	Channels and Mud basin*	Fresh/ brackish creeks and wetlands*	Nearshore sand/ pelagic	Offshore sand/ pelagic	Seawall*	Coastal Reefs
Australian salmon	Juv.	Juv.	Juv.	Ad.		Ad.	Ad.	Ad.	Ad., Spw.
Australian anchovy						Ad.	Spw.		
dusky flathead	Juv., Ad.	Spw., Juv., Ad.	Spw., Juv., Ad.	Ad., Juv.	Juv., Ad.**	Spw.			
greenback flounder	?	Juv., Ad.	Juv., Ad.	Juv., Ad.	Juv.	Sp., Ad.	Sp., Ad.		
river garfish	Juv., Ad.	Juv., Ad., Spw.	Juv., Ad.		Juv., Ad.				
school shark	Juv.	Juv.	Juv.	Juv.			Ad.		
King George whiting	Juv.	Juv.	Juv.	Juv.		Ad.	Ad., Spw.	Ad.	Ad.
silver trevally		Juv.	Juv.	Juv., Ad.		Ad.		Ad.	Ad., Spw.
snapper	Juv.	Juv.	Juv.	Juv.			Spw.	Juv., Ad.	Juv., Ad.
tailor		Juv., Ad.	Juv., Ad.	Juv., Ad.		Spw., Juv., Ad.			
black bream	Juv., Ad.	Juv., Ad.	Juv., Ad.		Spw., Juv., Ad.**	Ad.		Ad.	Ad.
mulloway	Ad.	Juv., Ad.	Juv. Ad.	Juv., Ad.	Juv., Ad.**	Ad. Spw.		Juv., Ad.	Juv., Ad.
luderick	Juv. Ad.	Juv. Ad.	Ad.	Ad.	Juv., Ad.**	Ad. Spw.	Ad.	Ad.	Ad.
sea mullet	Juv. Ad.	Juv.	Juv.	Juv., Ad.	Juv.	Spw.	Spw.		
yellow-eye mullet	Juv. Ad.	Juv.	Juv.	Juv., Ad.	Juv.	Spw., Ad.			
southern calamari		Spw., Juv.	Juv., Ad.	Juv., Ad.		Ad.			Spw.
estuary perch		Juv.		Juv. Ad.	Juv. Ad.	Spw (estuary mouth)			
king prawn	Juv.	Juv.	Juv.	Juv.		Ad.	Ad., Spw.		
school prawn		Juv.	Juv., Ad.	Juv., Ad.			Spw.		

Note: Juv. = Juvenile, Ad. = Adult, Spw. = Spawning; \* denotes habitat type found in the Ramsar site; \*\* often in association with large woody debris; blue shading = habitats not represented in the site

**Table 3-8 Catch Per Unit Effort (Commercial Production in Tonnes Caught Divided by Number of Boats) for Corner Inlet (20<sup>th</sup>, 50<sup>th</sup> and 80<sup>th</sup> Percentile Values) around the time of listing (1978/79 to 1988/89) and post 1989**

Species	1978/79 to 1988/89				1989/90 to 2008/09
	<i>n</i>	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	50 <sup>th</sup>
Australian salmon	11	379	1047	3799.3	404.6
bream, black	8	18.9	28.5	41.1	58.9
bream, yellowfin	1		621.4		545.3
calamari, southern	8	96.8	235	490.8	802.3
flathead, rock	11	316.3	411.7	579.7	2051.8
flathead, sand	11	347.3	415.7	434.1	1450
flounder	11	514.4	332.2	1165	491.7
garfish, southern sea	11	1452.3	1573.5	1672	2415
mullet, sea	11	68.0	108.2	125.9	128.8
mullet, yellow-eye	11	739.7	809.1	903.5	817.4
shark, gummy	11	167.4	261.5	415.9	411.9
whiting, King George	11	1347.1	1490	2988	2813.4

*Note: no data where less than five fishers. Values are kilogram production per boat*



**Figure 3-9 Long-term Trends in Commercial Fisheries Catch Data between 1978–2008**  
(Source: DPI 2008)



## **3.8 Supporting Services/Benefits**

The supporting services/benefits outlined below are considered to be important or noteworthy in the context of maintaining the character of the site, but are not considered to represent critical services/benefits. In this context:

- The supporting services/benefits are not, in isolation, thought to fundamentally underpin the listing criteria. However, supporting services/benefits may, in combination with other elements, underpin Nomination Criteria
- Some supporting services/benefits are already partially covered by other critical components or processes.

