



Australian Government

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

Gippsland Lakes Ramsar site

Ecological Character Description

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Chapter 3 (excluding Figures 3-22, 3-23 and 3-24)

Other chapters can be downloaded from:

www.environment.gov.au/water/publications/environmental/wetlands/21-ecd.html

3 DESCRIPTION OF ECOLOGICAL CHARACTER

3.1 Basis of the ECD

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

3.1.1 Interaction of Wetland Elements

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

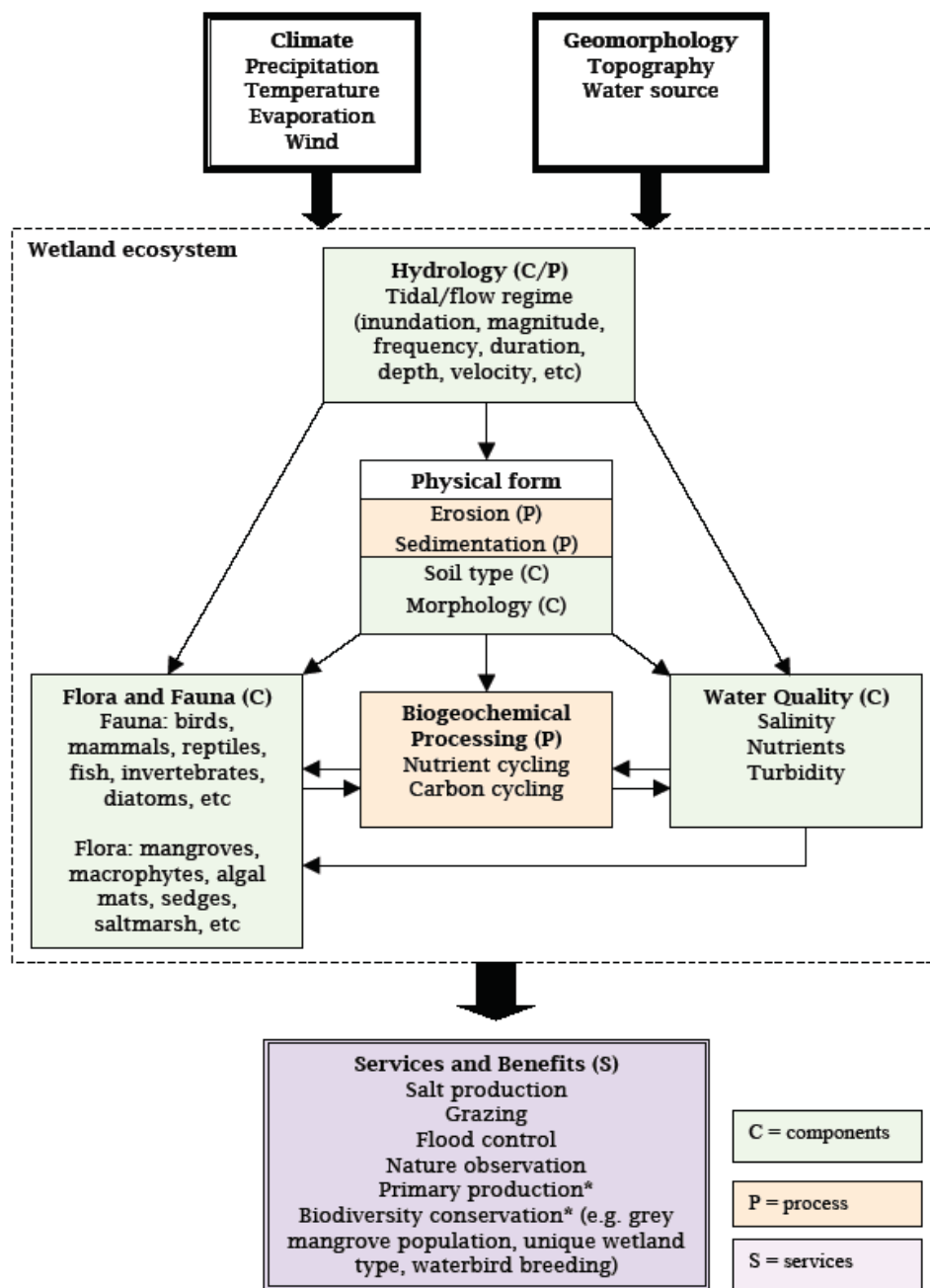


Figure 3–1 Generic conceptual model showing interaction between wetland ecosystem processes, components and services/benefits

(Source: National ECD Framework, DEWHA 2008)

3.1.2 Study Approach

The method employed to identify critical components, processes and services/benefits is presented in Appendix A. Following the direction provided within the National 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
- the component, process or service/benefit is important for supporting one or more of the Ramsar Nomination Criteria under which the site was listed
- 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.

3.2 Overview of Critical Components, Processes and Services/Benefits

A summary of the critical components, processes and services/benefits for the Gippsland Lakes Ramsar site are shown in Table 3-1.

In summary, the following have been identified:

- eight critical components and two supporting components
- two critical processes and six supporting processes
- two critical services/benefits and two supporting services/benefits.

Table 3-1 Summary of critical components, critical processes and critical services/benefits of the Gippsland Lakes Ramsar site

Critical components	Critical processes	Critical services/benefits
<p>Wetland habitats: grouped as follows.</p> <ul style="list-style-type: none"> • (C1) marine subtidal aquatic beds (seagrass/aquatic plants). • (C2) coastal brackish or saline lagoons (open water phytoplankton-dominated habitats). • fringing wetlands that can occur within the site as– <ul style="list-style-type: none"> ○ (C3) predominantly freshwater wetlands ○ (C4) brackish wetlands ○ (C5) saltmarsh/hypersaline wetlands. <p>Wetland flora and fauna:</p> <ul style="list-style-type: none"> • (C6) abundance and diversity of waterbirds. • (C7) presence of threatened frog species (green and golden bell frog; growling grass frog). • (C8) presence of threatened wetland flora species. 	<p>Hydrological regime: (P1) patterns of inundation and freshwater flows into the wetland system, groundwater influences and marine inflows that affect habitat structure and condition.</p> <p>Waterbird breeding functions: (P1) critical breeding habitats for a variety of waterbird species.</p>	<p>Threatened species: (S1) the site supports an assemblage of vulnerable or endangered wetland flora and fauna that contribute to biodiversity.</p> <p>Fisheries resource values: (S2) the site supports key fisheries habitats and stocks of commercial and recreational significance.</p>
Supporting components	Supporting processes	Supporting services/benefits
<p>Other wetland habitats: supported by the site (sand/pebble shores, estuarine waters, etc.).</p> <p>Other wetland fauna: supported by the site (for example, fish, aquatic invertebrates).</p>	<p>Climate: patterns of temperature, rainfall and evaporation.</p> <p>Geomorphology: key geomorphologic/topographic features of the site.</p> <p>Coastal and shoreline processes: hydrodynamic controls on coasts and shorelines through tides, currents, wind, erosion and accretion.</p> <p>Water quality: water quality influences aquatic ecosystem values, noting the key water quality variables for Gippsland Lakes are salinity, dissolved oxygen, nutrients and sediments.</p> <p>Nutrient cycling, sediment processes and algal blooms: primary productivity and the natural functioning of nutrient cycling/flux processes in waterbodies.</p> <p>Biological processes: important biological processes such as primary productivity.</p>	<p>Tourism and recreation: the site provides and supports a range of tourism and recreational activities that are significant to the regional economy.</p> <p>Scientific research: the site supports and contains features important for scientific research.</p>

3.3 Critical Components – Wetland Habitats

The Gippsland Lakes system supports a wide range of habitats including planktonic systems in the water column of the main lakes, submerged and emergent macrophytes, and extensive zones of freshwater-saltwater interface that is dominated by vegetation types such as rushes, reeds and sedges.

The following sections describe wetland habitat critical components. Where data are available, trends in wetland extent over time (and space) are described, mostly on the basis of wetland mapping described in Section 2. In most cases, there are few data describing baseline conditions in wetland habitats at the time of listing. Where data from other periods (typically post-listing) have been adopted as the baseline data set, commentary is provided on whether it is likely that these data are likely to be representative of conditions at the time of listing. When describing wetland habitat critical components, vegetation community extent has typically been adopted as the primary indicator given its ecological relevance (particularly as fauna habitat), and that it is likely to reflect the range of hydrological and water quality conditions existing at the time of vegetation community mapping.

Ecos (unpublished) and other sources (DSE 2003, Parks Victoria 2008) refer to and group wetland habitats within the site under common attributes as follows:

- ‘Marine subtidal aquatic beds’ (waterbodies with seagrass and/or algae species present).
- ‘Coastal brackish or saline lagoons’ (waterbodies generally).
- ‘Fringing wetlands’, often brackish but sometimes freshwater and sometimes hypersaline, that are vegetated with a wide range of vascular and non-vascular plants.

Table 3-2 presents the groupings applied to the major named wetland/waterbodies within the site and their equivalent Ramsar wetland type. This approach has been adopted in the ECD to ensure consistency with source information (including DSE 2003 and other management plans) and lends itself well to describing the critical components related to habitat, LAC and conceptual models presented in later sections.

Table 3-2 Groupings of Gippsland Lakes wetlands according to major habitat (Source: various)

Major Habitat Groupings	Equivalent Ramsar Wetland Types	Locations
Coastal Brackish or Saline Lagoons (that also include marine subtidal aquatic beds)	Type B	Lake King, Lake Victoria, Reeve Channel, Lake Tyers, Bunga Arm and Lake Bunga
Coastal Brackish or Saline Lagoons	Types J and F	Lake King, Lake Victoria, Reeve Channel, Lake Tyers Bunga Arm and Lake Bunga, Jones Bay Lake Wellington
Fringing Wetlands	Types E, H, Sp, Tp or Xf	Sale Common* Tucker Swamp Lake Reeve** Backwater Morass Balfour Swamp Blond Bay Area Blue Horizons Estuary - Main Swamp Bosses Swamp Clydebank Morass Cygnet Swamp Dowd Morass [#] Dolomite Swamp Half Moon Swamp The Heart Morass [#] Hickey Swamp Lake Betsy Lake Coleman Lake Kilarny Lake Morley (aka Morley Swamp) Macleod Morass* Phiddians Swamp Red Morass Russels Swamp Salt Creek Marsh Salt Lake Snipes Wetland Spoon Bay Victoria Lagoon Waddy Point Swamp Yendalock Swamp

NOTES:

* Sale Common and Macleod Morass are considered to be predominantly freshwater wetlands

** Lake Reeve is a saltmarsh-dominated, hypersaline wetland.

The remaining fringing wetlands in this category are variably saline (brackish), except (#) Dowd Morass and The Heart Morass that while brackish, are being managed as predominantly freshwater wetlands under the Lake Wellington Wetlands Management Plan (Parks Victoria 2008).

3.3.1 Critical Component 1 - Marine Subtidal Aquatic Beds

Reasons for selection as 'critical'

Seagrass and other marine subtidal aquatic beds are present in several of the main lagoons including Lakes King, Victoria and Tyers. The values of seagrass to ecosystem functioning (and ecological character of the site) are well documented (Roob and Ball 1997, Hindell 2008, Ecos, unpublished) and include the following:

- primary production by seagrasses and associated algae
- direct grazing of living seagrass tissue in herbivory-based food webs

- direct grazing of algae in herbivory-based food webs
- decomposition of plant material by sediment bacteria and consequent effects on sediment biogeochemistry
- consumption of dead plant material and microbes in detritus-based food webs
- predation by higher consumers in complex food webs
- stabilisation of sediments and reduction in flow velocities, creating quiescent and sheltered habitats.

Description

Four species of seagrass occur in the Gippsland Lakes: *Heterozostera tasmanica*, *Lepilaena cylindrocarpa*, *Ruppia spirilis* and *Zostera muelleri*. In addition to these aquatic angiosperms, the charophyte *Lamprothamnium papulosum* has been recorded in the Gippsland Lakes (Roob and Ball 1997).

Zostera muelleri is widely distributed throughout the Gippsland Lakes and grows in sheltered and moderately exposed sand and silts to a water depth of approximately 2.5 metres (Roob and Ball 1997). It is generally more tolerant of desiccation than the other species of seagrass, which accounts for it commonly being found in the intertidal zone. *Heterozostera tasmanica* is also widely distributed in the Gippsland Lakes and like *Z. muelleri* grows to a depth of approximately 2.5 metres. Poore (1978) reported that these Zosteracea and other seagrass in the Gippsland Lakes were most abundant where salinities rarely fell below 25 grams per litre.

The third species, *Ruppia spiralis*, is usually found growing among *Z. muelleri* meadows. It is a robust perennial species that can tolerate a wide range of salinities and thus is found in environments varying from fresh water to hypersaline. The fourth angiosperm, *Lepilaena cylindrocarpa*, is a small native annual about 20 centimetres long. Like *R. spirilis*, it can tolerate a wide range of salinities and is found commonly in ephemeral fresh or brackish waters.

A diverse flora is associated with seagrasses but can be grouped into two functional categories:

- Periphyton: thin biofilms of microbes growing on seagrass leaves
- Epiphytes: algae growing on seagrass leaves.

Periphyton communities associated with seagrasses are diverse and highly productive; although Ecos (unpublished) indicates that no work has been undertaken on estimating productivity of seagrass periphyton in southern Australian waters.

Epiphytes are abundant on seagrass leaves and may account for between 10 and 90 per cent of the total primary productivity of seagrass beds (Keogh and Jenkins 1995). Diatoms, hydroids, coralline and filamentous red algae are common epiphytes, as well as bryozoans such as *Densipora corrugata*. Roob and Ball (1997) noted that epiphyte cover on seagrasses of the Gippsland Lakes was confined to areas that were of low energy and with relatively little tidal flow; high-energy environments seemed to cleanse seagrass blades of attached algae and/or provided limited opportunities for the algae to attach.

Patterns in variability

There is great inter-annual variability in seagrass cover within the Gippsland Lakes (Roob and Ball 1997). A near-complete loss of seagrasses was reported for the Gippsland Lakes between the 1920s and the 1950s (Coles et al. 2003). Between 1959 and 1997, there was a peak in seagrass cover in the late 1960s and in the late 1990s, with complex patterns that varied among lakes (Roob and Ball 1997). Roob and Ball (1997) showed that there had been a continual fluctuation in seagrass cover at the five sites sampled within the Gippsland Lakes Ramsar site over their study period of 1959 to 1997.

There are no empirical estimates of seagrass cover and extent around the time of site declaration (1982). Based on qualitative historical assessments undertaken by Roob and Ball (1997), it is noted that for the year 1976, three of the locations examined had 'medium' cover and two locations sparse cover, which was generally lower than recorded in 1969. The three locations examined in 1979 had denser seagrass cover than recorded in 1976. By 1984, the sample period closest to the time of site declaration, four of the five locations had sparse cover, whereas one location (Fraser Island) had dense cover that was similar to that recorded in 1969. Roob and Ball (1997) noted that 1984 was 'clearly the year in which seagrass cover was its lowest for the years examined'.

Roob and Ball (1997) noted that there was a general increase in seagrass cover between 1984 and 1997. A more recent study of seagrass extent and density to assess the impacts of recent algal blooms on seagrass communities in Lake King, Lake Victoria and Lakes Entrance, showed a reduction in density at sampling sites when compared to Roob and Ball's study. However it was noted in the findings of the report that these differences could 'reflect natural cycles in productivity and/or changes in environmental conditions that could be independent of the current phytoplankton bloom' (refer Hindell 2008).

The overall patterns in temporal variability matches the long-term (decadal) variability observed for seagrass beds in south-eastern Australia since the 1970s. Given the dynamic nature of seagrass meadows here and the absence of empirical estimates of seagrass coverage around the time of listing, it is not possible to define an empirical baseline value describing seagrass extent. The most reliable estimate of seagrass extent within the site is from Roob and Ball (1997) (see Figure 3-2), which is based on assessments undertaken in 1997 (15 years after site declaration). Based on this mapping it was estimated that total seagrass extent was approximately 4330 hectares. It should be noted that 1997 represented the maximum recorded extent of seagrass at two of the five locations assessed by Roob and Ball (1997). EVC mapping indicates that seagrass extent within the site was 5013 hectares in 2005. Based on temporal trends observed by Roob and Ball, it is considered highly unlikely that these values are representative of baseline conditions around the time of listing.

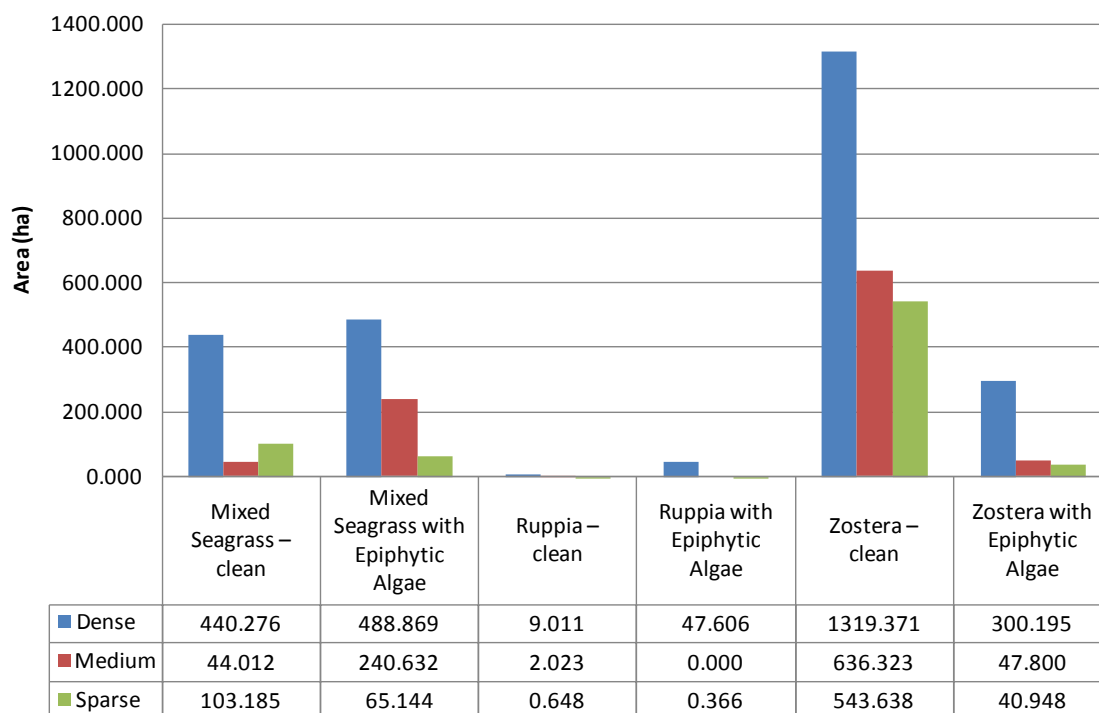


Figure 3–2 Seagrass cover estimates for Gippsland Lakes (source: Roob and Ball 1997)

3.3.2 Critical Component 2 - Coastal Brackish or Saline Lagoons

Reasons for selection as ‘critical’

The main waterbodies of the Gippsland Lakes Ramsar site include the connected lagoons of Lake Wellington, Lake Victoria, Lake King, and Jones Bay as well as Lake Tyers (which is intermittently connected to Bass Strait) and Lake Bunga. These waterbodies make up the bulk of the brackish or saline lagoons of the site.

The lagoons play an important role in nutrient and energy dynamics throughout the Lakes system, providing for the consumption of phytoplankton biomass by a range of herbivores, including zooplankton (Ecos unpublished). These systems provide the building blocks of the site’s ecosystem, on which higher trophic levels such as macroinvertebrates, fish and waterbirds ultimately depend. As such they are critical to the ecological character of the site.

Description

The large areas of open water in the Gippsland Lakes and abundance of phytoplankton suggest that planktonic food webs are a critical component of the lagoon systems. These food webs operate in the lagoons as well as in the fringing wetlands of the waterbodies, especially the hypersaline ones where vascular plants are less abundant. Phytoplankton are consumed by a range of herbivores, including zooplankton (animals larger than 50 micrometres). Larger filter-feeding animals, such as mussels, also consume phytoplankton.

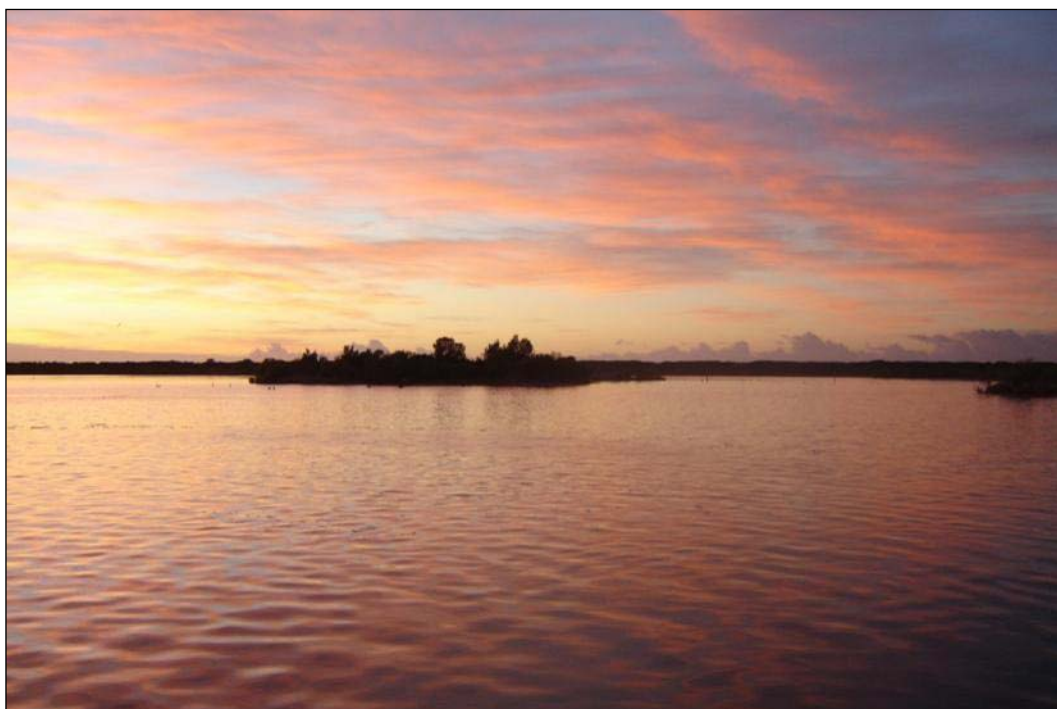
Concentrations of phytoplankton (expressed in terms of chlorophyll *a*) in the Gippsland Lakes are commonly around five to 20 micrograms per litre, but can exceed 20 micrograms per litre at times.