### **3.8.1 Recreation and Tourism Values**

#### **Reasons for Selection**

This supporting service recognises the importance of the site as a recreational and tourism resource. While not intrinsically key determinants of the ecological character of the site, tourism and recreation are among the most important uses of the Corner Inlet, and have a major impact on employment and the economic wealth of the region.

#### **Description**

Tourism is a vital industry for Victoria's regional economy, worth \$3.4 billion annually and responsible for an estimated 61 000 jobs (Minister for Tourism and Major Events 2007). In the Gippsland Region alone, since 1999, the Victorian Government has allocated over \$4.6 million in direct tourism support (Minister for Tourism and Main Events 2007). The Gippsland region receives approximately seven per cent of all tourist visits to Victoria (Parks Victoria 2005).

Based on broad scale regional data, 84 per cent of overnight visitors to Gippsland were from intrastate, followed by 12 per cent from interstate and three per cent from the international market (Tourism Victoria 2007).

There are several important factors underpinning this service:

- The perceived 'naturalness' of the site. To a large extent, the degree of naturalness perceived by visitors will depend on the existing low levels of development in the surrounding areas, as well as aesthetic considerations
- The diversity of landscape and seascape types. Parks Victoria (2005) suggests that the notable landscape and seascape values include:
  - a spectacular backdrop of granite and peaks within Wilsons Promontory National Park
  - extensive intertidal flats exposed at low tide
  - granite and Benisons Islands
  - low marshy shorelines
  - sandy beaches set between granite headlands
  - a dramatic change in seascape as the tide rises and falls

- Recreational fish economic values. Recreational fishing represents an important activity within the site. Approximately 43 per cent of Victorian recreational fishing that took place in 2000/2001 occurred in bays, inlets and estuaries such as Corner Inlet (FV 2007). Recreational fisheries are an important aspect of the Corner Inlet region, contributing significantly to regional economy and tourism (Ecos unpublished). Recreational fishing supports the tourism and recreational industries in the region that surrounds the Ramsar site, which has a major impact on the regional economy
- The status of fish stocks. Recreational catches are similar in quantity to commercial catches but are, in large part, reliant upon commercial bait fishing (Hundloe *et al.* 2006). Within the Ramsar site, there is recreational line fishing for King George whiting (*Sillaginodes punctatus*), sand flathead (*Platycephalus arenarius*), yank flathead (*Platycephalus speculator*), and snapper (*Pagrus auratus*) (CSIRO 2005). Recreational fishing catch/effort data for a six month period during 1983 and 1984 indicated that the recreational catch of King George whiting from Corner Inlet/Nooramunga was at least as large, and probably larger, than the total commercial catch of this species (MacDonald 1997). DPI (2007d) has prepared a Draft Fisheries Management Plan for the recreational fishing sector and seeks to identify and manage key fish habitats in the West Gippsland region. Existing management arrangements for the commercial sectors will remain unchanged by this plan. The plan covers the estuarine reaches of the rivers and streams flowing into Corner Inlet but not the inlet itself
- Accessibility, availability and types of recreational facilities and tourism infrastructure. Key considerations here include:
  - Tourism infrastructure offered by local coastal towns in the region. Coastal towns in the Corner Inlet region (particularly Port Albert, Port Welshpool, Yanakie, Tidal River, Sandy Point and Walkerville) are subject to large seasonal population fluctuations usually in summer which are directly related to tourist influx into the region's motels, hotels and caravan parks for holidays as well as holiday homes.
  - Commercial tour operations. A number of licensed operators offer boating and sea kayaking tours within Nooramunga and Corner Inlet Marine and Coastal Parks and Wilsons Promontory National Park.
  - Camping and recreational facilities. Bush camping is allowed on the sand barrier islands within Nooramunga Marine and Coastal Park, but not on the granite islands. There are also numerous picnic and other visitor areas, boating facilities and toilet blocks throughout the site (DSE 2003).

There are no available data on changes in the local scale recreation and tourism values of Corner Inlet over time. Tourism figures from 2007 showed positive results for the region with an increase of 3.6 per cent in international overnight visitors and an increase of 6.4 per cent in domestic visitor nights spent in the region compared to the same time in the previous year (Minister for Tourism and Main Events 2007). There was also a 3.8 per cent increase in domestic day trip visitors over the same period.

### **3.8.2 Scientific Research**

#### **Reasons for Selection**

The site has a number of values that make this a supporting service, most notably:

- Identification of the functions and ecological values of relatively undisturbed wetland ecosystems. In contrast to other large embayments within Victoria, Corner Inlet is in relatively good condition. This makes the inlet a good reference site for ecological research. Recent research on the trophic linkages between autotrophs and species of fisheries significance is a key example in this regard (for example, Klumpp and Nichols 1983)
- Monitoring population trends in key flora (for example, seagrass) and fauna (that is, bird) species. This research is not only important for identifying trends in ecosystem condition, but also provides an opportunity for local communities and natural historians to become involved in monitoring.

#### **Description**

The site does not contain any scientific research stations or environmental educational facilities. However, a wide range of research organisations use the site for scientific research programs including:

- Arthur Rylah Institute for Environmental Research (ARI), the research arm of the Department of Sustainability and Environment (DSE), which is based in Melbourne
- Marine and Freshwater Resources Institute (MAFRI) - Victoria Department of Primary Industries, based in Queenscliff
- CSIRO Marine and Atmospheric Research, based in Hobart.

Other universities and colleges use Corner Inlet for research and education, including University of Melbourne and Victoria University.

Numerous research programs and projects have been undertaken with respect to the Inlet's habitats and important species that are documented in Section 7, References. In terms of recent research activities, the following are of note (see DNRE 2002):

- The use of the site as a long term monitoring site of Chestnut Teal numbers by ARI.
- Snake Island is used annually as a field site to study floristic composition and fire ecology by Melbourne University.
- Research by MAFRI into the role of seagrass and algae on fisheries production.
- Mapping of seagrass extent and distribution in Corner Inlet by ARI.
- Collaborative saltmarsh research coordinated by Victoria University.
- Catchment load modelling undertaken by University of Melbourne.
- Community attitude assessments of environmental values, coordinated by Waterwatch and West Gippsland CMA.

Condition indicators such as water quality are monitored by State government departments. Other monitoring activities include extensive work by volunteers such as:

- Reef Watch community-based ecosystem health monitoring
- Seagrass Watch community-based seagrass monitoring
- Waterwatch water quality monitoring
- Wader bird observations collected by the Victorian Wader Study Group (VWSG).

Through the Coastal Catchments Initiative, the Australian Government has also invested a significant amount of research funding in the Corner Inlet area. Projects completed include an Ecological Monitoring Plan, development of Models and a Decision Support System, and geomorphologic and sediment studies.

### **3.9 Conceptual Model**

The interaction of processes and components are shown in conceptual models for the site as shown in Figure 3-9. The model simplifies many of the complex ecological attributes and processes occurring at the site, and provides a summary of the key attributes of the Corner Inlet that most strongly determine their ecological character. The model is based on the five wetland types used in this study to categorise the key components of the ecological character of Corner Inlet; namely:

- seagrass beds
- intertidal sand or mud flats
- mangroves
- saltmarshes
- permanent shallow marine water.