Deposition of phytoplankton biomass, which contributes to sediment accretion, is also important in controlling patterns of anoxia and nutrient release from the sediments.

Periodic and severe algal blooms, mostly of cyanobacteria such as *Nodularia* but also sometimes of dinoflagellates, can affect ecosystem integrity and human amenity value in the Gippsland Lakes. The saline or brackish lagoons of the Gippsland Lakes are highly sensitive to eutrophication (and subsequent algal blooms), for four reasons (CSIRO 2001):

- They are shallow, so loads per unit area from catchment runoff translate into high loads per unit volume of water.
- They experience episodic periods of very high nutrient loads from catchments that can result in marked increases in nutrient concentrations in the water column.
- The water column in at least some of the lagoons stratifies vertically due to differences in salt concentrations.
- Submerged macrophytes, such as seagrasses or the freshwater angiosperm *Vallisneria*, cover little of the sediment area.

Fundamental hydrological differences among the lagoons mean that the ecological processes operating within each lagoon are also dissimilar. Lake Wellington is a shallow body of water that is rarely if ever stratified, is characterised by highly disturbed and suspended sediment and while predominantly fresh, undergoes episodic saline intrusion that has affected its aquatic vegetation and fringing wetland communities. Lakes King and Victoria are deeper, less well mixed and more estuarine in character whereas Lake Tyers is an intermittently opening and closing lagoon with greater coastal hydrodynamic influences.



Lake Victoria (source: Parks Victoria, Tamara Boyd)

Patterns in variability

The ecology of the main lakes (King, Victoria and Wellington) is underpinned by a combination of freshwater inflows, marine inflows, ambient water quality and nutrient cycling processes associated with bed sediments. Salinity levels, water temperature and levels, dissolved oxygen concentrations, growth of aquatic vegetation and turbidity levels vary substantially over time in response to these underlying ecosystem processes.

As an intermittently closing and opening lagoon (ICOL), Lake Tyers is frequently closed to the ocean by a sand berm, but has been periodically breached as a result of beach erosion processes (that is, storm waves), flooding or by human intervention. The ecology of Lake Tyers therefore responds both to freshwater inflows (from its largely undeveloped catchment of forestry reserves) as well as natural and artificial entrance opening and closure regimes (Ecos unpublished).

Further discussion about these underlying processes and how they affect the ecology of the various lagoons are described in the sections on critical and supporting processes. Long term and more recent changes in the ecology of the lagoons are detailed in the section on changes to ecological character (refer Section 6).

3.3.3 Critical Component 3 - Fringing Wetlands (Predominantly Freshwater)

Reasons for selection as ‘critical’

The predominantly freshwater wetland habitats of Gippsland Lakes include Sale Common and Macleod Morass. However, Sale Common is regarded by Tilleard and Ladson (2010) as the only ‘true’ remaining freshwater wetland in the entire system.

The presence and continued functioning of these predominantly freshwater habitats are critical to the ecological character of the site for freshwater-dependent species such as amphibians and freshwater specialist avifauna as well as providing drought refuge for a broad range of waterbird species. Fringing vegetation in these wetlands also provides a dense, complex structure for nesting birds (DSE 2003).

Description

The dominant vegetation communities in the predominantly freshwater fringing wetlands are common reed (*Phragmites australis*), and native cumbungi (*Typha orientalis*). Extensive areas of giant rush (*Juncus ingens*) are also present but are in direct competition with cumbungi expansion in Macleod Morass. Swamp paperbark (*Melaleuca ericifolia*) are also present along the margins of the swamps.

A description of the two predominantly freshwater wetlands within the site is provided below.

Sale Common

Sale Common is a deep freshwater Nature Conservation Reserve which comprises 308 hectares. Directly influenced by the flows from the Thomson and Latrobe Rivers, Sale Common experiences seasonal variations in water levels with periodic flooding and draw down from evaporation. The site has had natural draw down of water as a result of drought in 1983 and managed draw downs in 1985, 1987, 1991 and 1995 and can dry out naturally as a result of seasonally dry conditions. Water levels can be controlled in the Common through constructed waterway control works (Parks Victoria 2008).

Sale Common is regarded as having the following attributes (refer WGCMA 2007) which contribute to its conservation value:

- relatively undisturbed vegetation
- diverse flora and fauna species
- presence of frog species of conservation significance (growling grass frog)
- presence of flora species of conservation significance (dwarf kerrawang)
- presence of avifauna species listed as threatened under National (EPBC Act) and State (*Flora and Fauna Guarantee Act*) legislation such as the little bittern, Australasian bittern, painted snipe and great egret.

Macleod Morass

Macleod Morass is a freshwater marsh forming an extensive wetland on the Mitchell River floodplain. The site supports the following (Parks Victoria 2003):

- up to 50 plant species with a number of ecological vegetation classes (EVCs) that are threatened in Victoria
- a diverse range of 141 fauna species within or in close vicinity of the wetland

- presence of frog species of conservation significance (green and golden bell frog)
- over 100 bird species including 53 waterbird species
- important breeding site for Australian white ibis, straw necked ibis and black winged stilt.
- state-level geomorphologic and geological significance.

Water inflows into Macleod Morass are dominated by catchment run-off from Cobbler Creek and several smaller intermittent streams, urban stormwater and direct rainfall. Treated sewage effluent from East Gippsland Water's Bairnsdale wastewater treatment plant also contributes about 14 per cent of freshwater input into the wetland. Major flood events in the Mitchell River result in complete inundation of Macleod Morass and serve to 'flush' the entire system (Parks Victoria 2003).

Patterns in variability

The ecology of both Sale Common and Macleod Morass have been influenced by long term changes in the surface water hydrology of the sites as a result of catchment modification and water control works within the sites. The sites are now actively managed to ensure a more natural wetting and drying regime is maintained.

Longer term trends in vegetation structure and condition in these wetlands includes the proliferation of cumbungi and *Phragmites australis*, generally at the expense of giant rush (Parks Victoria 2003). Quantitative studies of changes in vegetation condition and extent have not been conducted, although the following are noted:

- Both waterbodies are managed as predominantly freshwater wetlands by Parks Victoria, water quality within both wetland areas is characterised as having average salinities of generally less than two grams per litre.
- The Victorian Wetland Classification System (VWCS) maps 'primary category' and 'subcategory' wetland habitats around the time of listing¹ (refer to Figure 2-3 for the VMCS map of the site). Sale Common and Macleod Morass² are classified as "Deep Marsh" (primary category), and also includes shrub, reed and open water sub-categories (Figure 3-3). These data indicate that reeds form the dominant sub-category type at Sale Common, whereas open water tended to dominate at Macleod Morass. Note the data presented in Figure 3-3 should be considered as indicative only, recognising that wetland vegetation communities can show great variation over time, which is not accounted for in this snap-shot mapping assessment.

¹ The '1994' VWCS data is derived from the Corrick and Norman (1980) wetland assessments and is therefore an applicable baseline around the time of site listing

² Search based on "Main_name" categories of "Sale Common" and "Macleod Morass"

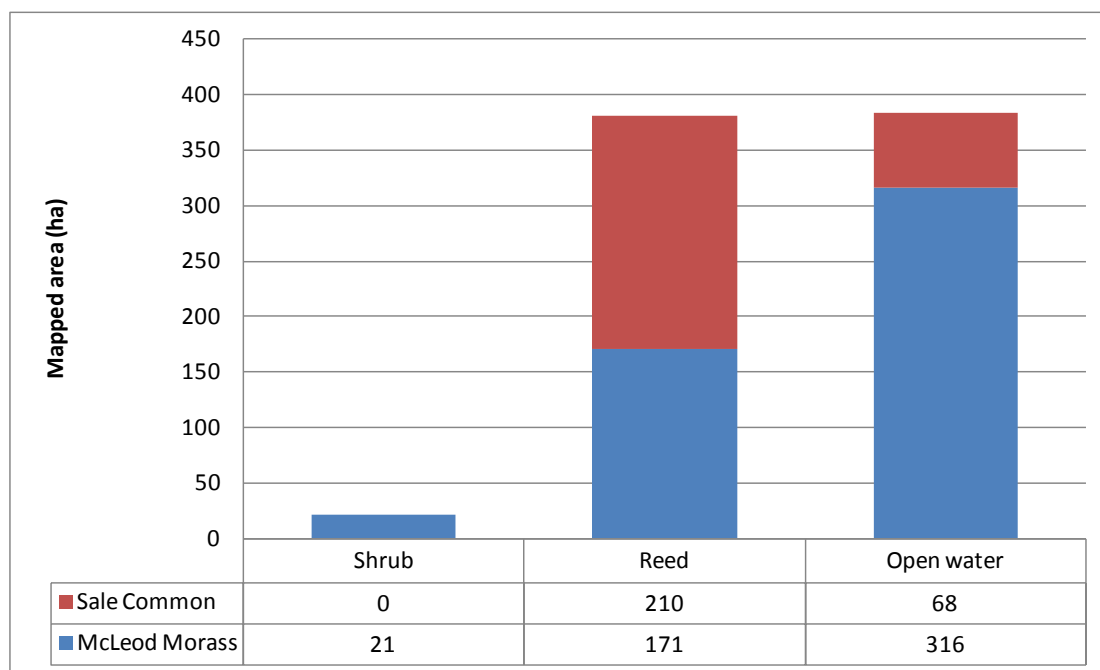


Figure 3–3 Mapped area of VWCS wetland subcategories at Sale Common and Macleod Morass in 1980 (Source: DSE unpublished data)

3.3.4 Critical Component 4 - Fringing Wetlands (Brackish)

Reasons for selection as 'critical'

The brackish fringing wetland habitats of Gippsland Lakes including Dowd Morass, the Heart Morass, eastern Lake Coleman and Tucker Swamp, and Clydebank Morass. The broad values of this habitat type to wetland functioning is as follows:

- habitat for juvenile fish and other marine and estuarine organisms
- stabilisation of soils
- detritus production and role in organic enrichment of substrate and sedimentation process
- fringing vegetation which provides a dense, complex structure for breeding and nesting birds.

The natural variability of these habitats to accommodate a range of hydrologic and salinity states is recognised as being important to the biodiversity of the Ramsar site.

Description

The permanent opening at Lakes Entrance means that many of the wetlands that fringe the Gippsland Lakes experience a mixture of fresh water and sea water, and therefore are brackish to varying degrees.

The dominant vegetation communities of the brackish fringing wetlands are swamp paperbark (*Melaleuca ericifolia*), common reed (*Phragmites australis*), and various saltmarsh communities that occurs as an understorey associated with swamp paperbark woodlands or as the predominant vegetation type in the more highly saline wetlands.

The brackish wetlands of the site (as outlined in Parks Victoria 2008) support:

- a diverse array of wildlife including 45 fauna species listed as threatened in Victoria
- over 187 bird species that use the wetlands for wide array of life cycle functions including important breeding sites at Dowd Morass for Australian white ibis and straw-necked ibis and breeding habitat for pied cormorant at Tucker Swamp
- a range of flora including 11 species listed as rare or threatened in Victoria
- four Ecological Vegetation Classes (EVC) that are threatened in Victoria
- sites of state or regional geomorphologic significance.

Patterns in variability

There are no data describing patterns in condition and community structure of brackish fringing wetlands at a whole of site scale. As discussed in Section 3.3.3, existing vegetation mapping does not have consistent analogues with the Ramsar wetland typology or the broad definition of a brackish wetland adopted here, and therefore is of limited value in terms of describing baseline conditions and changes over time.

There is some available information describing long term patterns in variability in this component within different parts of the wetland. *Phragmites* reed beds are in long term decline within the brackish wetlands of the site and along the margins of Lake Wellington. Although the hypothesis most commonly cited to explain the loss of reed beds is an increase in salinity due to the inexorable salinisation of the Gippsland Lakes following the opening of the channel at Lakes Entrance in 1889, other reasons for the loss of common reed in the Lake Wellington region may include:

- high salinities in Lake Wellington during drought years
- shallow water tables discharging saline water into the root zone
- limited grazing pressure.

Boon et al. (2008) mapped changes in vegetation communities at Dowd Morass between 1964 and 2003, which provides the most comprehensive description of baseline conditions of this critical component (albeit at a local scale) at the time of site listing. On the basis of data presented in Figure 3-4, the following trends are apparent:

- There was a marked decline in common reed over time, ranging from approximately 490 hectares in 1964, to approximately 480 hectares in 1982 (that is, at site listing) to approximately 340 hectares in 2003.
- There was an increase in the extent of (*Melaleuca*) swamp paperbark, ranging from approximately 350 hectares in 1964, to approximately 400 hectares in 1982 (at site listing) and approximately 600 hectares in 2003.

These data show that (i) common reed was gradually being replaced by swamp paperbark over the measurement period, and (ii) this process was occurring at the time of site declaration in 1982.

Similar studies have not been undertaken to quantify changes to vegetation structure within the other brackish morasses of the site, but similar patterns of change have been observed (refer DSE 2003).

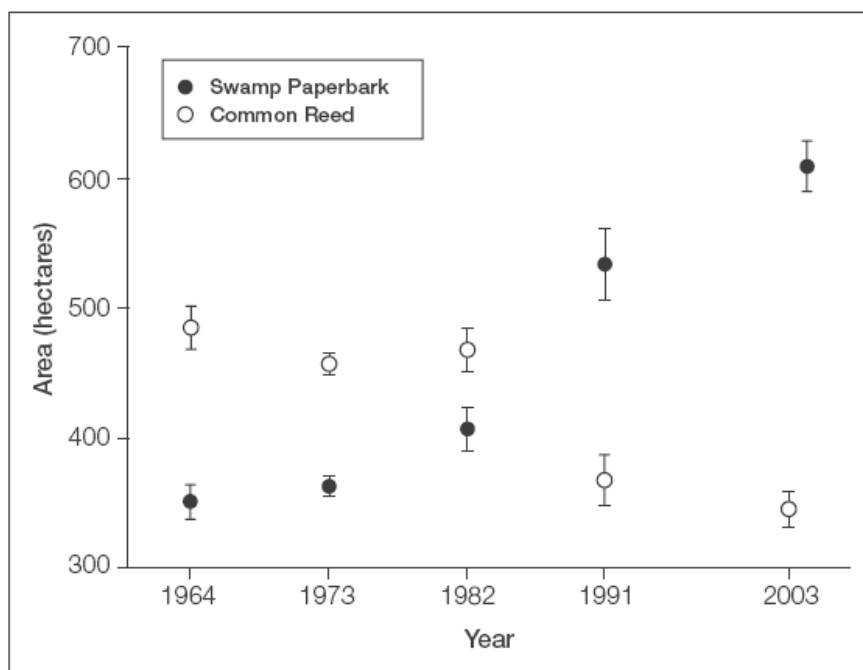


Figure 3–4 Changes in total area of swamp paperbark and common reed at Dowd Morass between 1964 and 2003 (Source: Boon et al. 2007)

The brackish fringing wetland areas of the site are naturally variable in terms of salinity over time depending on marine inflows, rainfall, catchment run-off and evaporation. Electrical conductivity measurements at Dowd Morass (1991 to 2001) by Boon et al. (2007) had a mean of 4.0 ± 0.33 SE millisiemens per centimetre (approximately 2.6 grams per litre), and a maximum value of 19.4 millisiemens per centimetre (approximately 12 grams per litre). Similar salinity conditions have been observed at the Heart Morass. There are no good quality salinity data available for Dowd Morass or other brackish water wetland sites around the time of site listing (see Appendix B).

Lake Coleman (east) and Clydebank Morass experience and maintain much higher ambient salinity levels than either Dowd Morass or the Heart Morass with surface waters between 6.7 and 29 grams per litre and groundwater between 21 and 27 grams per litre (Ecos unpublished; Tilleard and Ladson 2010; Parks Victoria 2008).

The high salinity levels results from the fact that these wetlands have a more direct connection to Lake Wellington (Parks Victoria 2008; Tilleard and Ladson 2010). Water levels and salinity in the lower section of the Clydebank Morass have resembled those of Lake Wellington since the breaching and erosion of the barrier between the Morass and the Lake by a flood in the Avon catchment in 1990. The hydrology of Lake Coleman has been altered by construction of channels connecting it to Lake Wellington (Parks Victoria 2008).

Vegetation communities in these areas are therefore more characteristically salt tolerant (Tilleard and Ladson 2010, Ecos unpublished) and both wetlands are currently being managed as estuarine wetlands based on the current Parks Victoria management plan (Parks Victoria 2008).

3.3.5 Critical Component 5 – Fringing Wetlands (Saltmarsh/Hypersaline)

Reasons for selection as ‘critical’

While saltmarsh can be found across a range of brackish wetland habitat types within the site (as discussed above), saltmarsh represents the main vegetation community in Lake Reeve as a result of the hypersaline conditions of the lake and its surrounds from tidal processes.

In the Management Plan for The Lakes National Park and Gippsland Lakes Coastal Park (Parks Victoria 1998), Lake Reeve is described as a significant feature of the Coastal Park and is a site of special scientific interest. The Plan indicates that the fringing saltmarsh of the lake contains a number of plant species relatively uncommon in Victoria east of Seaspray.

Description

Lake Reeve is a long, narrow wetland that runs parallel to the coast for nearly 60 kilometres alongside the south-westerly parts of the Gippsland Lakes Ramsar site, from Rotamah Island in the north-east to Seaspray in the south-west (SKM 2004).

The combination of shallow water levels and regular (seasonal) filling of the lake and inundation of its margins and drying as a result of evaporation creates the conditions suited for development of saltmarsh communities. The saltmarsh of Lake Reeve provide habitat and food for a wide range of animals. A large part of their habitat value derives from their providing a complex mosaic of low, dense vegetation in areas that are otherwise periodically inundated with saline water.

Whilst sharing the broad wetland values identified for brackish wetlands, saltmarsh such as Lake Reeve also provide notable roosting habitat for shorebirds as well as valuable fisheries nursery habitat. In particular, the saltmarsh of Lake Reeve provides summer feeding and roosting grounds for migratory waterbirds of international importance.

Lake Reeve also differs fundamentally from other lagoons in the Gippsland Lakes in its geomorphology. The bed of Lake Reeve is of sand, shell and mud, and as large areas of the lagoon frequently dry up completely, extensive saltmarsh areas develop. Along much of the shoreline of Lake Reeve, are sets of low, curving parallel ridges, the ridge crests commonly only five centimetres to 30 – 40 centimetres above the intervening swales. The ridges are often shelly, or of silty sand. They indicate a progressive reclamation of Lake Reeve by shoreline progradation and have been termed contraction ridges or concentric ridges. They are best developed on the eastern shoreline due to the predominance of wave action here generated by westerly winds. For these reasons Lake Reeve is identified as a geological and geomorphological site of State significance (DPI 2007) and is an excellent representative hypersaline saltmarsh that is both rare and unique in the context of the bioregion/drainage division and at greater spatial scales.



Lake Reeve showing saltmarsh wetlands (source: Paul Boon)

Patterns in variability

In terms of hydrology, Lake Reeve is periodically inundated with saline water and then dries out to form an intermittently wet-and-dry saltmarsh environment. Water enters Lake Reeve from the eastern end near Lake Victoria and permanent water extends westwards for about 13 kilometres. Water levels in Lake Reeve are usually lowest in summer and early autumn when stream flows are low but may be tens of centimetres above sea level during floods. Only the eastern end of Lake Reeve contains permanent water. The rest of the lake is shallow and usually dries up by early summer.

In terms of water quality, Lake Reeve can range from freshwater at its northeast end to 100 grams per litre in some isolated lagoons. Salinity levels vary seasonally, with lower salinity during wet (winter) compared with dry (summer) seasons (Davis and Fitzgerald 2004). Given the wide range of variability in hydrology and water quality in space and time, together with the paucity of data describing these patterns, it is not possible to establish a reliable empirical 'baseline' description of conditions at the time of site declaration, or present day.

To a large extent, patterns in hydrology and water quality will be reflected in vegetation community structure. While broad-scale mapping of wetland and vegetation community types exists (for example, Ecological Vegetation Class mapping), there are no data describing the range of natural temporal variability in extent of different saltmarsh vegetation communities and the controls on these changes. Based on VWCS mapping for the year 1980 (DSE unpublished), Lake Reeve is classified as a semi-permanent saline wetland (Figure 2-3). Based on VWCS data approximately 2322 hectares of saltpan was mapped for areas coded as "Lake Reeve Nature Reserve", which represented approximately 67 per cent of the total saltpan habitat resource of the site (Figure 3-5). Salt flat habitat within "Lake Reeve Nature Reserve" covered 318 hectares, which was approximately 43 per cent of the total salt flat habitat area of the site, and the area of salt meadow habitat within

Lake Reeve was 85 hectares (approximately two percent of the total salt meadow habitat within the site).