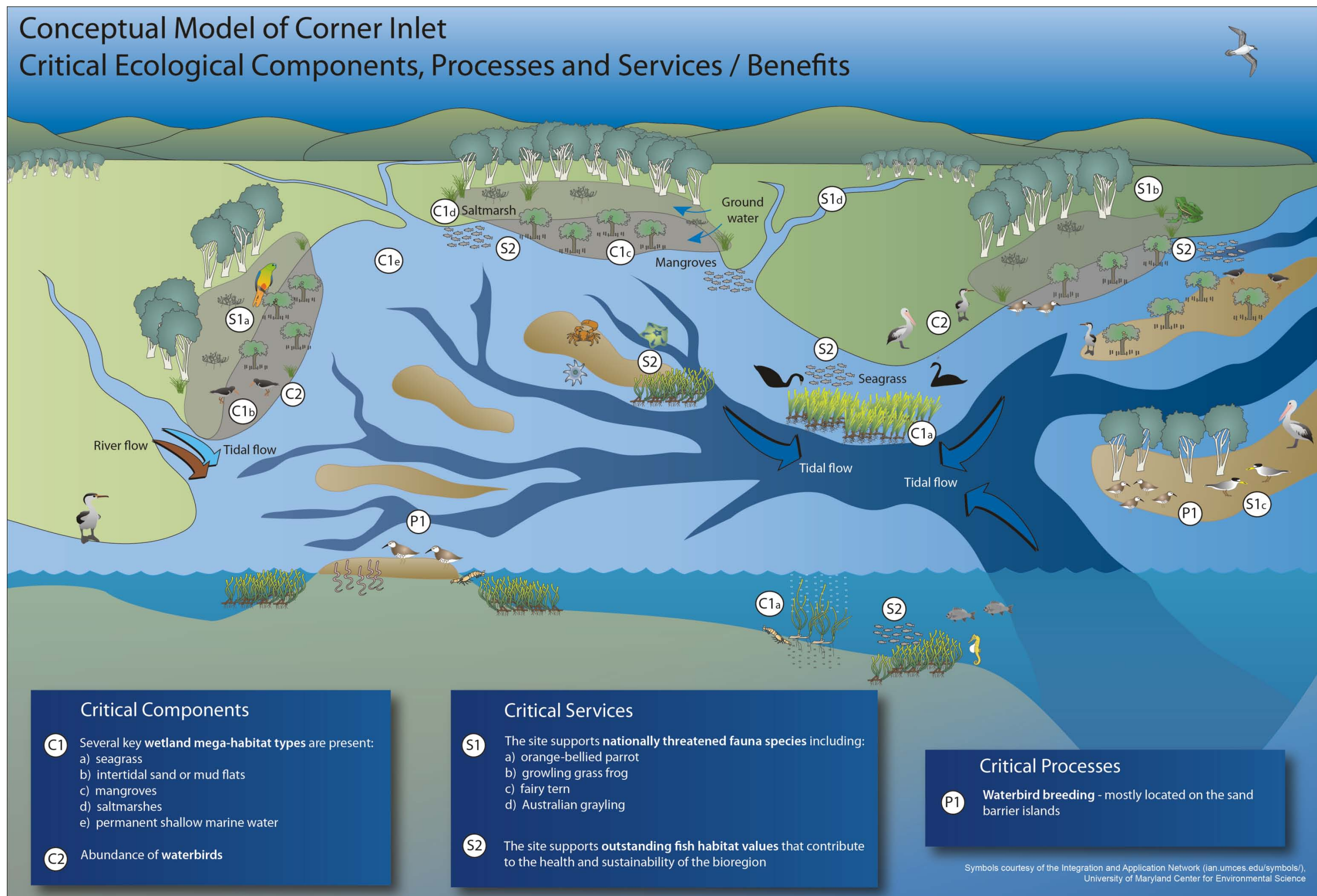


Figure 3-10 Conceptual Model of Components, Processes and Services/Benefits at Corner Inlet

## 4 LIMITS OF ACCEPTABLE CHANGE

### 4.1 Background and Interpretation

A key requirement of the ECD is to define the limits of acceptable change (LACs) for the critical components, processes and services/benefits of the wetland. Limits of acceptable change are defined as, 'the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland' (DEWHA 2008). The limits of acceptable change may equal the natural variability or may be set at some other value. Where possible, limits of acceptable change should be based on quantitative information from relevant monitoring programmes, scientific papers, technical reports, or other publications and information about the wetland or input from wetland scientists and experts. In most cases, however, the datasets are not ideal but enough information is available to set limits of acceptable change based on expert judgment and to review and revise the limits over time with improved data and understanding.

Exceeding or not meeting a LAC does not necessarily indicate that there has been a change in ecological character. While the best available information has been used to prepare this Ecological Character Description and define LACs for the site, in many cases only limited information and data is available for these purposes. The LACs in Table 4-1 may not accurately represent the variability of the critical components, processes services and benefits under the management regime and natural conditions that prevailed at the time the site was listed as a Ramsar wetland

Exceedence of a LAC may indicate a potential change to the ecological character of the Ramsar site. In most cases this will need to be determined through monitoring of the extent and condition of key wetland parameters (refer Section 6.2 regarding monitoring needs) and may require several sampling episodes in order to determine that the change is not part of broader natural variability of the system (for example LACs based on a per cent reduction in the use of the site by waterbirds based on successive counts of waterbirds over a specified time period).

It should also be noted that there may be a range of processes occurring outside of the site that could affect the exceedance of a particular LAC, for example, the populations of migratory species that use the site. As such, in the future evaluation of LACs it is important to determine if the underlying reason for the exceedance of an LAC is attributable to natural variability, related to anthropogenic impacts at or near the site (for example, catchment related processes) or alternatively a result of anthropogenic impacts off the site (for example, lack of available breeding habitat for migratory birds in the northern hemisphere).

### 4.2 Derivation of Limits of Acceptable Change

In developing LACs as part of this ECD, a number of approaches were applied, using existing data sets and information as well as national, state and local guidelines. In this context, LACs identified in the study generally fall into one of two categories:

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



such, LACs as part of the current study have also been based on a statistical measure of baseline data for a particular parameter. These LACs can be derived for both process/stressors (for example, water quality) and condition indicator based parameters (for example, maximum depth range at which seagrass can grow). For those parameters that exhibit a high degree of natural variability (for instance, water quality parameters such as salinity), LACs derived using this method can help to define more meaningful long term shifts in ecological character such as for example, where the long term (10 year) median for a particular parameter moves from the 50<sup>th</sup> percentile to the 10<sup>th</sup> percentile.

- **Broad ecosystem state and function.** This type of LACs is based on a broad change in an ecosystem from one state to another or on the basis of the wetland continuing to provide a particular function (such as provision of breeding habitat). An example of this type of LAC is a change in a particular wetland from a freshwater system to a brackish water system. This type of LAC has the advantages of encompassing a variety of indicators, and specifically addresses an ecosystem 'end-point' that can be directly linked to critical components (and/or services). This type of LAC is particularly relevant where there is a lack of data and information to support a more quantitative LAC about ecological response or threshold.

Wherever possible, the LACs derived as part of the current study have been based on existing benchmarks, data and guideline values used in other programs or documents that have the key aim of protecting environmental values of relevance to this ECD. In this context, indicators and LACs set out in other ECD studies (prepared by BMT WBM and other authors) have also been reviewed for their applicability to the Corner Inlet ECD.

## 4.3 Characterising Baseline Information

In characterising the baseline information used in deriving LACs, the following typology has been used:

Level A – This LAC has been developed from data and/or information (such as bird count data, fisheries catch data or similar) that has been reviewed by the authors and deemed to be sufficient for setting an LAC. This type of LAC is typically derived from long-term monitoring data.

Level B – This type of LAC is derived from empirical data, but is unlikely to describe the range of natural variability in time. This can include two sub-types:

- repeated measurements but over a limited temporal context
- single measurement (no temporal context) of the extent of a particular habitat type, abundance of a species or diversity of an assemblage.

Level C – This type of LAC is not based on empirical data describing patterns in natural variability. This can include two sub-types:

- Based on a published or other acceptable source of information, such as personal communication with relevant scientists and researchers, or is taken from referenced studies as part of management plans, journal articles or similar documents

- Where there are no or limited data sets and a lack of published information about the parameter, and the LAC has been derived based on the best professional judgement of the authors.

In most cases, the LACs in the current ECD have been subjectively derived (level C) based on the best scientific judgement of the authors. This is due to:

- a largely incomplete data set for key parameters such as waterbird usage, fish usage and environment condition (both geographically and temporally) since listing
- the general lack of scientific knowledge about the response of particular species and habitats to multiple stressors (for instance a combination of water flows, salinity and habitat availability).