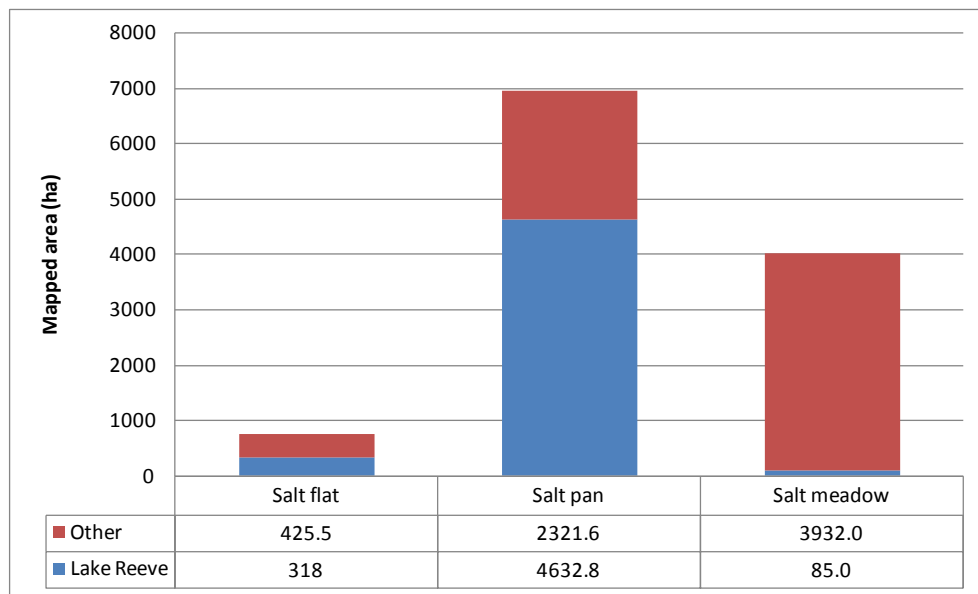


Figure 3-1 Area of saltmarsh, saltpan and salt meadow VWCS subcategories at the ‘Lake Reeves Nature Reserve’ and other parts of the site based on 1980 mapping (Source: DSE unpublished data)

3.4 Critical Components – Wetland Flora and Fauna

Within the wetland habitat types described above, a rich diversity of wildlife exists from all the major groups of organisms (from planktonic organisms to vertebrates) which make up the ecosystem components of the wetland.

3.4.1 Critical Component 6 - Abundance and Diversity of Waterbirds

Reasons for selection as ‘critical’

Waterbird abundance and diversity of the site are referred to within several site management plans (DSE 2003, Parks Victoria 2003, Parks Victoria 2008) as being significant and underpin listing of the site under Ramsar Nomination Criteria 4 and 5 (and the original site nomination documentation - see Section 2.4.1). The abundance and diversity of waterbirds are therefore fundamental to the site’s ecological character.

Description

Gippsland Lakes provide important feeding, resting and breeding habitat for 86 waterbird species (DSE 2003, Corrick and Norman 1980 – see Appendix D for species lists). Many are listed under JAMBA, CAMBA, ROKAMBA and/or the CMS. In terms of carrying capacity, it is documented that the Gippsland Lakes and associated swamps and morasses regularly support approximately 40 000 to 50 000 waterbirds (DSE 2003).

The high conservation value of the Gippsland Lakes Ramsar site for avifauna results from the range of freshwater, brackish, and estuarine habitats present.

Corrick and Norman (1980) undertook four-weekly counts in selected representative wetland habitats within the Gippsland Lakes in 1980 which is one of the few data sets available to describe conditions at the time of listing. The study recorded 86 species of waterbirds (including seabirds) with highest usage of the site occurring in deep freshwater marshes (for example, Dowd Morass, the Heart Morass, Sale Common) but with salt marsh and shallow permanent saline wetlands also important areas for waterbird usage (for example, Lake Reeve). Migratory species were present during summer (snipe, sandpipers, godwit, Eastern curlew and common tern) or winter (cattle egret and double banded dotterel). Several nomadic species were observed all year round (white-eyed duck, pink-eared duck and grey teal) (Corrick and Norman 1980).

A total of 86 waterbird species are currently recorded for the site (DSE 2009, Birds Australia 2009) which represents approximately 93 per cent of the waterbird avifauna diversity recorded in Victoria (Barrett et al. 2003).

The Ecos (unpublished) analysis of waterbird data (total biomass and total species diversity) generally supports the findings of Corrick and Norman (1980), noting large open water bodies (coastal brackish or saline lagoons) of the site were relatively unimportant compared with marine sub-tidal aquatic beds (seagrass) and fringing wetlands. Whilst a variety of waterbirds (mainly piscivores) forage on large open water bodies, feeding activity of waterbirds is mainly concentrated along the margins of the lakes and/or shallow wetlands where conditions support foraging opportunities.

Specific waterbird values listed at a wetland-specific scale in the Strategic Management Plan (DSE 2003) include:

- Clydebank Morass, Macleod Morass and Jones Bay supporting many species of migratory waterbird.
- Lake Wellington, Lake Victoria and Lake King supporting migratory waterbirds, including the little tern and fairy tern.
- Lake Reeve providing highly significant habitat for a large number of migratory shorebirds, and is one of the five most important areas for shorebirds in Victoria.
- Bunga Arm supporting breeding populations of species of little tern, fairy tern, hooded plover and white-bellied sea-eagle

Information contained in DSE (2003) and within Ecos (unpublished) identified the most notable locations for waterbirds in terms of abundance within the site as follows:

- the southern sector of the Roseneath Wetlands (Victoria Lagoon and Morley Swamp)
- Macleod Morass and the western end of the Silt Jetties
- Dowd and the Heart Morass
- Swan Reach Bay and Bosse's Swamp

- the southern part of Lake Tyers and Reeve Channel
- shorelines of the Gippsland Coastal Park, including Bunga Arm.

Appendix C of this report presents analyses of waterbird count data provided by DSE (Flora and Fauna Database) and Birds Australia. While broad trends in habitat use can be derived from the data, there are insufficient data to develop a robust baseline description of abundance for most waterbird species. Analysis of the Birds Australia and DSE database data revealed similar spatial trends to that described by DSE (2003) and Ecos (unpublished). Key findings from the analysis of Birds Australia and DSE Fauna Database data are highlighted below.

In terms of avifauna species that meet Nomination Criterion 6 for regularly supporting one per cent of the individuals within a population, Bamford et al. (2008) lists two species which have been recorded at the site in numbers exceeding the one per cent population threshold, that is, the red-necked stint (*Calidris ruficollis*) and sharp-tailed sandpiper (*Calidris acuminata*).

- Red-necked stint - approximately 8000 red-necked stints were recorded as part of a flock of shorebirds at Lake Reeve in January 1995 (cf. previous published total of 5397 as reported in Barter 1995; current flyway one per cent threshold is 3250, Bamford et al. 2008). Ecos (unpublished) notes that the site may not be expected to regularly support internationally significant numbers of this species. There is an absence of reliable data to substantiate the one per cent population threshold occurring and/or on a regular basis. The Birds Australia database contains 99 records of red-necked stint at the site, with a maximum count of 147 individuals per 20 minute search (at Swan Bay Reach). The DSE database contains 244 records of red-necked stint at the site, with counts of 1800 to 2570 individuals per station recorded on four occasions in March-April 2006, and a count of 1000 individuals recorded in 1987. All other DSE records for this species had counts less than 1000 individuals.
- Sharp-tailed sandpiper – this entry is for a recorded flock of 3187 in 2003 (AWSG 2003). The current flyway one per cent threshold is 1600 (Bamford et al. 2008). Since 2003, there is an absence of reliable data to substantiate the one per cent population threshold occurring and/or the frequency that this occurs. The Birds Australia database contains 28 records of sharp-tailed sandpiper at the site, with a maximum count of 70 individuals per 20 minute search (at Swan Bay Reach). The DSE database contains 205 records of sharp-tailed sandpiper at the site, with counts of 712 to 2300 individuals per station recorded on 11 occasions (1991, 1992, 1993 and 2006). The one per cent population threshold was exceeded on two occasions: 1660 and 2300 birds recorded in March 2006. All other DSE records for this species had counts less than 1000 individuals.

Other waterbird species which have occurred (or are considered likely to occur) in internationally significant numbers at the site include (after Ecos unpublished):

- Black swan (*Cygnus atratus*) –11 530 birds recorded in 1991 at Roseneath Wetlands. Areas of potential importance include: Russell's Swamp; areas of eel grass beds (*Vallisneria* spp.) along southern shores and bays (Lake Victoria and Tyers, and the Bunga Arm); southern part of Lake Reeve; and Sale Common (breeding site; 300 to 500 breeding pairs recorded). The one per cent population threshold for this species is 10 000 birds (Wetlands International 2006). Ecos (unpublished) notes that overall numbers probably exceed 10 000 almost all of the time, but this

is speculation. Based on DSE database data, counts of greater than 10 000 birds occurred on three occasions: 10 000 individuals were recorded twice in January 1987 and 11 530 individuals were recorded in December 1991. Furthermore, counts approaching the one per cent threshold have been recorded in January 1987 (7500 individuals) and November 1991 (9000 individuals). Note that these counts are for individual monitoring stations within the site, and that total abundances at a whole of site would likely be far greater.

- Chestnut teal (*Anas castanea*) – undated records of 3730 birds at Lake Reeve and 3308 birds at Roseneath Wetlands (Ecos unpublished). Other areas of potential importance include: Bunga Arm (eel grass beds *Vallisneria* spp.); Macleod Morass; Sale Common; Raymond Island (northern tip); and Russell's Swamp (north-east corner of Lake Wellington). The one per cent population threshold (south-east Australia) for this species is 1000 birds (Wetlands International 2006). The 1999 RIS (Casanelia 1999) included this species within a group of waterbirds in support of Ramsar criteria 3(b) for the following reason - 6300 recorded in Lake King, Lake Victoria and Lake Wellington wetlands. The DSE database includes 45 records where the one per cent population threshold was exceeded: 1976, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1998, 1991, 2001 and 2006. Based on this, the site can be considered to support internationally significant numbers of this species.
- Fairy tern (*Sterna nereis*) – undated record for up to 80 birds recorded at Lake Tyers (Ecos unpublished). Other areas of potential importance include: the Bunga Arm (breeding site); and Metung-Lakes Entrance area (breeding sites). The one per cent population threshold for *Sterna nereis nereis* (of south-eastern Australia) is 25 birds (Wetlands International 2006). The DSE database includes 34 records where the one per cent population threshold was exceeded: 1987, 1988, 1993, 2001, 2002 and 2003. Based on this, the site can be considered to support internationally significant numbers of this species.
- Little tern (*Sterna albifrons*) - undated record for up to 300 birds at Jones Bay (Ecos unpublished). Other areas of potential importance include: Metung-Lakes Entrance area (feeding habitat; breeding site for 200-300 pairs); Lake Tyers (breeding site for up to 40 pairs); Crescent Island (breeding site for up to 25 pairs); and Roseneath Wetlands and Morley Swamp (feeding habitat for post-breeding adults and juveniles). The one per cent population threshold for *Sterna albifrons sinensis* is 1000 birds, and for *Sterna albifrons placens* is 150 birds (Wetlands International 2006). The DSE database includes 31 records where there were greater than 150 little terns: 1987, 1988, 1991, 1993, 2000, 2001, 2002, 2003, 2004 and 2006. However, there are no records where bird abundance exceeded 1000 individuals. It is uncertain at this stage whether the one per cent population threshold is exceeded due to lack of information on whether the records are for *S. albifrons placens* or *sinensis*.
- Musk duck (*Biziura lobata*) - Areas of importance include: Jones and Swan Reach Bays (feeding and sheltering areas for up to 200 birds); and Roseneath Wetlands (pre-breeding aggregations of 400-500 birds). The one per cent population threshold for this species (in south-eastern Australia) is 250 birds (Wetlands International 2006). The DSE database includes three records where the one per cent population threshold was approach or exceeded: 1992 (233 birds/station), 1994 (212 birds/station) and 1998 (250 birds/station). Note that these counts are for individual monitoring stations within the site, and that total abundances at a whole of site would likely be far greater.

Other notable waterbird species (listed within Casanelia 1999) that may not meet the one per cent threshold due to uncertainty with data sets, but are likely to exist in substantial numbers within the site are:

- Australasian grebe (*Tachybaptus novaehollandiae*). The 1999 RIS (Casanelia 1999) reported a count of 4500 individuals at Lake King wetlands. The DSE database includes four records where more than 200 individuals per station were recorded, including one record of 1000 individuals. Wetlands International (2006) does not identify a one per cent population threshold because of the “considerable” uncertainty in regards to overall population estimates. The Ecos (unpublished) data analysis identifies this species has declined substantially and is not present in significant numbers. That report also raises concerns about the validity of the previous large count reported in the 1999 RIS (Casanelia 1999) as annual average counts are low and the species could have been easily misidentified for the hoary-headed grebe.
- Grey teal (*Anas gracilis*). The 1999 RIS (Casanelia 1999) provided the following information - 7270 recorded in Lake King, Lake Victoria and Lake Wellington wetlands. The one per cent population threshold for this species is 20 000 birds, though noting that aerial survey data suggests that the population can exceed two million in Australia (Wetlands International 2006). The Ecos (unpublished) data analysis identifies this species has not been present in significant numbers, nor would the site population exceed the current one per cent population threshold required for this species. The DSE and Birds Australia database records examined in the present study support this argument, with a maximum of 4500 birds recorded on any one occasion and monitoring station.
- Eurasian coot (*Fulica atra*). The 1999 RIS (Casanelia 1999) provided the following information – 10 000 recorded at Lake King wetlands, 1000 at Lake Victoria wetlands, 2000 at Lake Wellington wetlands. The current one per cent population threshold for the subspecies *australis* (of Australia and New Zealand) is 10 000 birds (Wetlands International 2006). The Ecos (unpublished) data analysis identifies this species has declined substantially, though acknowledges that total abundance for the site could exceed the one per cent population threshold though the regularity of this is speculation. The DSE database does not contain any records where bird counts exceeded 10 000 birds, however there were three records with counts greater than 5000 birds: twice in March 1990 (8000 and 9350 birds per station) and May 1992 (5000 individuals per station). Based on this, there is insufficient information to determine if site can be considered to support internationally significant numbers of this species.
- Great cormorant (*Phalacrocorax carbo*). The 1999 RIS (Casanelia 1999) provided the following information - 7000 recorded at Lake Victoria wetlands, 440 at Lake Wellington wetlands. Wetlands International (2006) does not identify a one per cent population threshold because of the “considerable” uncertainty in regards to overall population estimate. The Ecos (unpublished) data analysis identifies that there is no evidence of a substantial change in numbers compared to the early 1980s, though the regular total population for the site as a whole is not known.
- Red knot (*Calidris canutus*). The 1999 RIS (Casanelia 1999) provided the following information – Lake Reeve has supported the largest concentration recorded in Victoria, that is, 5000 birds. The DSE database does not contain any records of bird counts greater than 150 birds. The current flyway one per cent threshold is 2200 (Bamford et al. 2008). However, there is an absence of

reliable data to substantiate the one per cent population threshold occurring and/or the frequency that this occurs.

- Curlew sandpiper (*Calidris ferruginea*). The 1999 RIS (Casanelia 1999) recorded up to 1800 birds at Lake Reeve. The current flyway one per cent threshold is 1800 (Bamford et al. 2008). Apart from the before mentioned exceptional count at Lake Reeve in the mid-1990s, it is only usual to record small numbers of less than 50 birds (see also DSE and Birds Australia data; Appendix C). Bamford identifies this species has not been present in significant numbers at the site since 2000, nor would the site population exceed the current one per cent population threshold required for this species.

Patterns in variability

Patterns in abundances of all avifauna species are thought to vary across a range of spatial and temporal scales in the site. While 23 per cent of the waterbirds regularly occurring within the site are migratory shorebirds (21 species), a small proportion may remain within the site during the Australian winter. Populations of migratory species can fluctuate seasonally and the reasons for such changes may be influenced by local factors and/or influenced by external factors (within other parts of the populations' migratory routes and/or breeding grounds).

As outlined above, in terms of carrying capacity, the site has previously been attributed with regularly supporting approximately 40 000 to 50 000 waterbirds. Whilst data collection has not provided systematic survey treatments across the extent of the site, data analysis found that the site continues to regularly support more than 20 000 waterbirds, though significantly less than population estimates of the early 1990s (based on analysis within Ecos unpublished).

Declines in waterbird abundance and community composition have been recorded within the site (Ecos unpublished) though the sampling data does not permit a sound basis to assess natural variability (or other factors) which may influence the site's population. Empirical estimates of the abundance of key waterbird species are provided in Appendix C. As discussed in Appendix C, due to uncertainties regarding survey effort it is difficult to determine clear long-term trajectories in bird abundance.

Periodic freshwater inputs appear to be essential to maintaining the site's importance for notable waterbird species in the long term, and occasional increases in bird numbers are likely to be critical for long-term carrying capacity. Ecos (unpublished) identifies that bird numbers at broader regional spatial scales are likely to depend on the Gippsland Lakes as a source of breeding productivity.

Generally though, analysis of site usage by various waterbird species since listing of the site in 1982 indicates that those species that utilise the freshwater habitats of the site have generally declined since 1982 whilst waterbirds that can withstand greater salinity and estuarine conditions have maintained or increased their numbers (Ecos unpublished).

3.4.2 Critical Component 7 - Threatened Frog Species

Reasons for selection as 'critical'

Threatened frog species that have been recorded regularly (though not systematically over time) within the site with known and potentially suitable habitat include green and golden bell frog and growling grass frog.

The presence of populations of these threatened fauna contributes to Ramsar Nomination Criterion 2 and Ramsar Nomination Criterion 4 in that the site also supports breeding habitat for these species.

Description

A summary of the nationally threatened frog species occurring within the Gippsland Lakes Ramsar site is contained in Table 3-3.

The green and golden bell frog (*Litoria aurea*) is listed as vulnerable under the EPBC Act and endangered under the IUCN Red List (IUCN 2010). This species mostly occurs within the eastern parts of the Ramsar site, with areas of particular importance being the Macleod Morass and freshwater pools on Rotamah Island. Site records for this species are recorded from the early 1960s up to the most recent record in 1998 (DSE 2003; Ecos unpublished; DSE 2009).

The green and golden bell frog has been recorded in various terrestrial habitats including lowland forest, Banksia woodland, wet heathland, riparian scrub complex, riparian shrubland, riparian forest, damp forest, shrubby dry forest and cleared pastoral lands (Gillespie 1996). Within these habitats, this species is known to use a wide variety of waterbodies, though avoids fast flowing streams (Pyke and White 1996). In Victoria, this species is predominantly found on the coastal plains and low hinterland foothills of the south-east within habitats with little human disturbance (cf. use of disturbed sites in other parts of range) which support a range of lentic (still water; low salinity) permanent or ephemeral wetland habitats (Pyke and White 1996; Gillespie 1996; Pyke et al. 2002). The following are regarded as threats to the green and golden bell frog: predation by introduced fish (especially *Gambusia holbrooki*, although this species is not presently known to be a key threat in the site), water pollution (herbicides, insecticides, biocides), and disease (chytrid fungus) (DEWHA 2009).

The growling grass frog (*Litoria raniformis*) is listed as vulnerable under the EPBC Act. The most recent record within the Ramsar site for this species was recorded in 2007 in the Heart Morass (DSE 2010) with a prior record in 1975. This species mostly occurs within the western parts of the site, with areas of particular importance including the southern end of the Roseneath wetlands (for example, Morley Swamp and Victoria Lagoon).

The growling grass frog is found mostly amongst emergent vegetation (for example, bullrush *Typha* sp., sedges and reeds (for example, *Phragmites* sp. and *Eleocharis* sp.), in or at the edges of still or slow-flowing water bodies such as lagoons, swamps, lakes, ponds and farm dams (DEWHA 2009). 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 (esp. *Gambusia holbrooki*), chemical pollutions of water bodies (herbicides, insecticides, biocides), salinisation, and disease (chytrid fungus) (NSW DEC 2005, DEWHA 2009).

Table 3-3 Nationally threatened frog species occurring within the Gippsland Lakes Ramsar site

Species	Status	Habitat	Key locations within Ramsar site
<i>Litoria reniformis</i> (growling grass frog)	V	Emergent vegetation (for example, bullrush <i>Typha</i> sp., sedges and reeds (for example, <i>Phragmites</i> sp. and <i>Eleocharis</i> sp.), in or at the edges of still or slow-flowing water bodies such as lagoons, swamps, lakes, ponds and farm dams	Southern end of Roseneath Wetlands (for example, Morley Swamp, Victoria Lagoon) Lake Coleman and Tucker Swamp Sale Common The Heart Morass
<i>Litoria aurea</i> (green and golden bell frog)	V	Lowland forest, Banksia woodland, wet heathland, riparian scrub complex, riparian shrubland, riparian forest, damp forest, shrubby dry forest and cleared pastoral lands	Macleod Morass Rotamah Island

*Conservation status as listed under the EPBC Act, V=vulnerable.

Patterns in variability

As information on the key populations for both species within the site is currently insufficient, it is not possible to appreciate natural variation in population size. Key habitat and populations for both frog species needs to be identified and monitoring implemented in order for their proper management.

Anecdotal advice indicates a substantial reduction in the presence of growling grass frogs at areas of particular importance, such as the southern Roseneath Wetlands (Ecos unpublished). Rising salinity and lack of freshwater input is thought to have a continued significant negative impact on habitat for all amphibians, including the growling grass frog and green and golden bell frog (Ecos unpublished).

Green and golden bell frog and growling grass frog are capable of hybridising, thus there is a hybrid zone in the Gippsland Lakes Ramsar site where the species, and hybrids, co-occur. As shown in Table 3-3, growling grass frog mostly occurs in the western portions of the Ramsar site and is replaced by green and golden bell frog further east.

Maintaining the populations of these threatened species over time is most dependent on the following:

- Water Quality - Maintenance of high quality freshwater habitats (low nutrient levels, adequate dissolved oxygen, low salinity).
- Hydrology - Maintenance of natural patterns of freshwater inundation and prevention of increases in saline intrusion (noting the preferred habitat for these species are in predominantly freshwater wetlands).

- Biological/Biophysical Processes - Maintenance of natural vegetation patterns, extent, condition, and habitat interconnectivity. Maintenance of key biological processes occurring at the site such as growth, reproduction, recruitment, feeding and predation.

3.4.3 Critical Component 8 - Threatened Flora Species

Reasons for selection as 'critical'

The site supports nationally listed (under the EPBC Act) wetland-associated flora species: the endangered dwarf kerrawang and metallic sun-orchid; and the vulnerable swamp everlasting. The presence of these threatened flora species contribute to Ramsar Nomination Criterion 2.

Description

A summary of the nationally threatened flora species occurring within the Gippsland Lakes Ramsar site is contained in Table 3-4.

The habitat preferences of these species incorporate various terrestrial wetland types such as mesic heathlands, ephemeral wetlands, swamps and waterbody margins.

With the exception of *T. epipactoides* (see Calder et al. 1989; Cropper and Calder 1990), an understanding of the ecology and biology of these threatened species is highly limited. Consequently a number of knowledge gaps regarding the factors influencing their survival of these species exist (refer Table 7-1 for further details).

Table 3-4 Nationally threatened wetland-associated flora species occurring within the Gippsland Lakes Ramsar site

Scientific name	Status	Habitat	Key locations within Ramsar site
<i>Rulingia prostrata</i> (dwarf kerrawang)	E	Ephemeral wetlands and lake margins; peaty soils	Blond Bay Sale Common
<i>Thelymitra epipactoides</i> (metallic sun-orchid)	E	Mesic coastal heathland; wetland fringes; sandy soils that are periodically waterlogged	Blond Bay Gippsland Lakes Coastal Park
<i>Xerochrysum palustre</i> (swamp everlasting)	V	Lowland freshwater wetlands and swamps	Blond Bay

*Conservation status as listed under the EPBC Act, where E=endangered, V=vulnerable.

Patterns in variability

Dwarf kerrawang (*Rulingia prostrata*) was the only nationally threatened flora species listed as present at the time of declaration of Gippsland Lakes as a Ramsar site. This species has been observed within the site as recently as 2006 (FIS database). However, it is not known whether populations within the site have declined, noting that the national conservation status of this species has been upgraded from vulnerable to endangered during this time period. Likewise, metallic sun-orchid (*Thelymitra epipactoides*) was only listed at the State-level at the time of Ramsar declaration and is now listed nationally as endangered.

Localities and population sizes have been determined for *R. prostrata* (see Carter and Walsh 2008), whereas this information is lacking for the other two species. As such, it is difficult to assess the levels of natural variability displayed by these species without the required long-term and/or detailed data.

A number of ecosystem processes underlie the natural variability of these species:

- freshwater wetland hydrologic processes in terms of surface water inflows/interaction and groundwater inflows/interaction
- freshwater wetland geomorphologic processes including topography and soil type
- climatic processes in terms of provision of a direct freshwater supply to wetlands by precipitation as well as loss of freshwater through evaporation
- freshwater wetland biological processes including population dynamic processes (reproduction, dispersal, recruitment) and species interactions (herbivory, competition).

Overall, there are no available data on water requirements of threatened plant species, nor are there suitable baseline (pre-1982) data describing water regimes/water levels at particular locations supporting the three threatened plant species.

3.5 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 critical components in the context of the considerations outlined in section 3.1.1 of this report. In this context:

- Some supporting components are already partially covered by other critical components, processes or services/benefits.
- The supporting components, while not critical, are important to wetland functioning and are noteworthy in this regard.

3.5.1 Other Wetland Habitats

As described in Section 2, a range of wetland habitat types are supported by the site. In addition to the wetland types that have been identified in the context of the critical component habitats (C1 to C5), other habitats types that support/contribute to the site's wetland values include:

- Type E - Sand, shingle or pebble shores – along foreshores of the Gippsland Lakes Coastal Park
- Type F - Estuarine waters – within the larger lakes and at Lakes Entrance channel
- Type L - Permanent inland deltas – associated with the Mitchell Delta
- Type M - Permanent rivers, streams or creeks – associated with the lower parts of the Nicholson, Latrobe, Avon, and Perry Rivers that are within the boundaries of the site.

These wetland habitats contribute to the ecological character of the site but do not support critical processes such as bird breeding, critical component species and groups or critical services/benefits to the extent of the other critical component habitats. For this reason, they are seen as supporting components.

3.5.2 Other Wetland Fauna

Fish

The fish community within the Gippsland Lakes Ramsar site is diverse, with approximately 179 species inhabiting all of the Lakes' wetland types except for the most hypersaline wetlands. The marine subtidal aquatic beds wetland type is particularly important to many species of fish as a nursery area.

Key fish species of commercial significance include: yellow eye mullet, black bream, tailor, river garfish, estuary perch, Australian anchovy, dusky flathead, luderick, Australian salmon, silver trevally, leatherjackets and sea mullet. Key species of recreational significance include dusky flathead and black bream, as well as snapper, whiting, squid and prawns.

The high diversity of fish assemblages reflects in part the 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 are also likely to maintain fish biodiversity values. It is suspected that the increased influence of saline waters due to permanent opening of the lakes system has dramatically altered fish communities, potentially resulting in an increase in diversity associated with greater usage by marine species. 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 (Ecos unpublished).

Fish (and to a lesser extent marine invertebrate species such as crabs, prawns, squid and similar animals) are important for their inherent value and, for some species, for their value as a fisheries resource. Fish also have a significant ecological role in the Gippsland Lakes as a food source for many water-birds and marine mammals. They are keenly sought after by recreational and professional fisherman linking to the site's importance in supporting tourism and recreation activities.

Fish populations within the site contribute to its ecological character but have been addressed as a critical service/benefit (refer Critical Service-S2), 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.

Aquatic invertebrates

The aquatic invertebrate fauna of the Gippsland Lakes has been little studied. The composition of invertebrate fauna is greatly influenced by the physical conditions in the local habitats in which the animals live. Within the lakes and fringing wetland areas, the key physical factors determining the types of invertebrate fauna present are most likely to be salinity, depth, sediment particle size, water velocity and habitat structure. Biological processes, most notably competition, predation and recruitment success, are also likely to exert a strong influence on patterns in community structure in space and time.

Invertebrates play an integral part in the function of aquatic ecosystems including supporting or forming the basis of food chains (including those supporting commercial fisheries), cycling of nutrients, the breakdown of plant matter and other detritus, provision of habitat for other species (for example, sessile colonial forms such as sponges and ascidians), regulating populations of other organisms by predation, parasitism, or grazing, and helping to maintain water quality by filtering water during feeding.

Aquatic invertebrates have been selected as a supporting component instead of a critical component on the basis of a lack of quantifiable information about the group across the range of wetland environments within the site.

3.6 Critical Processes

A broad range of ecosystem processes are occurring within the Gippsland Lakes. Within the Gippsland Lakes, many of these processes are highly interlinked such as, for example, the relationship between increased rainfall, catchment inflows and the resultant runoff affecting water quality and triggering of algal blooms. Those ecosystem processes that are considered to most strongly influence the ecological character of the site have been described below.

3.6.1 Critical Process 1 - Hydrological Regime

Reasons for selection as 'critical'

The Gippsland Lakes Ramsar site's hydrological regime can be separated into:

- surface freshwater inflows
- groundwater inflows and influences
- marine in-flows (from Bass Strait at Lakes Entrance).

Each of these aspects of the hydrological regime are considered to be critical 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

A description of each of the aspects of the hydrological regime and how they affect the ecology of the Gippsland Lakes are outlined in the following sub-sections.

3.6.1.1 *Freshwater Inflows (surface hydrology)*

The hydrological record demonstrates that riverine in-flows into the Gippsland Lakes demonstrate both high inter-annual and intra-annual variability. Each of the inflowing rivers contributes freshwater with different volumes, timing and duration and quality to different parts of the Gippsland Lakes system (Tilleard et al. 2009).

Stream flow exhibits significant seasonal trends, with higher flows in winter-spring (August-September-October) and lower flows occurring in late summer - autumn.

For the Gippsland Lakes Ramsar site, this high degree of variability means that the lower estuaries of the rivers and the lakes/lagoons receive a seasonal signature of freshwater inputs, which can provide important lifecycle triggers for various species.

In general the connections between the main rivers and the Gippsland Lakes are as follows:

- Tambo River (principally flows into Lake King)
- Mitchell River (principally flows into Lake King)
- Thomson River (principally flows into Lake Wellington)
- Latrobe River (principally flows into Lake Wellington)
- Merrimans Creek (can flow into the western end of Lake Reeve at times of high flow).

Superimposed over the background of the seasonal cycle of flows, the system experiences occasional large fresh and flooding flows. The high flow events can “flush” the estuarine sections of the rivers, making them completely fresh, and introduce large volumes of freshwater, sediment, nutrients and other pollutants into Gippsland Lakes. While these high flow and flood events have a moderate duration (a few days to one to two weeks), the poor flushing of Gippsland Lakes means there is significant opportunity for the pollutants associated with flood events to be retained in the Gippsland Lakes system for extended periods (several months to years).

In providing a historical context of hydrological processes since the time of site listing, Figure 3-6 shows the total annual discharge (in megalitres) from major rivers within the Gippsland Lakes catchment from 1976-2009. Figure 3-7 and Figure 3-8 show annual discharges from individual major western and eastern rivers, respectively.

When compared against rainfall records (refer Figure 3-9) over the same period (noting that two rainfall gauging sites have been used to provide a complete data set over that time period and do not include all the relevant catchment areas of the Lakes), there is a reasonable correlation between rainfall and inflows, particularly in major rainfall events such as that most recently experienced event in 2007-2008.

As shown by these graphs, the overall trend for inflows into the Gippsland Lakes are heavily influenced by rainfall, and in particular the overall declines in inflows over the past decade into the site corresponds with the prolonged period of below average rainfall over the past 13 years (State of Victoria 2010).

Notwithstanding, the anthropogenic influences on the hydrology and freshwater inflows into the Gippsland Lakes can also be significant in some rivers, notably the Latrobe and Thomson/Macalister

Rivers. Figure 3-10 (appended from Tilleard et al. 2009), shows the average annual discharge and surface water extraction from the major rivers entering the Gippsland Lakes system. The flow data is averaged for the period 1965 to 2003 noting the listing date for the Ramsar site would be in the middle of this data range in 1982.

Overall, at the current time, about 20 per cent of the available average annual riverine discharge to the Gippsland Lakes is extracted as surface water for agricultural, industrial and domestic purposes before it reaches the lakes. As identified above, river regulation and extraction of water is greatest for the western rivers Latrobe and Thomson (95 per cent of total extraction), while flows into the eastern rivers are largely unregulated and average annual extraction represents a significantly smaller proportion of flows.

Numerous environmental flow studies of the western tributaries of Gippsland Lakes were undertaken in the 1990s and early 2000s (refer Earthtech 2003; Gippel and Stewardson 1995). Reduced freshwater flows were also discussed as part of the Environment Audit for the Gippsland Lakes (refer CSIRO 1998), noting river regulation and water extraction in the major Gippsland catchments had changed the variability of water residence times in the Lakes by cutting down on the high flows and reducing flows during drier periods. The Audit noted that this effect has been exacerbated by longer term decline in rainfall since the 1950s leading to 'markedly reduced run-off entering the Lakes (CSIRO 1998).

The Victorian Government's White Paper (refer Victorian Government 2004) sought to respond to these issues by determining new procedures for setting the environmental water reserve (EWR) for the river systems. In particular, for the Thomson/Macalister and Latrobe systems, it noted that these river basins are fully allocated and the EWR needs to be enhanced as a high priority. The EWR would be set for these systems by capping consumption and a moratorium on new diversions was applied until the EWR was put in place.

At the time of preparation of this report, there has been a further response to achieving a balance between consumptive use and EWR through the Draft Gippsland Regional Sustainable Water Strategy (State of Victoria 2010). The Strategy aims to identify and understand potential challenges for water management and opportunities to secure water resources for the next 50 years. The draft Strategy indicates that the Government will protect Gippsland Lakes by:

- Managing the freshwater needs of the high value fringing wetlands, river estuaries and Jones Bay by:
 - placing precautionary caps on winter surface water diversions from the Mitchell, Tambo and Nicholson Rivers
 - identifying opportunities for improved environmental flows through the development of local management rules on these rivers
 - actively managing the environmental water needs of fringing wetlands along the lower Latrobe, including Sale Common, Dowd and the Heart Morass.
- Continuing to invest in catchment management activities that have a significant impact on water quality within the lakes system.

- Monitoring and undertaking further research on the condition of the lakes to ensure management activities continue to be effective in protecting the lakes' high environmental and social values.
- Implementing improved governance arrangements (State of Victoria 2010).

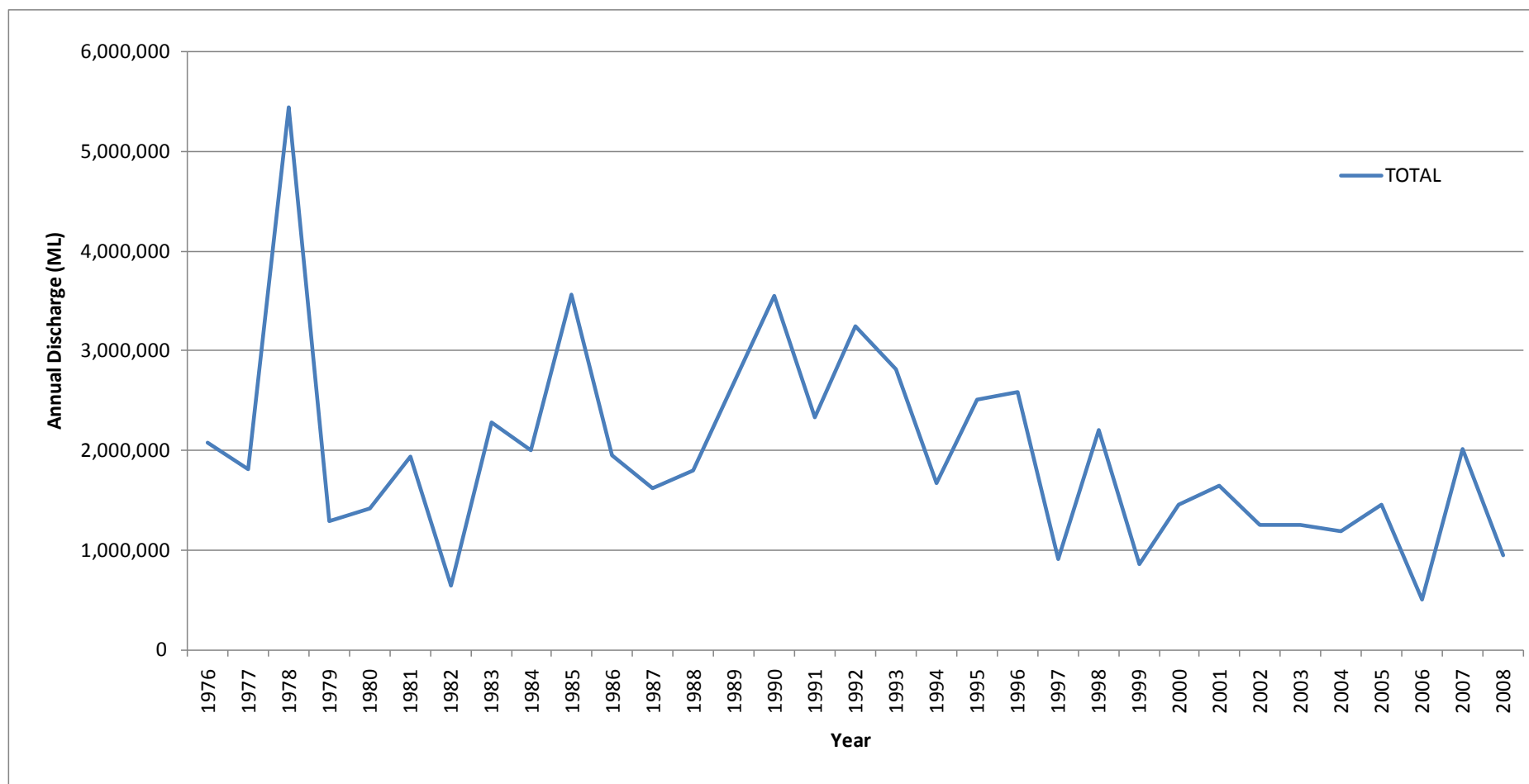


Figure 3-2 Annual total discharge from major rivers into Gippsland Lakes since 1976

Data taken from the Victorian Water Resources Data Warehouse – accessed 29th July 2009. <http://www.vicwaterdata.net/vicwaterdata/home.aspx>

Note that the time of listing of the Ramsar site is 1982.

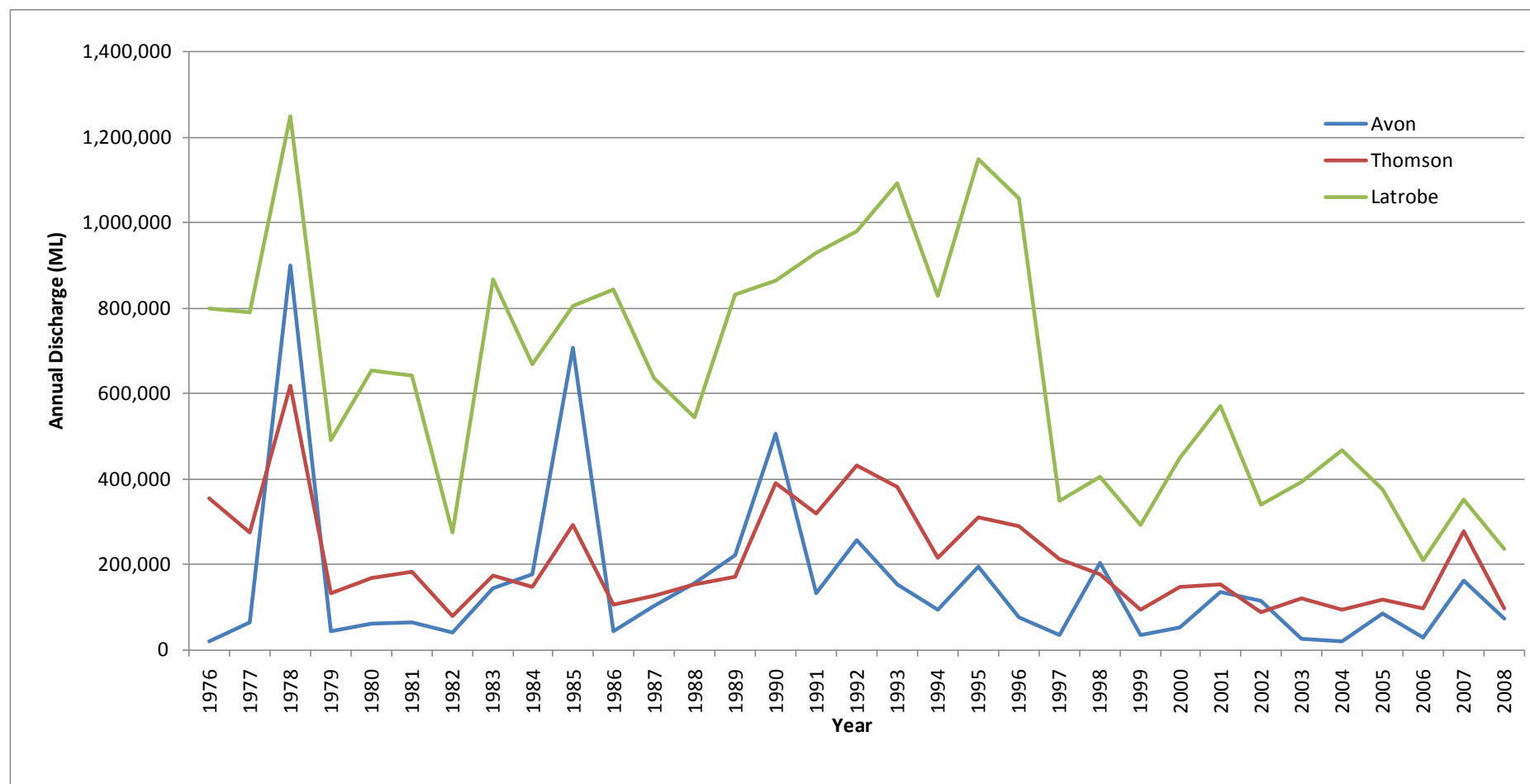


Figure 3-3 Annual discharge from major western rivers into Gippsland Lakes since 1976

Data taken from the Victorian Water Resources Data Warehouse – accessed 29th July 2009. <http://www.vicwaterdata.net/vicwaterdata/home.aspx>

Note that the time of listing of the Ramsar site is 1982.