## 4.4 Summary of Limits of Acceptable Change

Table 4-1 lists the LAC indicators relevant to each critical component, process and service/benefit. For each LAC indicator, the following information is provided:

- (i) The primary critical component, process or service benefit relevant to the LAC.
- (ii) The relevant timescale at which the LAC should be assessed. This recognises that different LACs are relevant to different timescales. For example, multiple cyanbacteria blooms over multiple years could result in a change to character within a relatively short time frame (measured in years), whereas changes in wetland vegetation are typically considered over longer timeframes (decadal scale). Three timescale categories are used: short-term (within five years), medium term (between five and 10 years) or the long-term (greater than 10 years).
- (iii) The LAC value. The LAC value is typically expressed as the degree of change relative to a baseline value. The adopted baseline values are typically described in the relevant critical component, processes and services/benefits sections of this report, or in the case of some of the habitat type indicators, the wetland types described in Section 0.
- (iv) The spatial and temporal scale at which measurements must be undertaken to assess the LAC. This column provides guidance on how the LAC should be applied.
- (v) Data quality rating for baseline data. This is based on the baseline data quality categories described in Section 4.3.
- (vi) Any other (secondary) critical components, processes or service/benefits that are also addressed by the LAC indicator.

As a general rule, short-term LACs listed in Table 4-1 will need to be reviewed to determine their potential applicability in subsequent periods.



Table 4-1 Limits of Acceptable Change for each Critical Service – Corner Inlet Ramsar Site

Number	Indicator for Critical Component / Process/Service for the LAC	Relevant timescale <sup>4</sup>	Limit(s) of Acceptable Change	Spatial scale/temporal scale of measurements	Underpinning baseline data	Secondary critical C,P,S addressed through LAC
<b>Critical Components</b>						
C1	Seagrass extent	Long Term	<ul style="list-style-type: none"> <li>Total mapped extent of dense <i>Posidonia</i> will not decline by greater than 10 per cent of the baseline value outlined by Roob et al. (1998) at a whole of site scale (baseline = 3050 hectares; LAC = mapped area less than 2745 hectares) on any occasion. (Note: the small degree of allowable change recognises that this seagrass species is a critical habitat resource and generally shows low natural variability)</li> <li>Total mapped extent of the dense and medium density <i>Zosteraceae</i> will not decline by greater than 25 per cent of the baseline values outlined by Roob et al. (1998) at a whole of site scale on two sampling occasions within any decade. <ul style="list-style-type: none"> <li>Dense <i>Zostera</i> - Baseline = 5743 hectares (LAC = mapped area less than 4307 hectares)</li> <li>Medium <i>Zostera</i> - Baseline = 1077 hectares (LAC = mapped area less than 807 hectares)</li> </ul> </li> </ul> <p>(Note: the moderate degree of allowable change recognises that these seagrass species generally show moderate degrees of natural variability)</p>	<p>Sampling to occur at least twice within the decade under consideration.</p> <p>Note that the seagrass assessment by Hindell (2008) did not produce mapping but did use similar sampling sites to Roob <i>et al.</i></p>	<p>Level B - Recent quantitative data describes seagrass condition at various sites but over a limited timeframe. It is thought that the Roob <i>et al.</i> (1998) study underestimated the total available seagrass habitat (J. Stevenson, Parks Victoria, pers. comm. February 2011), hence a 10 per cent change from this baseline value would represent a larger actual change from the true baseline.</p> <p>Note: Prior to declaration, <i>Posidonia</i> covered approximately 44 per cent (119 square kilometres) of the site (Poore 1978). Morgan (1986) estimated that <i>Posidonia</i> meadows covered 119 square kilometres in 1965, 35 per cent of the site in 1976 and 90 to 95 square kilometres in 1983–84. There is significant uncertainty regarding these mapping data and it is not recommended that empirical LACs are based on these data.</p>	S2
	Mangrove forest extent	Long term	<ul style="list-style-type: none"> <li>Based on EVC mapping, it is estimated that mangroves presently cover an area of 2137 hectares within the site (see Section 3.3.1). A 10 per cent reduction in the total mapped mangrove area, observed on two sampling occasions within any decade, is an unacceptable change. (LAC – mapped area less than 1924 hectares). (Note: the small degree of allowable change recognises that mangroves are a critical habitat resource and generally shows low natural variability)</li> </ul>	<p>Sampling to occur at least twice within the decade under consideration.</p>	<p>Level B - No available data to determine changes in extent over time. It is unlikely that this has changed markedly since Ramsar listing. Note that there are uncertainties regarding the quality of existing mapping, and therefore the baseline value should be</p>	S2

<sup>4</sup> Short Term – measured in years; Medium Term – five to 10 year intervals; Long term – 10+ year intervals.