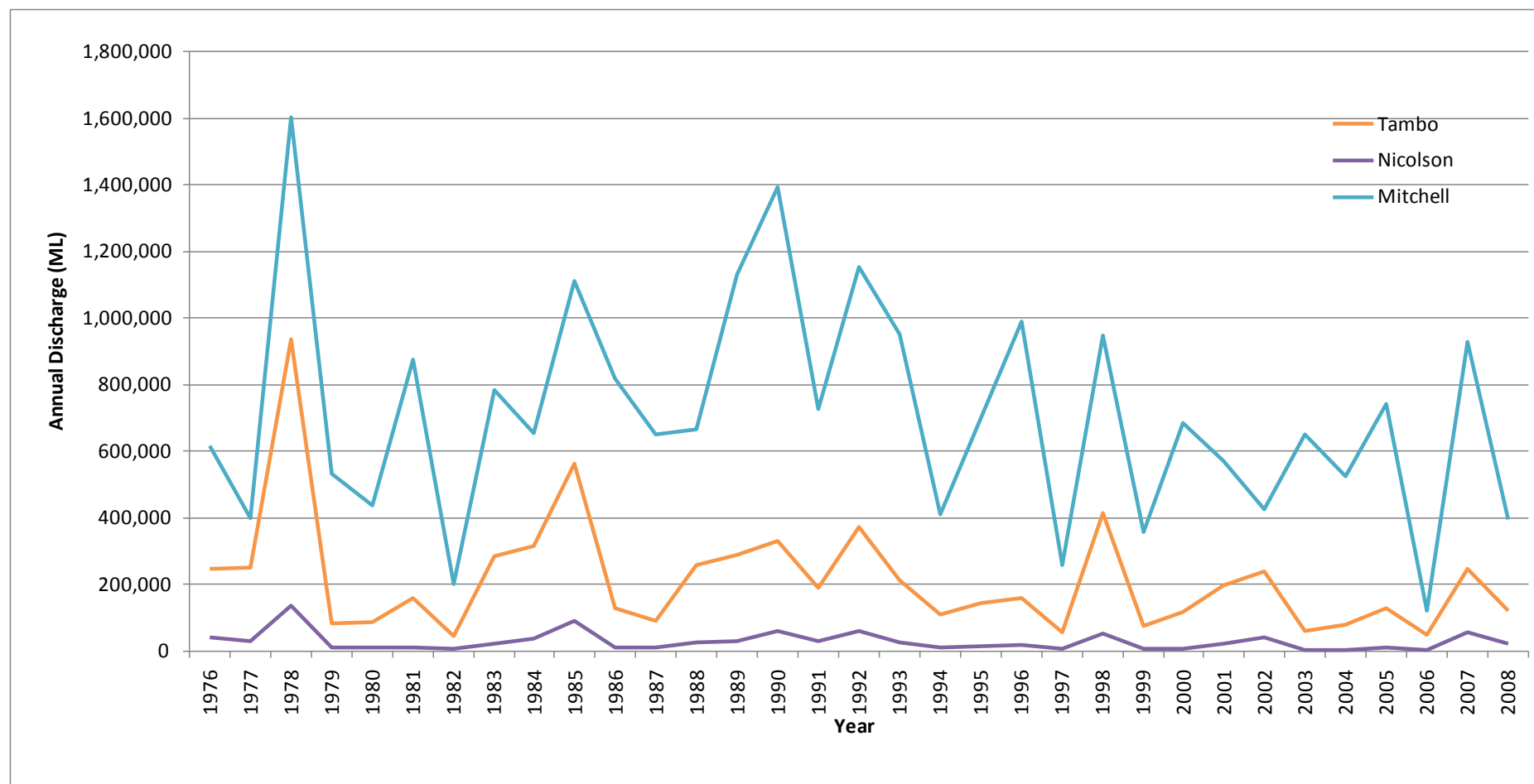


Figure 3-4 Annual discharge from major eastern rivers into Gippsland Lakes since 1976

Data taken from the Victorian Water Resources Data Warehouse – accessed 29th July 2009. <http://www.vicwaterdata.net/vicwaterdata/home.aspx>

Note that the time of listing of the Ramsar site is 1982.

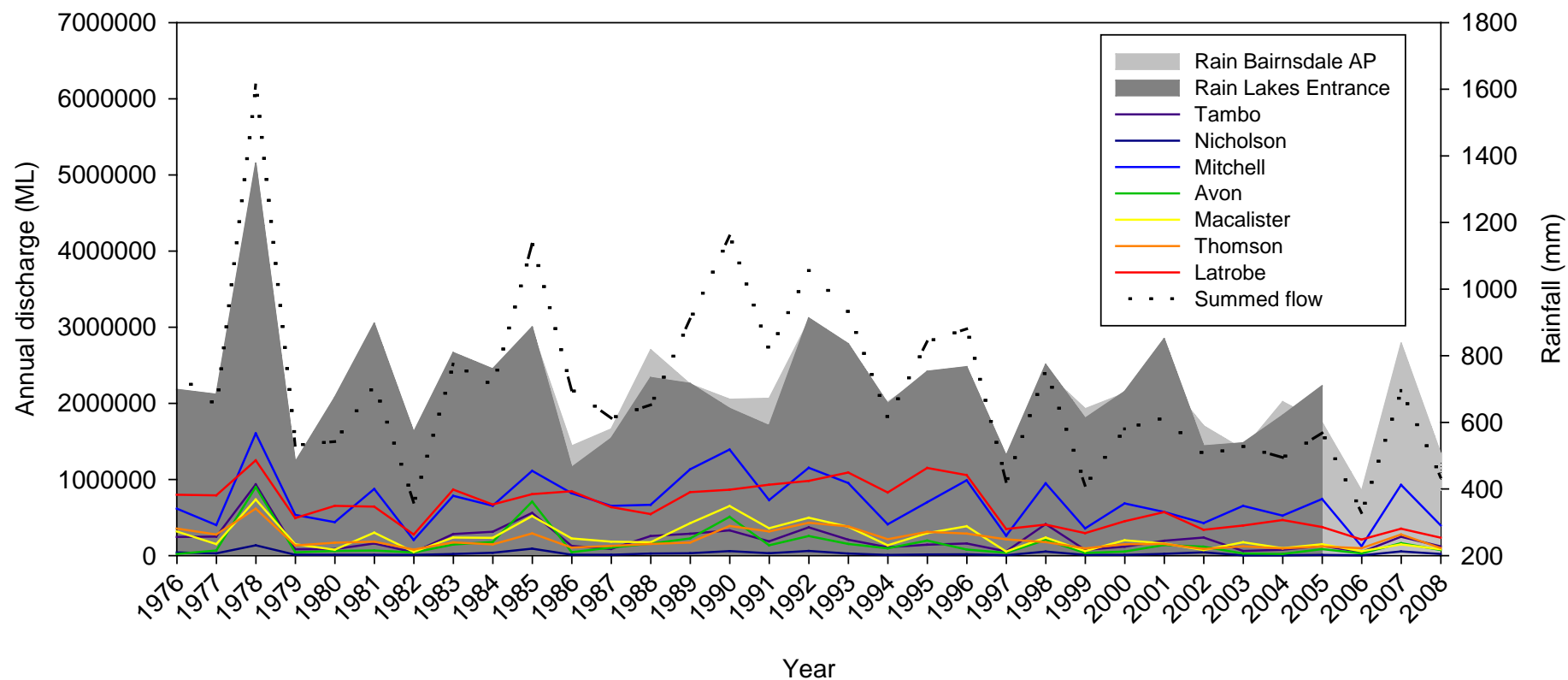


Figure 3-5 Annual discharge from major rivers into Gippsland Lakes since 1976 correlated against rainfall data

Notes:

- The time of listing of the Ramsar site is 1982.
- Data from rainfall gauges at Bairnsdale and Lakes Entrance may not be entirely representative of rainfall in the catchment areas of the Gippsland Lakes but demonstrates a reasonable correlation with inflows.

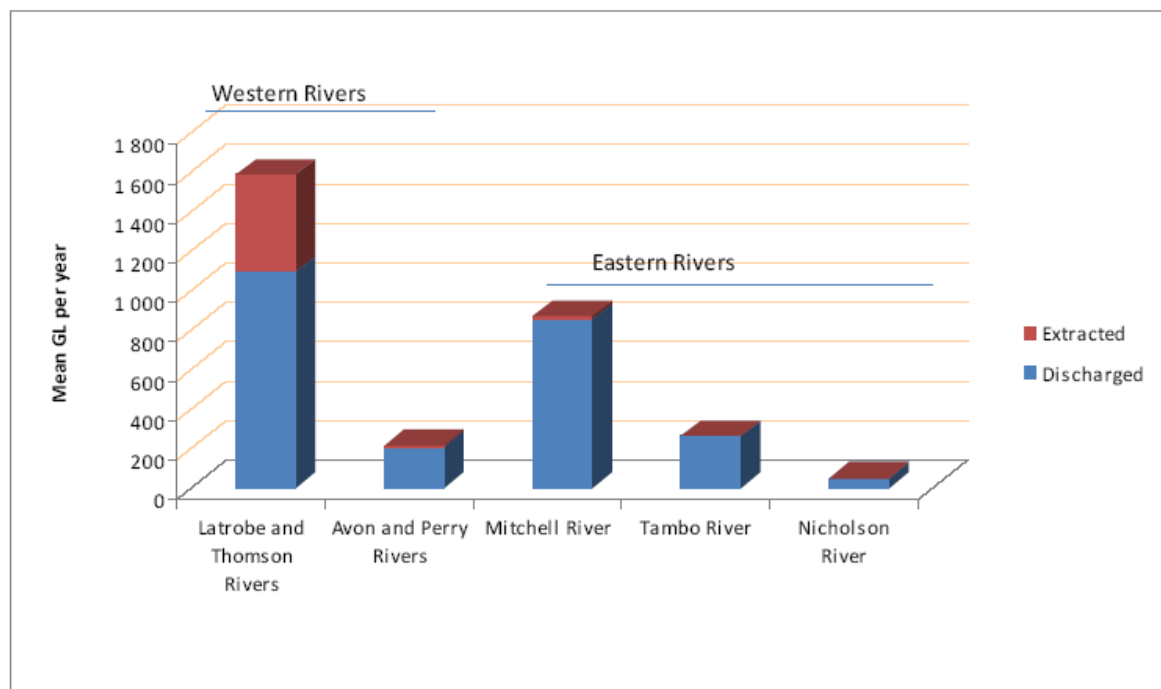


Figure 3-6 Average annual discharge and surface water extraction from the major rivers entering the Gippsland Lakes system. The flow data is for the period 1965 to 2003 (from Tilleard et al. 2009)

In the context of the draft Sustainable Water Strategy, a snapshot of the annual extent of water use (in terms of surface water extraction, groundwater extraction and recycled water use) compared to annual total water resource available for each of the five major rivers flowing into the Gippsland Lakes is provided in the Victorian Government's *State Water Reports/Accounts* (refer Victorian Government 2005, 2007 and 2010).

Data from these reports is presented in Figure 3-11 to Figure 3-14, and Table 3-4 below summarises all EWR that have been set for the Rivers (including updated provisions from the Gippsland section of the draft Water Strategy - see State of Victoria 2010).

Table 3-5 Environmental Water Reserves for river basins that influence the site (Victorian Government 2005, 2007 and 2010; State of Victoria 2010)

River name	Environmental Water Reserve (EWR)
Tambo	<ul style="list-style-type: none"> • Passing flows released as a condition of consumptive bulk entitlements held by East Gippsland Water • Water set aside for the environment through the operation of licensed diversions in passing flow conditions • Two gigalitre cap on new consumptive allocations (under review) • All other water in the basin not allocated for consumptive use
Mitchell	<ul style="list-style-type: none"> • Passing flows released as a condition of consumptive bulk entitlements held by East Gippsland Water • Water set aside for the environment through the operation of licensed diversions in passing flow conditions • Two gigalitre cap on new consumptive allocations (under review) • All other water in the basin not allocated for consumptive use
Thomson/ Macalister	<ul style="list-style-type: none"> • A bulk entitlement for the environment of 10 000 megalitres (gazetted in August 2005); an additional 8000 megalitres is proposed from water saving efficiencies by 2012 • 8100 megalitres of entitlement for the environment is proposed for the Macalister River (State of Victoria 2010) • Water set aside for the environment through the operation of passing flows released as a condition of consumptive bulk entitlements held by Melbourne Water and Southern Rural Water • Water set aside for the environment through the operation of licensed diversions in passing flow conditions • All other water in the basin not under entitlements
Latrobe	<ul style="list-style-type: none"> • Water set aside for the environment through the operation of passing flows released as a condition of consumptive bulk entitlements held by Gippsland Water, Southern Rural Water and Power Authorities • Water set aside for the environment through the operation of licensed diversions in passing flow conditions • All other water in the basin not under entitlements
Merrimans Creek	<ul style="list-style-type: none"> • Water set aside for the environment through the operation of passing flows released as a condition of consumptive bulk entitlements held by Gippsland Water • Water set aside for the environment through the operation of licensed diversions in passing flow conditions • All other water in the basin not under entitlements

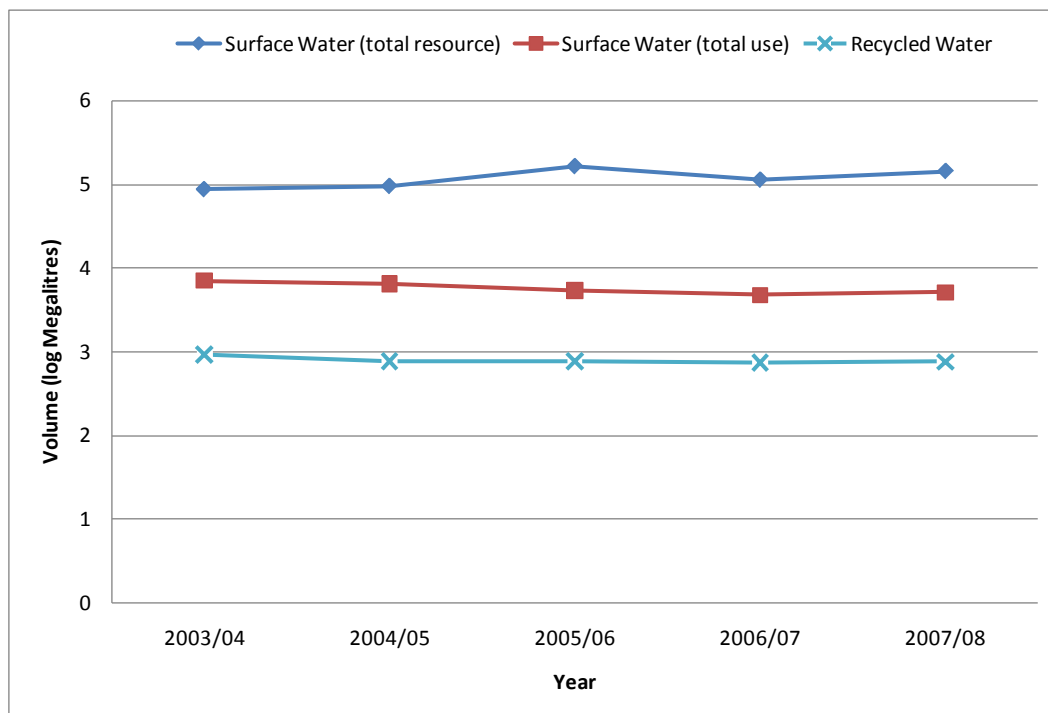


Figure 3-7 Water resource and water use within the Tambo basin over a five year period

Data obtained from Victorian Water Accounts, Our Water Our Future <http://www.ourwater.vic.gov.au/monitoring/accounts>

Notes: Recycled water total resource and total use were equal. There are no groundwater management areas or water supply protection areas within the Tambo basin.

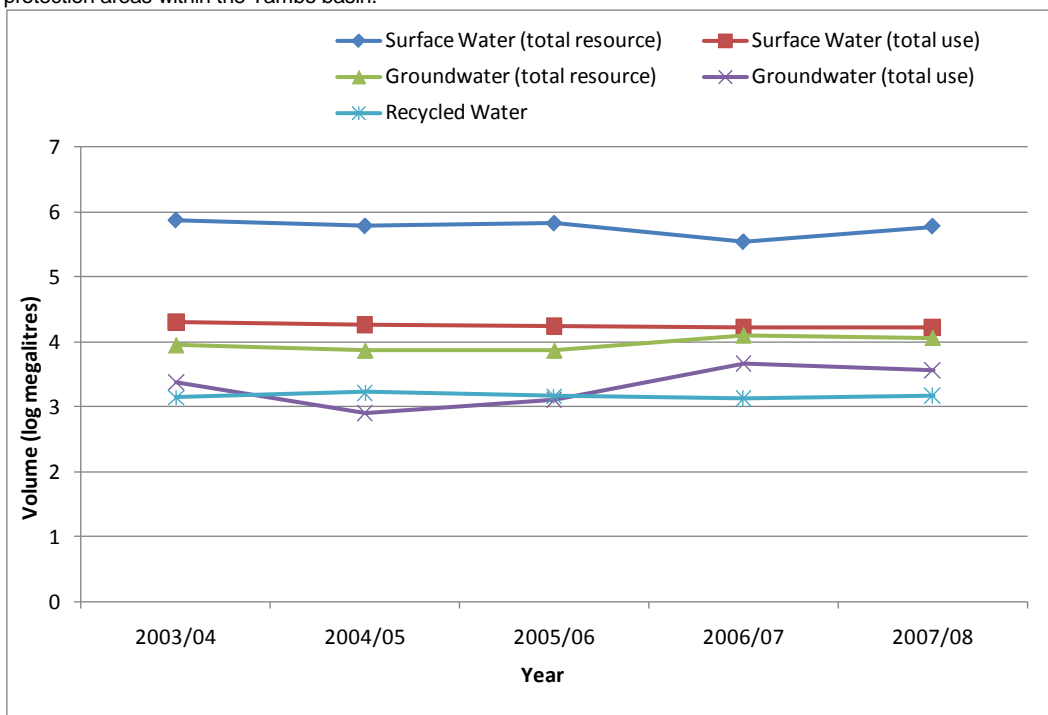


Figure 3-8 Water resource and water use within the Mitchell basin over a five year period

Data obtained from Victorian Water Accounts, Our Water Our Future <http://www.ourwater.vic.gov.au/monitoring/accounts>

Notes: Recycled water total resource and total use were equal.

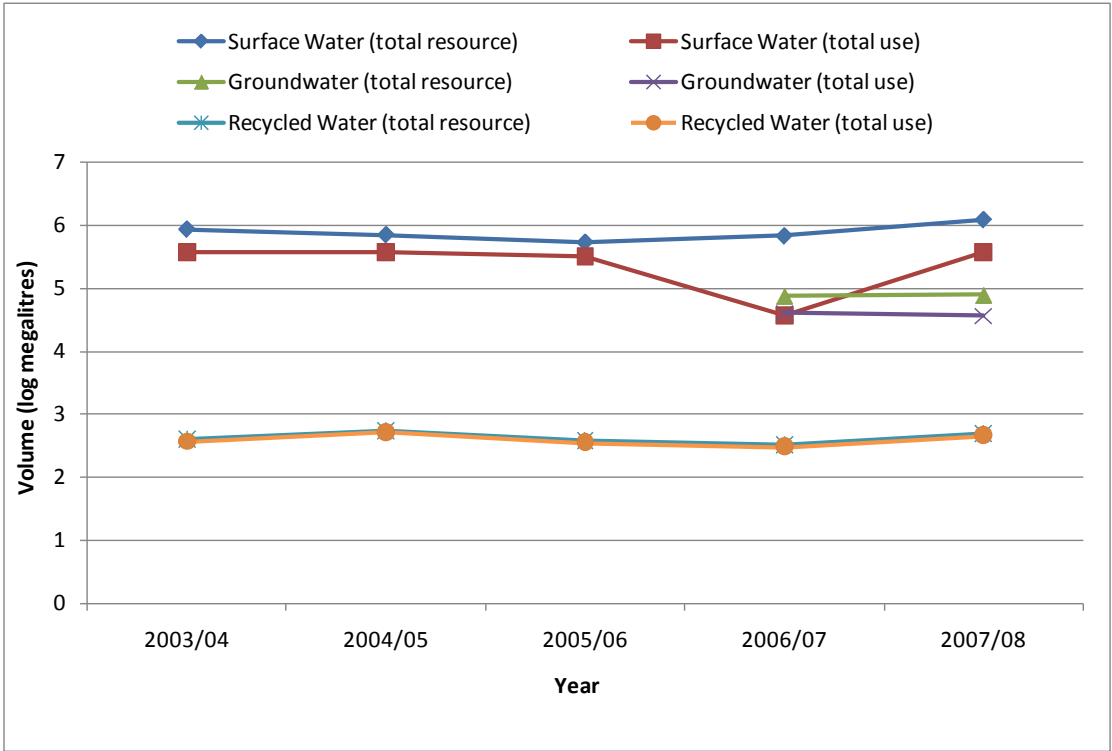


Figure 3-9 Water resource and water use within the Thomson basin over a five year period

Data obtained from Victorian Water Accounts, Our Water Our Future <http://www.ourwater.vic.gov.au/monitoring/accounts>

Notes: Data for groundwater total resource and total use were not available for the first three years.

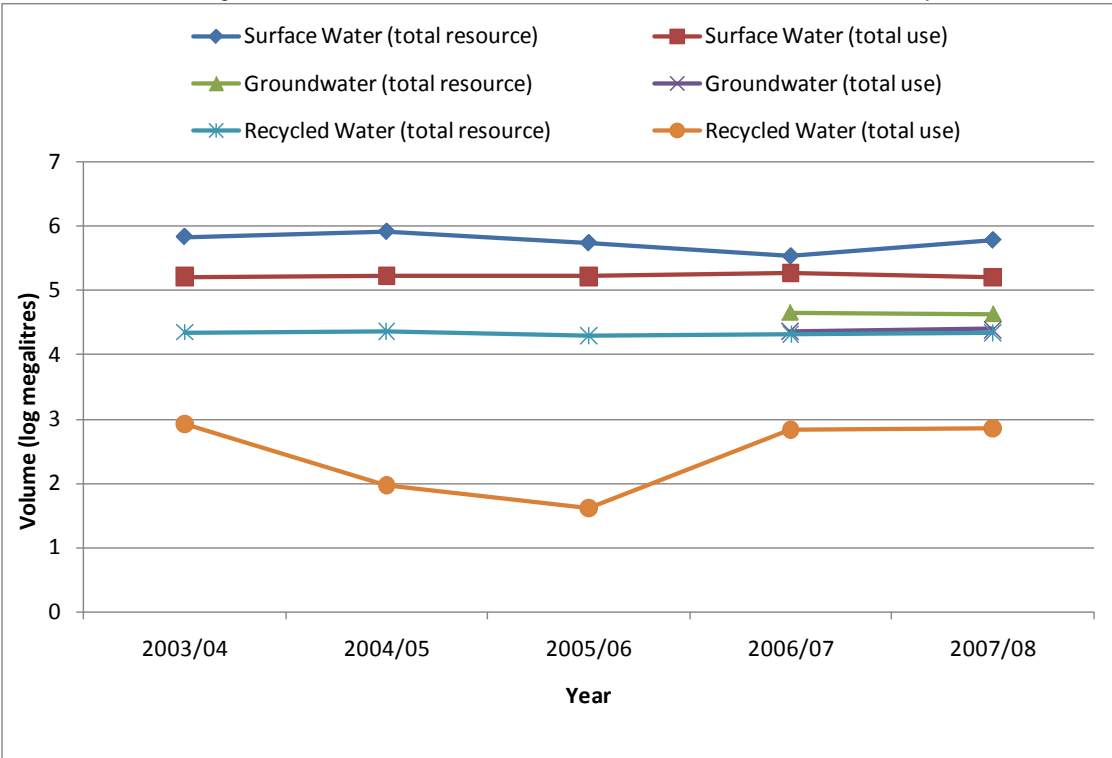


Figure 3-10 Water resource and water use within the Latrobe basin over a five year period

Data obtained from Victorian Water Accounts, Our Water Our Future <http://www.ourwater.vic.gov.au/monitoring/accounts>

Notes: Data for groundwater total resource and total use were not available for the first three years.

3.6.1.2 Groundwater

In terms of groundwater processes, it is difficult to quantify groundwater flows to and from the Gippsland Lakes lagoons and associated fringing wetlands due to the large uncertainty in aquifer permeability, aquifer thickness and groundwater gradient (SKM 2009). No direct calculation of groundwater/surface water interactions has been undertaken for the whole of the Gippsland Lakes. However, in some wetland areas within the site (Clydebank Morass, Dowd Morass) calculated groundwater inflows have been derived based on modelling studies.

The lower estuarine reaches of the rivers discharging into Gippsland Lakes are likely to be the predominant groundwater discharge features with the volume of groundwater discharge into the river dependent on the relative elevation of the river and nearby water table (SKM 2009).

The water table can become artificially elevated as a result of a combination of land clearing and irrigation resulting in land and wetland salination particularly in western catchments (SKM 2009). In particular, high groundwater salinity has been recorded in Clydebank, the Heart and Dowd Morasses. Rising saline groundwater tables can directly increase the salinity of wetlands through seepage and indirectly through run-off of salinised land. If salts entering a wetland via groundwater are not periodically leached from the soil, salts will accumulate over time. Leaching can occur laterally via surface flow or vertically via groundwater recharge. In groundwater discharge zones, the hydraulic gradient may not allow surface water to drain away as groundwater, hindering the leaching of salts into the groundwater table. Intermittently-flooded wetlands can be at particular risk from salinisation because of increasing salt concentration during drawdown (Boon *et. al.* 2008). Groundwater inflows with high nutrient loads may also be affecting the water quality of coastal lagoons of Gippsland Lakes in the context of the stimulation of algal blooms.

While there remains considerable uncertainty about the nature and effects of groundwater processes, the available studies on groundwater influences on the wetlands of the site have generally found that (SKM 2009):

- Inflows are small in comparison to the equivalent surface water inflows.
- The underlying aquifer is responsive to climate patterns with the water table rising and falling with rainfall.
- In periods of reduced rainfall and drought, there is lower groundwater discharge to the wetlands of the Gippsland Lakes.

3.6.1.3 Marine In-Flows

As already discussed, the Gippsland Lakes are connected to the ocean (Bass Strait) by a narrow, maintained man-made channel at Lakes Entrance. As a result, mean water level in Lake King and Lake Victoria correlates with the mean water level in Bass Strait on moderate time scales (one week or more). These variations are in response to the effect of longer period changes in atmospheric pressure or storm events on water level. The resulting longer term variation in water levels dominates the observed pattern of water level variation throughout the lakes and can result in mean water level variations within the lakes of ± 0.2 m about mean sea level.

Mean ocean levels in Bass Strait have a much greater influence of water levels in the lakes than ocean tidal variation. During large ocean surge events in Bass Strait the lakes respond with variations in mean water level up to 1.0 m. These variations in mean sea level typically occur over periods of a week or more. Additionally, wind setup across the lakes can also have a significant influence on local water levels, and is the main driver of internal circulation processes. In this context, the water level in the lakes can vary locally over a range greater than the observed tidal range which is strongly attenuated across the relatively narrow Lakes Entrance (McInnes et al. 2006).

3.6.1.4 Hydrological Regime Influence on Ecology

The ecological values of Gippsland Lakes are strongly influenced by the variable salinity regime that exists across the system. As described above, Lakes Entrance provides a permanent connection to the sea which, together with the variable freshwater flow regime, creates a highly dynamic salinity regime across the site and over time. This variable salinity regime controls a number of natural ecological patterns and processes including:

- The distribution, community structure and condition of vegetation communities associated with the fringing wetlands.
- The distribution, condition and community structure of submerged aquatic plants.
- Patterns in fish community structure and key processes controlling fish populations, including availability of suitable habitat, food supplies and the continued existence of life cycle cues for successful recruitment.
- The extent and strength of water column stratification in the main lakes and associated algal bloom production.
- The risk of invasion by exotic pest and animal species.

The ecology of the Gippsland Lakes is not just dependent on the annual volume of freshwater inflows but on the frequency, duration, timing and magnitude of inflows. The Environmental Water Requirements (EWR) study being undertaken for the Gippsland region (refer Tilleard et al. 2009 - Stage 1 report) outlines a summary of flow requirements, flow components and their functions for various habitats of the Lakes system. These can be summarised as:

- Main Lakes/Lagoons – Freshwater flows in to the lagoons stimulate ecological responses by providing organic material, nutrients and sediments. In-flows that reduce salinity will benefit fringing wetlands such as reed beds, and the variability will create a desirable environment for estuarine fish and limit the incursion of marine specialists in the lakes. Flows into the lagoons drive sediment and water column phytoplankton blooms as well as influence benthic algae, seagrasses and fundamental biological processes such as rates of primary production and decomposition. These are discussed further below in relation to water quality and biological processes.
- Fringing Wetlands – The ecological condition of these wetland areas is closely linked to influxes of freshwater, which under natural conditions predominantly occur in Spring. Both wetting and flushing flows are needed to maintain vegetation and habitat values with dry periods of several months desirable about every three to five years. Such dry periods are required to prevent tree

death from waterlogging and facilitate decomposition of accumulated organic matter, thereby making it available for uptake on re-wetting.

- Estuarine River Reaches - Annual flow in these areas drives the average extent and location of the salt wedge and has impacts on average lake salinity. This promotes breeding and recruitment of fish species such as black bream and is likely to have an impact on fringing plant communities, particularly freshwater species such as common reed. Likewise, flow pulses will drive variations in extent and position of the saltwedge within the waterways, also promoting breeding and recruitment by black bream and other estuarine fish species and the extent and distribution of fringing wetland plant communities.

In considering the relative sensitivity of different wetland habitat types to the hydrological regime, Tilleard et al. (2009) sought to identify priorities within the system. Table 3-6 (adopted from Table 10 of Tilleard et al. 2009) indicates that the ecology of predominantly freshwater and brackish fringing wetlands, the shallow lakes (such as Jones Bay) and the estuarine reaches of the rivers are critically affected by hydrological flows.

Table 3-6 Relative priority of wetland habitats when considering environmental flow requirements (appended in a modified form from Tilleard et al. 2009)

Wetland Habitat Type		Priority	Comment
Fringing wetlands	Freshwater wetlands	Very high	Wetting flows and flushes are known to be vital to wetland condition. Wetland condition is a crucial contributor to the overall value of the lakes system. Ecologically important flows are in the range that is significantly affected by river regulation.
	Variably saline (brackish) wetlands	Very high	
	Hypersaline wetlands	Moderate	Freshwater inflows are an important contributor to the condition of hypersaline wetlands but generally at a magnitude not significantly impacted by river regulation and diversion.
Main lakes/lagoons	Deep lakes	Moderate	Salinity from the entrance dominates environmental condition. Except for step climate change, deep lakes are likely to be relatively insensitive to likely changes in inflows.
	Shallow lakes: Jones Bay	High	The ecological condition of Jones Bay is vulnerable to changes in freshwater inflows. Jones Bay is in relatively good condition and is important to the value of the lakes system because it provides high quality fish and waterbird habitat.
	Shallow lakes: other	Moderate	Lake Wellington is important to the condition of its fringing wetlands however the lake has undergone a significant change in state which diminishes its value in the overall lakes system. The change is thought to be irreversible without dramatic intervention. Salinity from the entrance dominates the environmental condition of the remaining shallow lakes (North Arm and Cunninghame Arm). The median salinity of the Lake has also increased from about 4.6 to 8.1 ppt (~76per cent increase) as a result of reduced inflows as a result of existing river regulation and diversion.
Estuarine reaches of rivers		High	The length and location of the halocline is dominated by freshwater flows. Length and location of the halocline are thought to be important for fish breeding and for condition of bank vegetation and hence stability of estuarine reaches. The range of flows that are heavily impacted by river regulation and diversion have a strong physical and ecological influence on the estuarine river reaches.

The EWR study has also sought to define indicative thresholds for ecological conditions, which have been defined for:

- The fringing wetlands of Lake King and Lake Wellington (refer Table 4 within Tilleard et al. 2009).
- The estuarine river reaches of the major tributaries that flow into the site (refer Table 6 within Tilleard et al. 2009).
- The main lakes/lagoons (refer Table 8 within Tilleard et al. 2009).

Each of the threshold tables outline a range of quantifiable limits or flow objectives for maintaining ecological values of particular wetland features. While these form the basis for setting empirical limits of acceptable change (LAC), more detailed modelling and historical analysis at an individual waterway and/or wetland scale would be needed to assess the extent to which the required environmental flow objectives have been achieved or not achieved over time. This analysis is outside the scope of the current study but would be useful to consider as part of future studies that are currently being contemplated as part of further implementation of the EWR study.

Stage 2 of the EWR study (Tilleard and Ladson 2010) was completed as an addendum to the Stage 1 Scoping Study in 2010, with the selection of priority areas for investigation. These included: the Latrobe – estuarine river reach and freshwater and variably saline fringing wetlands including Sale Common, Dowd Morass and the Heart Morass; the estuarine reach of the Avon River and associated wetlands; the estuarine reach of the Mitchell River, Jones Bay and Macleod Morass; and the estuarine reaches of the Nicholson and Tambo Rivers and associated variably saline wetlands.

Outputs from the Stage 2 report have been considered as part of the ECD including the setting of LAC in Section 4.

3.6.2 Critical Process 2 - Waterbird Breeding Sites

Reasons for selection as ‘critical’

The site supports habitat and conditions that are important for a variety of waterbird species at critical stages in their life cycles (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

Breeding habitat is identified within the site for a variety of waterbirds, including several species occurring in significant numbers.

Significant breeding sites within the Gippsland Lakes (based on NRE 1999a in Parks Victoria 2009; Peter Lawrence, Parks Victoria, *pers. comm.* 2010) include:

- Lake Coleman (east) and Tucker Swamp: Australian pelican (200 pairs); pied cormorants (numbers unknown but significant)
- Bunga Arm: little tern (25 pairs); fairy tern (three pairs); hooded plover (two pairs); Australian pelican (200 pairs)
- Macleod Morass: Australian white ibis (up to 300 pairs); straw-necked ibis (up to 300 pairs)
- Roseneath Wetlands: black-winged stilt (130 pairs)
- Sale Common: black swan (up to 500 pairs)
- Dowd Morass: large egret (50 pairs), little pied and little black cormorants (1000+ pairs), large black cormorants (two – 50 pairs), royal spoonbill (250 pairs); sacred ibis (1500 pairs); straw-necked ibis (1500 pairs); both rufous night heron and glossy ibis also breed in this wetland
- Lake Tyers: fairy tern (up to 40 pairs); little tern (up to 40 pairs).

Patterns in variability

There have been minimal studies to date that have sought to examine patterns and trends in waterbird breeding behaviour, frequency or success within the site. Notwithstanding, key controls on waterbird breeding usage of the site would include:

- Diversity of disturbance-free roosts and breeding sites that are spatially proximate to suitable feeding grounds (shorebirds, and terns mainly).
- Availability/quality of feeding sources such as the diversity and abundance of aquatic flora and invertebrate fauna (waterbirds generally).
- Densely vegetated permanent wetlands supporting submerged and emergent aquatic macrophytes, and fringing littoral vegetation (waterbird breeding habitat primarily, though also a key attribute for particular waterbirds as feeding habitat).

3.7 Supporting Processes

The supporting processes 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 processes. In this context:

- Supporting processes may operate over broad spatial scales and are not considered likely to be fundamentally altered by activities within the site.
- Some supporting processes are already partially covered by other critical components, processes or services/benefits.
- The supporting processes, while not critical, are important to wetland functioning and are noteworthy in this regard.

3.7.1 Climate

Reasons for selection

Key climatic processes that underpin the wetland values of the Gippsland Lakes 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

The climate of the Gippsland Lakes is temperate. In summer, the average maximum air temperature is about 24 degrees Celsius and the average minimum is 12 degrees Celsius. The average maximum temperature in winter is about 14 degrees Celsius and the minimum average ranges from three degrees to four degrees Celsius (obtained from the Bureau of Meteorology website: www.bom.gov.au).

Rainfall in the Gippsland Lakes catchment varies significantly from the coastal strip, where the lakes are located, to the upper catchment areas. This is due to the presence of the Great Dividing Ranges to the north, and the Strezlecki Ranges to the south of the Latrobe Valley. Rainfall across the site varies between 50 and 80 millimetres per month (around 700 millimetres annually) but with much higher rainfalls along the mountain ranges (situated north of the site) which affect hydrology and freshwater inflows into the site (Ecos unpublished). Rainfall is also naturally variable across the site along an east-west gradient, with more rainfall in the eastern lakes than in the western areas such as Sale Common (Paul Boon, *pers. comm.* 2009).

In general, Victoria has been subject to reduced rainfall over the past 13 years leading to drought conditions in many parts (State of Victoria 2010). Mean annual rainfall in Gippsland has also been somewhat reduced in recent years, leading to lower than normal base flows in the river systems. Murphy and Timbal (2007) undertook analysis of climate data for south-eastern Australia and conclude that during the last decade, the mean rainfall has been 14.1 per cent below the climatological (1961–1990) mean. While this should be considered part of the background variability in rainfall, the 1997-2006 drought was significant and affected flows to the Lakes.

As climate change occurs, 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.

3.7.2 Geomorphology

Reasons for selection

The geomorphology of the site underpins the diversity of wetlands types and waterbodies present. Geomorphological processes such as bathymetry and sediment transport are an important determinant of habitat structure and associated flora and fauna communities that use the site. Maintenance of these natural geomorphological processes are important for ensuring the biotic values of the Ramsar site can be maintained over time.

Description

Gippsland Lakes is a system of coastal lagoons sheltering behind sandy barriers. The present coastal morphology has taken shape since the Late Pleistocene. Three barriers were recognised by Bird (1961). These include a 'prior' barrier that stands to the north of the Lakes beneath the former sea cliff, an 'inner' barrier that occurs north of Lake Reeve and an 'outer' barrier that lies to seaward (includes Ninety Mile Beach). Each barrier is surmounted by beach ridges and dunes. Development and maintenance of this landform is promoted by small tidal ranges, abundant sand supply, and very slow or no relative sea level change (Bird 1967).

The system is linked to the sea by an artificial entrance near the eastern end, opened in 1889, where the town of Lakes Entrance is now situated. Saline intrusion into the system has occurred as a consequence of the permanent entrance, with the freshwater systems replaced by marine, estuarine and brackish habitats (and in some areas hyper-saline environments). Today, saline intrusion in the lakes can extend throughout the system. During periods of drought or low freshwater inflows, ocean salinity can penetrate well up into the river reaches.

The geomorphology of the site provides for a broad range of wetland/waterbody forms. These include: periodically inundated palustrine marshes; permanently inundated palustrine marshes; shallow lacustrine (lake) features; deep lacustrine features; coastal lagoons with narrow inlets; and broad embayments. The site also includes the lower reaches of several riverine environments, including a large reach of the Nicholson River which feeds into Jones Bay.

The soils within the catchment to the Gippsland Lakes are diverse, reflecting the great variety of rock and unconsolidated sediments, landforms, climates and vegetation, as well as varied ages of soil development (Aldrick et al. 1984). The soils found in the Gippsland Lakes Ramsar site are mostly relatively young and associated with dunes and Holocene sediments (Ecos unpublished).

Specific aspects of the geomorphology include bathymetry and sediment transport processes which are discussed below.

3.7.2.1 Bathymetry

The bathymetry of Gippsland Lakes is highly varied and includes shallow mudflats and sand banks that can be exposed as water levels in the lakes drop due to ocean mean sea level influences. Figure 3-15 illustrates the bathymetry of the lakes, highlighting the significant variability in depth throughout the system. Lake Wellington is quite shallow areas (two to three metres deep), as are other areas in the lakes (Jones Bay in Lake King, the western end of Lake Victoria, and between Barrier Landing and Kelly Head). The deepest areas, down to 10 – 12 m deep, occur in the central sections of Lake Victoria and Lake King (south of the Silt Jetties), and in Reeve Channel. In these deeper areas (greater than five metres), saline stratification can develop, and is considered one of the major influences on the occurrence of bottom hypoxia (low dissolved oxygen conditions) in these areas (Grayson et al. 2001, Ecos unpublished).

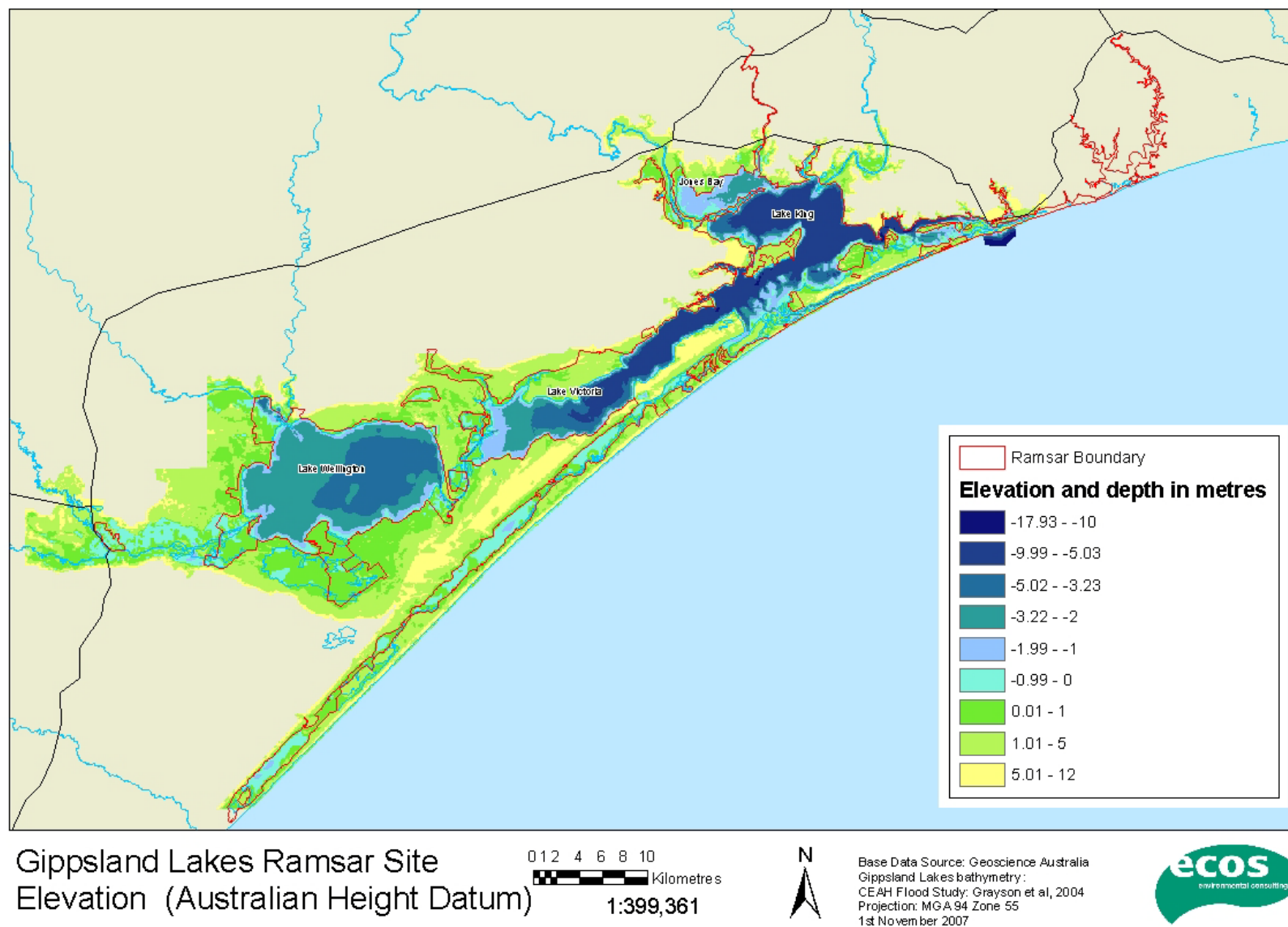


Figure 3-11 Gippsland Lakes bathymetry (after Grayson et al. 2001) reproduced from Ecos unpublished

3.7.2.2 *Sediment Transport Processes*

Marine sediment transport processes at Lakes Entrance and Lake Tyers

At Lakes Entrance sand is moved between the offshore bar and the internal channel and sand shoals of the site on a daily basis by the tide. Breaking waves cause seabed sediments to become suspended in the water and, if the tide is rising, then the tidal current will carry the water containing the suspended sediments into the lake system (Coastal Engineering Solutions 2003). On the ebbing tide a similar process occurs whereby sand is picked up from the channel between Bullock and Rigby Islands and transported out through the entrance channel. Entrainment of sand will depend on the tidal current velocities being high enough to initiate sediment motion (Coastal Engineering Solutions 2003).