## LIMITS OF ACCEPTABLE CHANGE

Number	Indicator for Critical Component / Process/Service for the LAC	Relevant timescale <sup>4</sup>	Limit(s) of Acceptable Change	Spatial scale/temporal scale of measurements	Underpinning baseline data	Secondary critical C,P,S addressed through LAC
					considered as indicative only.	
	Saltmarsh extent	Long term	<ul style="list-style-type: none"> <li>Based on EVC mapping, it is estimated that intertidal saltmarsh presently covers an area of 6500 hectares within the site (see Section 3.3.1). A 10 per cent reduction in the total mapped saltmarsh area, observed on two sampling occasions within any decade, is an unacceptable change (LAC – mapped area less than 5850 hectares). (Note: the small degree of allowable change recognises that saltmarsh is a critical habitat resource and generally show low natural variability)</li> </ul>	Sampling to occur at least twice within the decade under consideration.	Level B - No available data to determine changes in extent over time. It is unlikely that this has changed markedly since Ramsar listing. The note regarding data quality for mangroves applies also to saltmarsh.	S2
	Shallow subtidal waters	Long term	<ul style="list-style-type: none"> <li>A greater than 20 per cent reduction in the extent of subtidal channel (areas mapped by NLWRA = 16 349 hectares), observed on two sampling occasions within any decade, will represent a change in ecological character (LAC – mapped area less than 13 079 hectares). (Note: the moderate degree of allowable change recognises that shallow subtidal waters represent a critical habitat resource, generally show low natural variability, but data reliability is low)</li> </ul>	Sampling to occur at least twice within the decade under consideration.	Level B - NLWRA mapping data describes wetland extent. This is coarse scale mapping and should be considered as indicative only. Note: there is a need to develop a condition-based LAC for this critical component. While some water quality data exists, this is presently insufficient to derive a LAC (i.e. whether a change in water quality represents a true change in ecological character of the wetland)	S2
	Inlet waters (intertidal flats)	Long term	<ul style="list-style-type: none"> <li>A greater than 20 per cent reduction in the extent of permanent saline wetland – intertidal flats (areas mapped by DSE = 40 479 hectares, see Figure 3-1), observed on two sampling occasions within any decade, will represent a change in ecological character (LAC – mapped area less than 36 431 hectares). (Note: the moderate degree of allowable change recognises that intertidal flats represent a critical habitat resource and generally show low natural variability. A loss of intertidal flat would also result in changes in seagrass)</li> </ul>	Sampling to occur at least twice within the decade under consideration.	Level B - VMCS mapping data describes wetland extent. This is coarse scale mapping and should be considered as indicative only. Note: there is a need to develop a condition-based LAC for this critical component. While some water quality data exists, this is presently insufficient to derive a LAC (i.e. whether a change in water quality represents a true change in ecological character of the wetland)	S2
C2	Abundance and of waterbirds	Short term (All species)	<ul style="list-style-type: none"> <li>Mean annual abundance of migratory bird species - Birds Australia (2009c) notes that there is a maximum annual abundance of migratory species of 42 811 birds, with a mean annual abundance of migratory species being 31 487 birds (deriving from 28 years of data collection to September 2008). The annual abundance of migratory shorebirds will</li> </ul>	At least four annual surveys (summer counts) within the decade under consideration.	Level A	P2