Coastal Engineering Solutions (2003) estimated that the volume of sand that needs to be pumped off the bar channel system to maintain a navigable channel with a nominal depth of three metres is between 100 000 and 500 000 cubic metres per year. Based on advice from Lawson and Treloar, Jesz Flemming and Associates (2004) indicated that the mean accumulation rate was 130 000 cubic metres per year. However, the most recent estimate by Lawson and Treloar (2004) was that maintenance of the channel at a depth of three metres requires annual dredging of approximately 93 000 cubic metres during a moderate wave climate over a period of 75 days.

In Lake Tyers, deposits of fluvial sediment over time have resulted in the formation of mud banks near the mouth of the main lake, with the substrate covered by fine grained sands. Formations near the mouth of Lake Tyers also appear to have changed with deeper holes slowly disappearing and the main channel also becoming shallower (Fisheries Victoria 2007). The entrance to Lake Tyers is periodically closed by a sand bar, and may open naturally as a result of floods in the catchment.

Sediment transport processes within the Gippsland Lakes system

Sediment transport processes within the Gippsland Lakes system are not well understood, noting that landward bedload transport in the form of sand waves was observed by King (1981) in the inner channels from Lakes Entrance. Discussion in Ecos (unpublished) indicates that major flood events are likely to have sufficient power to significantly scour and redistribute coarse sediment in the channels. Wind is likely to be a key driver of sediment resuspension particularly in the more sheltered, shallow lakes.

The primary source of sediment input into the western lakes is from catchment sources. In the estuarine reaches of rivers/streams entering Gippsland Lakes, some infilling may occur following flood events but has not been identified as a major threat (Ecos unpublished).

Water quality data analysed by Grayson et al. (2001) indicate that sediment loads from the western catchments (discharging to Lake Wellington) deliver two to three times the nutrient and sediment loads than from the eastern catchments (Mitchell, Nicholson and Tambo Rivers). Total estimated loads of total suspended solids (TSS) to Lake Wellington are in the order of 165 000 tonnes per year whereas Lake King and Lake Victoria only receive 45 000 and 8500 tonnes per year respectively (Grayson et al. 2001). Lake Tyers whose estuary catchment is forested and lies within existing or proposed Forest Parks, State Forests or State Parks does not suffer the same degree of catchment erosion and sediment deposition as some other Gippsland lagoons (Fisheries Victoria 2007).

3.7.3 Shoreline and Coastal Processes

Reasons for selection

Shoreline and coastal processes influence habitat structure and vegetation communities that fringe the main lakes through natural processes of erosion or accretion. The shoreline and coastal processes of most significance to Gippsland Lakes are shoreline stability, erosion and accretion.

Description

Shoreline and coastal processes within the Gippsland Lakes have changed considerably since creation of the permanent opening at Lakes Entrance in the late 19th century. However, since listing of the site in 1982, the shorelines around the Gippsland Lakes have remained relatively stable (Sjerp et al. 2002).

Shorelines in Gippsland Lakes are influenced primarily by wave action. When the prevailing westerly winds are blowing, water levels in the eastern Gippsland Lakes will rise and in combination with wind-driven waves, will create erosion of the deltaic shoreline. By contrast, strong easterly winds will produce little shoreline erosion (Bird and Rosengren 1971). Scour of channels and the neighbouring coastline can occur during catchment flooding events as a result of current action. Floods and coastal storms also can have the effect raising water levels in the lakes, which as discussed above creates conditions favourable for shoreline wave erosion.

The presence of fringing vegetation along the margins of the lakes maintains shoreline stability as well as providing habitat for waterbirds and other wetland fauna. *Phragmites australis* once formed extensive fringing reedbeds around the Gippsland Lakes and was first noted to be in decline as early as 1922. By 1961 it became clear that die-back of *Phragmites* in Lake King, Lake Victoria and to a lesser extent in Lake Wellington was a response to the increased frequency and duration of higher salinity levels in the Lakes as a result of the permanent opening at Lakes Entrance. The initial loss of fringing *Phragmites australis* reedbeds was a marked event, giving the impression of a high erosion rate, but having receded to the backing *Melaleuca ericifolia* thickets, shoreline recession now appears less rapid, probably due to the sand/peat substrate being more robust (Sjerp et al. 2002).

Comparison of aerial photographs by Sjerp et al. 2002 (as discussed in Ecos unpublished) spanning 1935 to 1997 demonstrate that the vast majority of shorelines are eroding at an average of less than 0.1 metres per year. However, the deltas on the Latrobe, Avon, Mitchell and Tambo Rivers and on McLennan Strait all show evidence of continuing erosion as do particular locations such as Roseneath Point, Swell Point, Storm Point, Clydebank Morass and the northern shores of Jones Bay.

Evidence of shoreline accretion are reported as rare; the largest being several metres along the sandy eastern shores of Lake Wellington, north of McLennan Strait (Sjerp et al. 2002).

A range of structures including sea walls, rock rubble and timber groynes have been established to protect selected eroding areas, although the vast majority of the Gippsland Lakes shoreline remains in a natural state (Ecos unpublished).

3.7.4 Water Quality

Reasons for selection

Water quality within the wetlands of the Gippsland Lakes Ramsar site regulates the use of habitat by flora and fauna. The key parameter is salinity although dissolved oxygen, nutrients and pH are also important. Nutrients and sediments (total suspended solids and turbidity) in particular play a key role in the main lakes/lagoons in terms of production of algal blooms (see discussion on 'Nutrient Cycling' in next section).

Description

In characterising the water quality of the Ramsar site, water quality monitoring data was obtained from the EPA Victoria from five monitoring sites within Lakes Wellington, Victoria and King (Figure 3-16). The dataset consists of two main monitoring periods: (1) data from 1976 to 1980 from the Victoria State Rivers and Waters Commission (not longer existing) and (2) data from 1986 to present from the Victoria EPA fixed monitoring sites. No data exists from these five sites between 1980 and 1986. Data for catchment flow into the Gippsland Lakes was sourced from the Gippsland Catchment Management Authorities.

The periods 1976 to 1980 (pre-Ramsar listing) and 1986 to 2008 (Ramsar period) were analysed separately by calculating the minima and maxima values, and the 10th, 20th, 50th, 80th and 90th percentiles. The analysed parameters represent surface water measurements (0.5 metre water depth) and include salinity, pH, dissolved oxygen concentration, per cent saturation of dissolved oxygen, total suspended solids, total nitrogen, total phosphorus and chlorophyll *a*.

Where applicable, the calculated values were compared to the guideline values listed in Water of Victoria Schedule F3 (Gippsland Lakes and Catchment, No. S13, Gazette 26/2/1988). The guideline values listed in Schedule F3 differ between Lake Wellington and the eastern Gippsland Lakes. Schedule F3 uses minimum values, 50th and 90th percentiles as water quality objectives.

Total nitrogen, total phosphorus and chlorophyll *a* are not listed in Schedule F3 and therefore the ANZECC (2000) guideline values for southeast Australian estuarine systems were adopted for these parameters. The ANZECC guidelines use the 20th and 80th percentiles as lower and upper low-risk trigger values.

Water quality time series plots and the summed catchment flow discharging into the Gippsland Lakes is shown for Lake Wellington in Figure 3-17 and for the eastern Lake Victoria in Figure 3-18. Table 3-7 and Table 3-8 show the calculated percentiles and comparison to guideline values for Lake Wellington and the eastern Lake Victoria sites, respectively.

The patterns observed in the water quality time series for the remaining three monitoring sites were similar to the eastern Lake Victoria site and are provided in Appendix B.

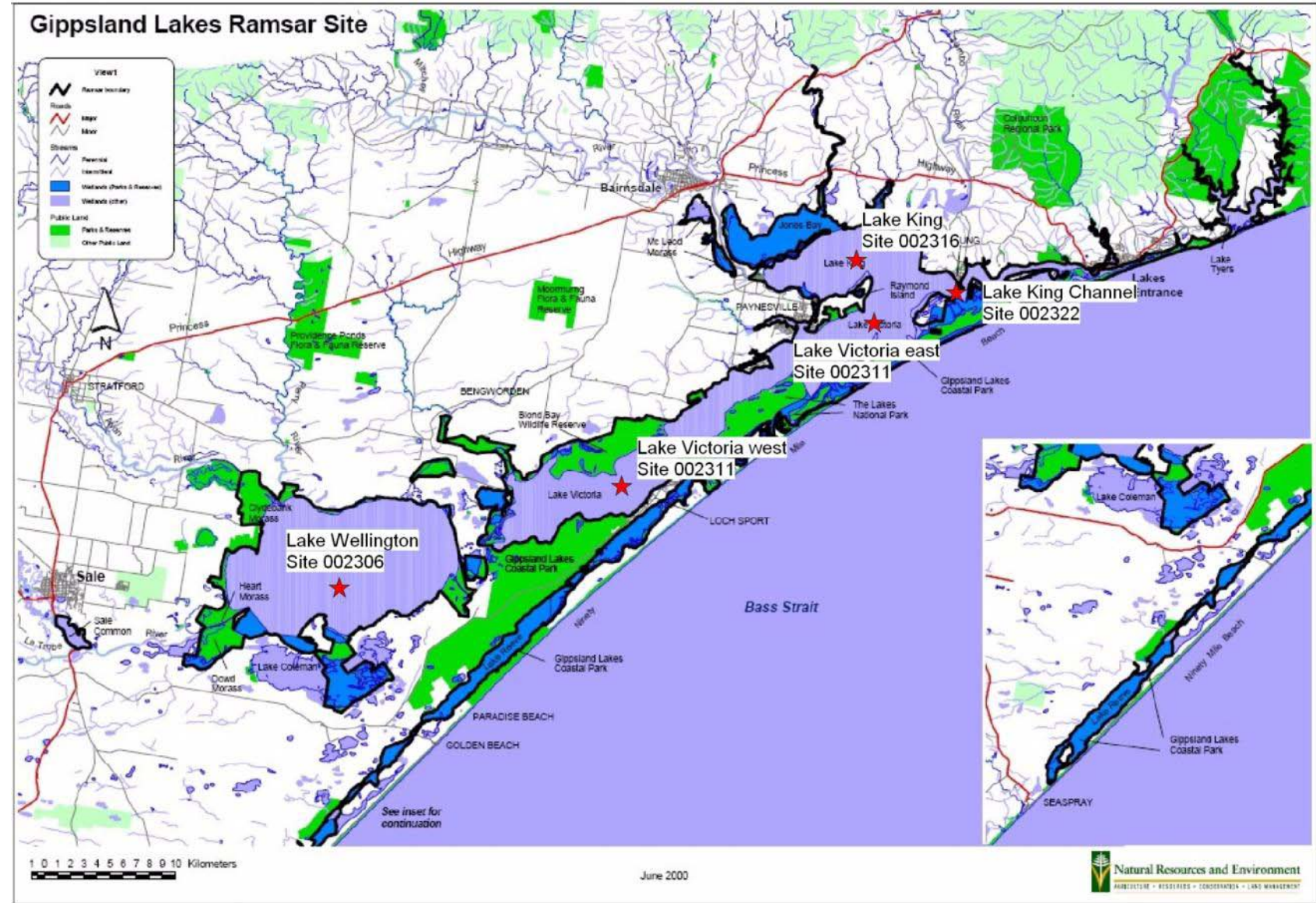


Figure 3-12 Locations of EPA water quality monitoring sites in the Gippsland Lakes (source: DSE)

3.7.4.1 Lake Wellington Water Quality

The water quality in Lake Wellington is strongly determined by flows entering the lake from the catchment (Figure 3-17). About one third of river flows in to the Gippsland Lakes and over half of the total nutrient load is supplied to Lake Wellington from the western rivers (mainly the Latrobe, Thomson and Avon Rivers). Due to these high catchment inflows and its distance from the Lakes Entrance in the east, Lake Wellington is less saline than the eastern lakes. Salinities are generally higher during years of low flow compared to lower salinities observed during high flow years (Figure 3-17). Correspondingly, increased input of sediments and nutrients during high flow years is reflected in higher concentrations of total suspended solids, total nitrogen and total phosphorus during these periods (Figure 3-17). As expected, the higher nutrient availability during high flow years ensues in higher chlorophyll *a* concentrations in the water column. Dissolved oxygen concentrations vary seasonally with higher concentrations during the cold winter months and lower concentrations during the warm summer months, most likely due to increased oxygen solubility with decreasing temperatures.

The comparison of ambient water quality against the relevant water quality guidelines from the SEPP in Table 3-7 show general conformance with the guideline values for the variables analysed noting exceedances have been observed for salinity, pH, nutrients and chlorophyll *a*. The increase in the median values of nutrients such as phosphorous over time are an indication of an increasingly eutrophied system. For further information refer Appendix B.

3.7.4.2 Eastern Lakes Water Quality

Time series of water quality parameters for eastern Lake Victoria and total catchment inflow are shown in Figure 3-18 (refer to Appendix B for time series of the other monitoring stations, including Lake King). Salinities are generally greater in the eastern lakes compared to Lake Wellington due to their proximity to the Lakes Entrance. As observed for Lake Wellington, salinities in the surface water of the eastern lakes are generally higher during years of low flow and lower during high flow years. Concentrations of suspended solids, total nitrogen and total phosphorus are not as clearly related to flow compared to observations from Lake Wellington. Dissolved oxygen concentrations generally follow a seasonal pattern with higher concentrations during the colder months due to increased oxygen solubility. Relatively low oxygen concentrations during some occasions may have been caused by mixing events with hypoxic bottom water, while particularly high oxygen concentrations may in part be attributable to high oxygen production during periods of algal blooms (Figure 3-18).

The comparison of ambient water quality against the relevant water quality guidelines in Table 3-8 show general conformance with the guideline values noting exceedances have been observed for pH, dissolved oxygen, nutrients and chlorophyll *a*. For further information refer Appendix B.

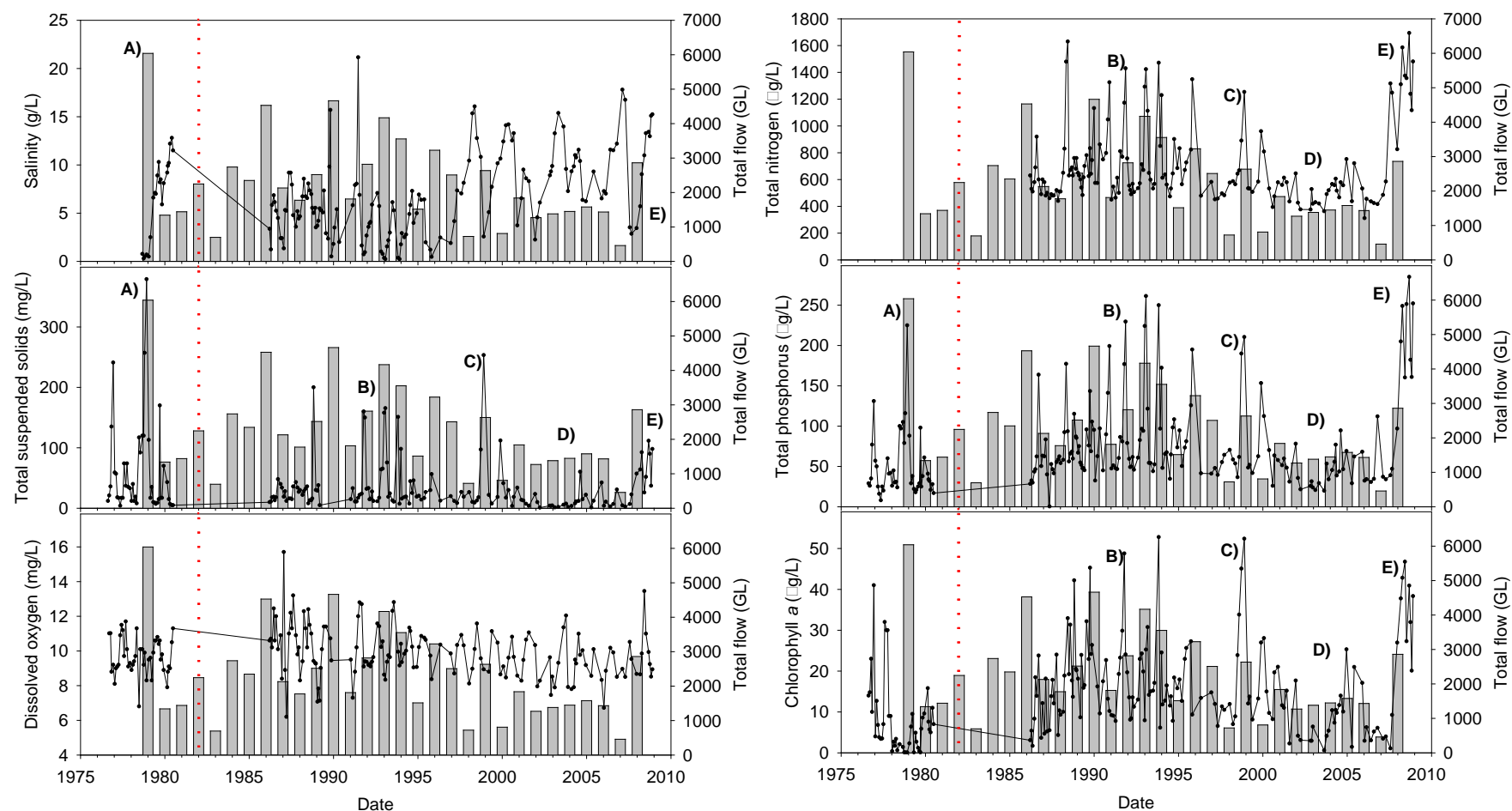


Figure 3-13 Lake Wellington surface water quality data (EPA monitoring site 002306)

Note: Total flow represents the summed flow recorded for all major catchment rivers and is given as hydrological year (June-May). Red dotted line denotes listing of Gippsland Lakes as Ramsar wetland in 1982. Refer to Appendix B for information on notable events A-E shown on the graphs.

Table 3-7 Lake Wellington surface water quality parameters and guideline values from EPA site 002306

Note: Orange and red colour represents slight and distinct exceedance of guideline trigger limits, respectively. Note that the ANZECC guideline values are representative of the broad southeast Australia estuaries and not specific to the Gippsland Lakes. It should be noted exceedance of the ANZECC Guidelines do not necessarily relate or otherwise equate to an Ecological Character Change – refer Limits of Acceptable Change in Section 4.

	Minimum		Maximum		10th percentile		20th percentile		50th percentile		80th percentile		90th percentile		Guideline	Source
	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008		
Salinity (g/L)	0.3	0.2	12.8	21.2	0.5	1.8	0.8	2.9	8.1	6.1	10.2	10.4	11.5	13.2	8	Waters of Victoria
pH	6.8	6.8	8.6	9.1	7.1	7.4	7.2	7.6	7.8	8.0	8.1	8.3	8.2	8.5	6-9	Waters of Victoria
Dissolved oxygen (mg/L)	6.8	6.2	11.7	15.7	8.5	8.3	9.0	8.7	9.6	9.7	10.6	11.0	11.1	11.6	6	Waters of Victoria
Dissolved oxygen (per cent saturation)		71.0		149.6		92.9		95.7		102.3		110.4		117.0	60	Waters of Victoria
Total suspended solids (mg/L)	4.0	0.9	379.0	253.3	7.4	4.6	11.6	10.0	21.0	18.7	96.2	39.6	129.0	74.5	25/80	Waters of Victoria
Total nitrogen (µg/L)		311.3		1693.9		451.6		490.0		587.1		830.0		1248.0	300	ANZECC
Total phosphorus (µg/L)	8.0	0.4	225.0	285.0	20.3	32.5	24.6	41.8	33.0	60.4	77.8	96.9	99.4	172.4	30	ANZECC
Chlorophyll a (µg/L)	0.1	0.6	41.0	52.8	0.2	4.2	1.4	7.8	5.7	13.8	11.3	24.0	20.1	31.2	4	ANZECC

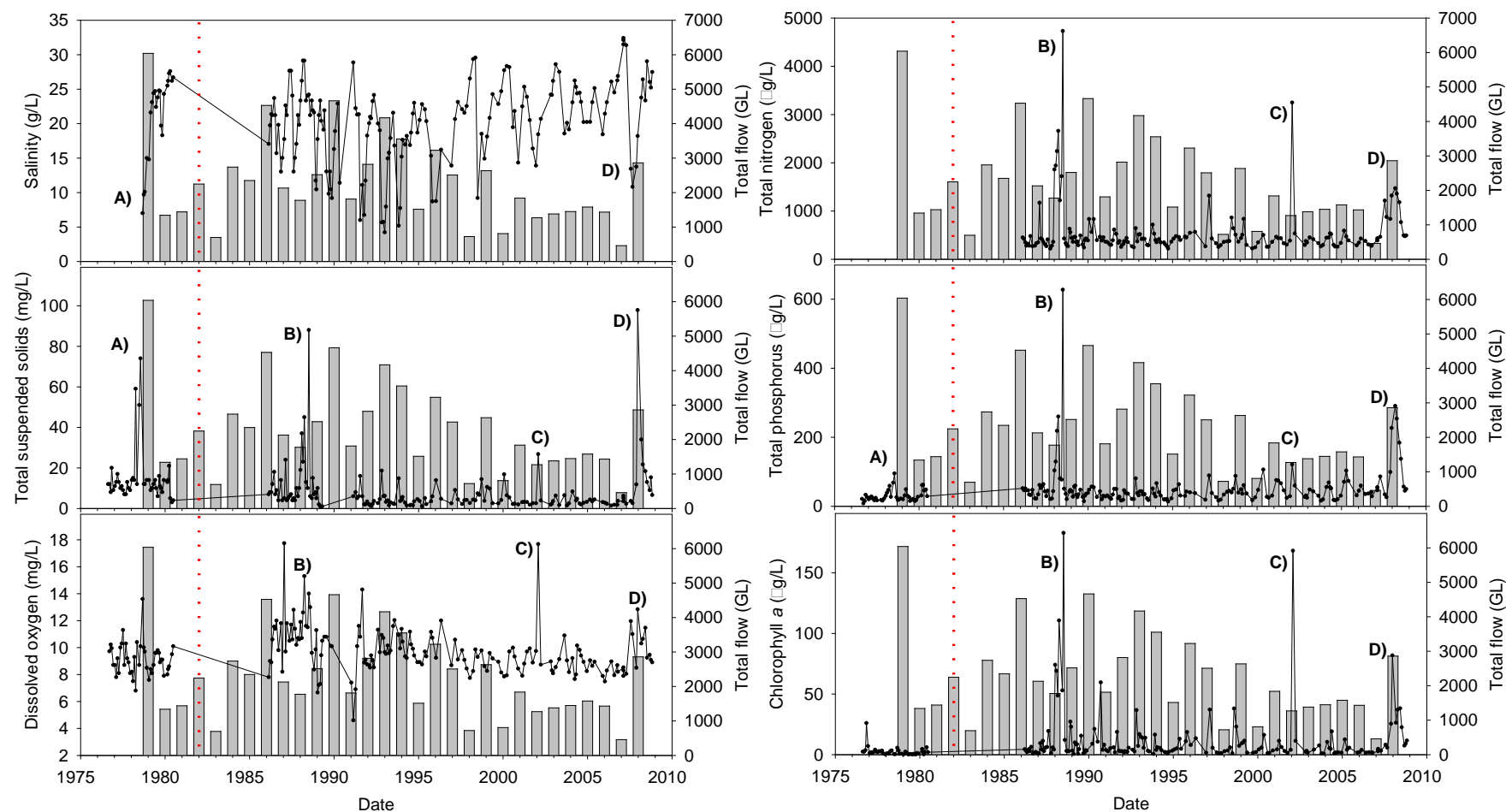


Figure 3-14 Eastern Lake Victoria surface water quality data (EPA monitoring site 002314)

Note: Total flow represents the summed flow recorded for all major catchment rivers and is given as hydrological year (June-May). Red dotted line denotes listing of Gippsland Lakes as Ramsar wetland in 1982. Refer to Appendix B for information on notable events A-D shown on the graphs.