## LIMITS OF ACCEPTABLE CHANGE

Number	Indicator for Critical Component / Process/Service for the LAC	Relevant timescale <sup>4</sup>	Limit(s) of Acceptable Change	Spatial scale/temporal scale of measurements	Underpinning baseline data	Secondary critical C,P,S addressed through LAC
			not decline by 50 per cent of the long-term annual mean value (that is, must not fall below 15 743 individuals) in three consecutive years. (Note: the large degree of allowable change recognises that these species can show high levels of natural variability, and that limitations of existing baseline data)			
		Short term (individual species)	<ul style="list-style-type: none"> <li>Mean annual abundance of migratory species that meet the one per cent criterion will not be less than 50 per cent of the long-term annual mean value in five years of any ten year period. These values are follows: <ul style="list-style-type: none"> <li>curlew sandpiper – baseline = 2588 birds, LAC = 1294 birds</li> <li>bar tailed godwit – baseline = 9727 birds, LAC = 4863 birds</li> <li>eastern curlew – baseline = 1971 birds, LAC = 985 birds</li> <li>pied oystercatcher – baseline = 893 birds, LAC = 446 birds</li> <li>sooty oystercatcher – baseline = 285 birds, LAC = 142 birds</li> <li>double-banded plover– baseline = 523 birds, LAC = 261 birds</li> </ul> </li> </ul> <p>There are insufficient baseline data to determine long-term average abundance of fairy tern and Pacific gull.</p> <p>(Note: the large degree of allowable change recognises that these species can show high levels of natural variability, and that limitations of existing baseline data)</p>	At least five annual surveys (summer counts) within the decade under consideration.	Level A	P2
<b>Critical Processes</b>						
P1	Waterbird breeding	Short Term	<p>A greater than 50 per cent decrease in nest production at two or more monitoring stations (based on two sampling episodes over a five year period) within any of the following locations and species:</p> <ul style="list-style-type: none"> <li>Clomel Island - fairy tern, hooded plover, Caspian tern, crested tern</li> <li>Dream Island - fairy tern, hooded plover, crested tern</li> <li>Snake Island and Little Snake Island - pied oystercatcher</li> </ul>	Recommended baseline monitoring program should comprise a minimum two annual sampling periods separated by at least one year (and within a five year period).	Level C - The use of the site by these species is well documented. However, there are no empirical data describing breeding rates. Baseline data will need to be collected to assess this LAC.	C2
<b>Critical Services/Benefits</b>						
S1	Threatened Species	N/A	For orange-bellied parrot and growling grass frog, an unacceptable change will have occurred should the site no longer support these species.	Based on multiple targeted surveys at appropriate levels of spatial and temporal	Level C – Most site records are based on opportunistic surveys	P1, C3

## LIMITS OF ACCEPTABLE CHANGE

Number	Indicator for Critical Component / Process/Service for the LAC	Relevant timescale <sup>4</sup>	Limit(s) of Acceptable Change	Spatial scale/temporal scale of measurements	Underpinning baseline data	Secondary critical C,P,S addressed through LAC
		Short Term	For Australian grayling, an unacceptable change will have occurred should all of the drainages that drain into Corner Inlet no longer support this species.	replication (at least four annual surveys in preferred habitats) over a 10 year period.  Based on four annual surveys in a 10 year period at multiple sites located in all major catchments.	Level C - This species has been recorded in the major drainages that drain into the site. There are no data describing the population status of this species in the site. Abundance data are available for drainages that discharge into the site (Ecowise 2007; O'Connor <i>et al.</i> 2009). O'Connor <i>et al.</i> (2009) notes that collection of this species is difficult and requires targeted survey techniques. Few targeted empirical surveys have been undertaken in the site's drainages to date.	P1, C1, C2
S2	Fish abundance (using fish catch of key species as a surrogate)	Medium term	An unacceptable change will have occurred if the long term (greater than five years) median catch falls below the 20 <sup>th</sup> percentile historical baseline values in standardised abundance or catch-per unit effort of five or more commercially significant species (relative to baseline) due to altered habitat conditions within the site. The 25 <sup>th</sup> percentile pre-listing baseline commercial catch per unit effort values for the site are as follows (units are tonnes per annum per number of boats – see Table 3-8): <div><div>Australian salmon</div><div>379</div><div>rock flathead</div><div>316</div><div>southern sand flathead</div><div>373</div><div>greenback flounder</div><div>514</div><div>southern garfish</div><div>1452</div><div>yelloweye mullet</div><div>740</div><div>gummy shark</div><div>167</div><div>King George whiting</div><div>1347</div></div>	Annual fish catch measured over a greater than five year period.	Level A – Commercial fish catch data. Note that there are presently no fisheries-independent baseline data (collected using empirical, systematic methods) describing patterns in the distribution and abundance of key species. Therefore, the limits of acceptable change should be treated with caution, noting socio-economic factors should be taken into account when assessing catch data underpinning this LAC.	S2