Table 3-8 Eastern Lake Victoria surface water quality parameters and guideline values from EPA site 002314

Red colour represents exceedance of guideline trigger limits. Note that the ANZECC guideline values are representative of the broad southeast Australia estuaries and not specific to the Gippsland Lakes. It should be noted exceedance of the ANZECC Guidelines do not necessarily relate or otherwise equate to an Ecological Character Change – refer Limits of Acceptable Change in Section 4.

	Minimum		Maximum		10th percentile		20th percentile		50th percentile		80th percentile		90th percentile		Guideline	Source
	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008	1976-1980	1986-2008		
Salinity (g/L)	7.0	4.2	27.6	32.4	10.6	11.2	15.7	15.2	24.1	21.2	26.1	24.5	26.7	27.5	N/A	
pH	7.5	7.4	8.5	9.4	7.8	7.9	8.0	8.1	8.2	8.3	8.3	8.5	8.4	8.7	6.5-8.5	Waters of Victoria
Dissolved oxygen (mg/L)	6.8	4.6	13.6	17.7	7.9	8.0	8.2	8.5	9.1	9.4	10.0	10.9	10.3	11.6	6	Waters of Victoria
Dissolved oxygen (per cent saturation)		60.9		240.2		97.4		100.4		109.8		121.5		132.6	75	Waters of Victoria
Total suspended solids (mg/L)	3.0	1.0	74.0	97.8	7.0	1.8	9.0	2.3	12.0	4.2	14.0	9.2	18.8	15.2	25/80	Waters of Victoria
Total nitrogen (µg/L)		218.9		4730.0		270.0		295.7		393.7		526.7		834.4	300	ANZECC
Total phosphorus (µg/L)	8.0	13.8	95.0	627.2	16.3	20.5	18.0	26.0	25.5	40.0	41.4	57.7	56.0	80.5	30	ANZECC
Chlorophyll a (µg/L)	0.1	0.5	26.0	182.9	0.3	1.4	0.4	1.9	1.7	4.3	3.3	12.9	4.3	24.0	4	ANZECC

3.7.5 Nutrient Cycling, Sediments and Algal Blooms

Reasons for selection

As outlined above, the Gippsland Lakes are characterised by highly episodic delivery of nutrients to the system due to typically large year-to-year variation in rainfall and, hence, varying river discharge from the catchment. The residence time of water in the Gippsland lakes system is long and CSIRO (2001) estimated the average flushing time of the Gippsland lakes (defined as volume of the lakes divided by net freshwater input) to be an average of 206 days between 1975 and 1999. Tidal flushing is minimal due to the relatively low tidal amplitude of the region and the single, narrow lakes entrance.

Nutrient loads to the system from catchment flows are high enough to stimulate growth of phytoplankton blooms, which are regularly observed in the Gippsland Lakes. Aside from external supply of nutrients from the catchment, another important internal source of nutrients supporting phytoplankton growth is the sediments in the Gippsland Lakes.

Description

The description of this supporting process can be separated into: (i) the role of sediments; (ii) nutrient cycling; and (iii) algal blooms.

3.7.5.1 *Role of Sediments*

In shallow coastal systems such as the Gippsland Lakes, the relatively long residence time of the water (low flushing rates) and episodic input of nutrients mean that benthic recycling and exchanges between sediment and water column play a critical role for nutrient cycling (CSIRO 2001, Cook et al. 2008).

Most of the algae produced in the Gippsland Lakes are eventually mineralised (decomposed) in the sediments, which is typical for shallow aquatic systems. Microbial processes in the sediment decompose the organic matter that is sinking to the lake bottom and eventually mineralise the organic matter to CO₂ and inorganic nutrients, such as ammonium and phosphate. While oxygen is available to sediment bacteria, organic matter is preferentially mineralised aerobically and oxygen is consumed in the process. Aerobic mineralisation is the most effective and fastest way of breaking down organic matter. Furthermore, when oxygen is available to sediment bacteria, the ammonium produced by organic matter mineralisation can be rapidly oxidised to nitrate by the microbial process of nitrification, an integral part of the nitrogen cycle in aquatic systems.

Due to the consumption of oxygen in the sediment by aerobic mineralisation, oxygen is usually only available in the uppermost millimetres of the sediment and needs to be constantly replenished from the overlying water column. Bacteria living in deeper, anoxic layers of the sediment need to mineralise organic matter by anaerobic processes, using electron acceptors other than oxygen. The nitrate produced by nitrification is one of these alternative electron acceptors that can be used by bacteria living in the transition zone between oxic surface sediment and anoxic deeper sediment for mineralisation of organic matter. This anaerobic mineralisation process is known as denitrification and leads to a transformation of the nitrate to N₂ gas as an end-product (similar to gaseous CO₂ as an end product of aerobic mineralisation). The processes of nitrification and denitrification are often closely coupled in sediments. One of the most important consequences of this coupled

nitrification/denitrification process is that nitrogen is effectively removed from the system through the production of N_2 gas, which is released from the system into the atmosphere. High denitrification rates are generally a good indicator of healthy ecosystem function of estuaries and lagoons such as the Gippsland Lakes and support the self-cleansing of the system by removal of excess nitrogen.

In contrast to nitrogen, there is no stable gaseous end-product of phosphate produced during aerobic and/or anaerobic organic matter mineralisation or other sedimentary processes. Phosphate is generally recycled internally within the ecosystem and the primary mechanism of its removal is by burial. When oxygen is present, a large fraction of the mineralised phosphate is readily adsorbed onto iron-oxides and iron-oxyhydroxides at the oxidised sediment surface and is therefore trapped as particles within the sediment (Howarth et al. 1995). However, this reaction is reversible and phosphate can be released from the sediment as soon as the sediment becomes anoxic. Phosphate release from the sediments may be exacerbated by sulfate reduction. Sulfate reduction is an anaerobic microbial process using sulfate instead of oxygen for the mineralisation of organic matter. This process is relevant in estuaries with marine influence, as seawater and sediment porewater have high concentrations of sulfate. Indeed, porewater profiles of sulfate/chloride ratios indicate that sulfate reduction occurs in sediments of the Gippsland Lakes (Longmore and Roberts 2006). The sulfide produced during sulfate reduction leads to the dissolution of iron-oxyhydroxides and ensuing release of phosphate from the sediment into the water column (Jensen et al. 1995, Howarth et al. 1995).

The important role of the Gippsland Lakes sediments for nutrient cycling is highlighted by the fact that sediments down to 20 centimetres hold very large stores of nitrogen and phosphorus, which can be more than 70 times the annual catchment loads (Longmore and Roberts 2006). The largest pools of ammonium and phosphate were found in Lake Victoria, comprising about 50 per cent of the total nutrient pool for the Gippsland Lakes. Monbet et al. (2007) demonstrated that about 85 per cent of the phosphorus in the sediment of Lake Wellington and Lake Victoria is stored in relatively labile fractions and is therefore immediately or potentially available for primary production. The immediately bioavailable forms of nutrients in the Gippsland Lakes sediments were estimated to be equivalent to four years (ammonium) and one and a half years (phosphate) of external catchment input (Longmore and Roberts 2006).

3.7.5.2 Nutrient Cycling in the Gippsland Lakes

In terms of nutrient cycling Lake Wellington differs markedly from Lakes King and Victoria (CSIRO 1998, CSIRO 2001), which is mainly caused by differences in circulation patterns and water column stratification. While Lake Wellington is very shallow with an average depth of 2.6 metres and is well mixed both vertically and horizontally, Lakes King (5.4 metres) and Victoria (4.8 metres) are deeper with maximum depths of up to 10 metres and are generally characterised by periodic salinity stratification (layering) of the water column (CSIRO 2001). This salinity stratification is particularly pronounced during wet years, when freshwater from river inflow overlays the denser, higher salinity bottom water of Lakes King and Victoria.

Lake Wellington

Inputs of dissolved nitrogen (ammonium, nitrate) from the catchment are usually rapidly assimilated by the phytoplankton resulting in very low dissolved nitrogen concentrations in the water column (CSIRO 2001). Due to the highly episodic input of nutrients from the catchment, phytoplankton growth

is primarily supported by release of nutrients from the sediment during summer and drought periods with low base loads. Owing to the narrow McLennan's Strait, Lake Wellington is poorly flushed during periods of low flow. However, the well mixed water column of this shallow lake means that enough oxygen is supplied to the sediments. Coupled nitrification/denitrification rates are therefore expected to be high, constituting an important sink for nitrogen introduced from the catchment (CSIRO 2001).

The well oxygenated water column and surface sediments may result in the trapping of large amounts of phosphate within the sediment by adsorption to iron-oxides and iron-oxyhydroxides. Indeed, CSIRO (2001) found it necessary to include a 30 per cent burial term for the total phosphorus load in Lake Wellington to render the modelling consistent with observations. The rest of the total phosphorus load is exported to Lake Victoria.

Although CSIRO (1998) state that Lake Wellington appears to be phosphorus limited, nitrogen appears more likely to be the limiting nutrient for Lake Wellington. While the ratio of total nitrogen to total phosphorus (19:1 by atoms) suggests slight phosphorus limitation for phytoplankton, inorganic nitrogen is rapidly depleted in the water column of Lake Wellington, while measured phosphate concentrations in surface water are generally at levels not limiting phytoplankton growth (CSIRO 2001). Probably most importantly, coupled nitrification/denitrification in the well oxygenated surface sediments acts as an important sink for nitrogen, which likely outweighs the internal sinks for phosphorus (CSIRO 2001, WBM 2005).

Lake King and Lake Victoria

Nutrient cycling is more complex in Lakes King and Victoria, primarily due to the alternating stages of a mixed and stratified water column. The periods of water column stratification are characterised by limited exchange between bottom and surface water, which frequently leads to periodic hypoxia (low oxygen concentrations) and accumulation of high nutrient concentrations in the bottom water of the Lakes (Bek and Bruton 1979, CSIRO 2001). When freshwater inflows are reduced during summer, mixing events can break up the stratification and the built-up nutrients will be available for phytoplankton production in the surface water (CSIRO 1998).

During periods of water column stratification, the limited vertical exchange within the water column means that oxygen cannot be replenished in the bottom water layer. Ongoing mineralisation processes in the sediment eventually lead to bottom water hypoxia or anoxia, as is frequently observed in Lakes King and Victoria. This has major implications for the nutrient cycling in these lakes. During periods of hypoxia, the sediment may become anoxic up to the sediment surface. This leads to a breakdown of the coupled nitrification/denitrification process (nitrification requires oxygen) and ammonium is released from the sediment in high concentrations instead of being removed from the system (CSIRO 1998). Furthermore, large quantities of phosphate are released from the large semi-stable iron-oxyhydroxide stores in the sediment (CSIRO 2001). Ammonium and phosphate accumulate in the bottom water and are available for phytoplankton growth after mixing events.

The described cycling of nutrients in Lakes King and Victoria has major implications for the development of toxic blue green algae blooms (for example, cyanobacteria *Nodularia spumigena*), which are a recurring problem for the Gippsland Lakes (Stephens et al. 2004). In a study evaluating catchment flow and water quality data from the last 30 years, Cook et al. (2008) described the sequence of events leading to a typical *Nodularia* bloom:

- High river flow during winter (June-September) introduces high concentrations of dissolved inorganic nitrogen to the lakes, which can trigger blooms of diatoms and/or dinoflagellates. The total nitrogen (TN) to total phosphorus (TP) ratio from catchment inflow is typically around 20 (CSIRO 2001).
- The rapid depletion of nutrients in the water column and ensuing collapse of the bloom results in sedimentation of the dying algae to the lake sediment, where they are mineralised.
- Nutrients with a greatly reduced ratio of N:P are released from the sediment via two mechanisms: a) a substantial fraction of the released nitrogen is initially lost via coupled nitrification/denitrification in the sediment, and b) high mineralisation rates of the sediment eventually leads to low bottom water oxygen concentrations and ensuing release of stored phosphorus from the sediment.
- Loss of nitrogen via denitrification and release of high concentrations of phosphate from the sediment shifts the TN:TP ratio to about six. This ratio indicates strong nitrogen limitation, which highly favours growth of cyanobacteria like *Nodularia*. These algae are able to derive nitrogen for their growth from fixing N₂, which is dissolved within the water column. Cyanobacteria often dominate systems with N:P ratios of less than 15 (Paerl 2008).
- Strong stratification in high flow years results in accumulation of nutrients with low N:P ratio in the bottom water of Lakes King and Victoria throughout late spring and summer, when warm conditions favour *Nodularia* growth.
- The following mixing events during summer combined with low salinity surface waters (15-20 PSU) ultimately trigger the *Nodularia* bloom.

The described sequence in the nutrient cycling and associated lowering of the N:P ratio of nutrient input from the catchment supports previous observations that nitrogen is the limiting nutrient in Lakes King and Victoria (CSIRO 1998, CSIRO 2001, WBM 2005).

However, it should be noted that nutrient cycling processes differ between lagoons, and within lagoons over time. Ecos (unpublished) describes the following key differences between the main lagoons:

- **Lake Wellington** – Ecos (unpublished) argue that nitrogen (N) is probably more limiting than phosphorus due to competition for inorganic forms of nitrogen, and rapid depletion of available N via sediment nitrification – denitrification processes.
- **Lakes King and Victoria** – Ecos (unpublished) suggest that nitrogen is the predominant control of algae in these lakes. They argue that when the lakes (particularly Lake King) becomes stratified, bottom waters become more readily anoxic, leading to sediment nitrification – denitrification processes being less efficient. The anoxic sediments are likely to facilitate substantial fluxes of ammonium to the overlying water column, which can be taken up by dinoflagellates which can migrate through the water column (and into well lit upper waters).

Ecos (unpublished) also note that phytoplankton in Gippsland Lakes can also become phosphorus limited under some conditions.

Relevant to this point, between 2007 and through the winter of 2008, an unprecedented bloom of the cyanobacteria *Synechococcus* developed within the system. Cook et al. (2008) suggested that the bloom was caused by extremely high nutrient loads (particularly nitrate) entering the lakes in the 2007 flood, which followed the 2006-2007 fires. Cook et al. (2008) predicted that future blooms could be avoided providing catchment nitrogen inputs did not elevate to similar levels.

3.7.5.3 Algal Blooms

As mentioned above, algal blooms have historically been observed in several waterways throughout the Gippsland Lakes area over the past two centuries. Details of algal blooms recorded over the past several decades are presented in Table 3-9 below (after Stephens et al. 2004). More recent accounts of algal blooms include 2004 (Cook et al. 2008) and 2007-2008 (Beardall 2008) already discussed.

Table 3-9 Reports of algal blooms in the Gippsland Lakes (after Stephens et al. 2004)

Date	Details of bloom	Previous flood
July 1965	<i>Nodularia</i> bloom in Lake Wellington after bushfires and heavy rain	
March 1971	<i>Microcystis</i> bloom in Lake Wellington	January-February 1971, major
May 1971	Lake King, dinoflagellate dominated Lake Victoria diatom dominated, <i>Nodularia</i> present Lake Wellington <i>Nodularia</i> /diatom-dominated <i>Nodularia</i> dominant in Bunga Arm	
February 1974	<i>Nodularia</i> bloom Lakes King and Victoria	August 1973
October 1984	Minor non-specified bloom in Lakes Victoria and Wellington	July 1984, moderate
January 1986	<i>Anabaena</i> bloom in Lake King	December 1985
February 1987	<i>Nodularia</i> bloom in Lake King	October 1986
August 1987	Non-specified bloom in Lake Victoria	July 1987, minor
December 1987 to April 1988	<i>Nodularia</i> bloom in Lake Victoria	
December 1988	Dinoflagellate bloom in Lake Victoria	November 1988, moderate
July 1989	<i>Nodularia</i> bloom in lakes	
December 1989	<i>Nodularia</i> bloom in east Lake Victoria and south Lake King	July 1989, minor
July 1990	Unspecified bloom in Lake King North	April 1990, major
September 1990	Unspecified bloom in lakes King South and Victoria	
January 1993	<i>Microcystis</i> bloom in Jones Bay/Lake King	September and December 1992, major
January 1996	Unspecified bloom in Lake Victoria	October 1995, major
May 1996	<i>Nodularia</i> bloom in Lake King	
February 1997	<i>Nodularia</i> bloom in Lake King	July to October 1996, minor

3.7.6 Biological Processes

Reasons for selection

Biological processes describe any process occurring within, or being facilitated 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 within the Gippsland Lakes Ramsar site.

Description

The following is a brief overview of some of the key biological processes operating at a whole of site scale.

Energy and nutrient dynamics

As vegetative and animal matter begins to senesce and die, microbes invade the tissues and transform the organic material into more bio-available forms of carbon and other nutrients. While microalgae, 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, some invertebrates fish and birds) are generally not directly grazed, but instead enter food-webs following microbial conversion of organic matter (Day et al. 1989). Carbon flows in freshwater wetlands are not well known and require further investigation, although freshwater marshes are recognised as important sinks for carbon as they actively accumulate organic matter.

In the context of energy flows through the ecosystem, some energy is lost during microbial respiration, some is leached as dissolved organic material into the water, some is incorporated into microbial biomass, and some may be transformed to other organic compounds not incorporated in microbial cells. Of particular importance to higher trophic levels (that is, consumers) is the conversion of detrital material into bacterial biomass, which is then in a bio-available form for animals (Day et al. 1989). Microbes also affect energy flow by using dissolved organic matter, which is largely unavailable to other estuarine community components (Day 1967; Nybakken 1982; Day et al. 1989).

Biogeochemical processes that control nutrient cycles underpin both pelagic and benthic ecosystem components. Studies on algae bloom dynamics within the site suggest that there is strong benthic - pelagic coupling. As discussed in the previous section, Cook et al. (2008) found that catchment derived nutrient inputs, together with internal recycling of nutrients, ultimately control cyanobacteria (blue green algae) and other algae blooms within the system.

Productivity and foodwebs

The main primary producers within the site include phytoplankton, benthic microalgae (microphytobenthos), seagrass, saltmarsh, fringing reed beds and fringing *Melaleuca* forest. The relative contribution of each of these components to total primary productivity will vary from place to place and across a range of spatial (and possibly temporal) scales.

Case studies elsewhere demonstrate that freshwater marshes, seagrass and saltmarsh represent particularly productive communities (on a 'productivity per unit area' basis). It is also notable that phytoplankton can form major blooms within the estuary, as a result of the influx of excessive catchment derived nutrients (Cook et al. 2008). 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, or bottom-dwelling, fauna

(meroplankton), including most species of direct fisheries significance. Little is known about the relationships between nutrient levels, phytoplankton dynamics, 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. 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 particularly likely to be the case in detritus-based foodwebs that characterise saltmarsh and freshwater wetland systems.

The relative importance of different primary producers in maintaining estuarine fisheries has not been investigated at the site to date. Recent studies in nearby 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).

Unlike Corner Inlet, Gippsland Lakes contains extensive areas of saltmarsh and brackish wetlands, and as discussed above, can have high phytoplankton biomass. Given the large area within Gippsland Lakes, seagrass is also likely to contribute significantly to foodwebs supporting commercially significant species, whereas the roles of marshlands and phytoplankton are unknown and warrant further investigation. Hindell (2008) predicts that a reduction in seagrass with Gippsland Lake would result in a comparatively greater contribution of other plants to the foodwebs supporting fish species (that is, a change in trophic structure), which we suggest may translate to a change in the growth and possibly relative abundance of some fish species.

The diet of wader bird species differs between species, and also within species, depending on food availability. While many shorebirds 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.

3.8 Critical Services/Benefits

Two critical services/benefits have been identified within the ECD. These critical services/benefits have been selected on the basis that they are unique determinants of the site's ecological character and underpin relevant Ramsar Nomination Criteria for the site.

3.8.1 Critical Service 1 – Maintaining 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.

The role of the site in maintaining threatened wetland fauna species underpins Ramsar Nomination Criterion 2.

In addition to the values of these species in terms of maintaining global biodiversity, some species are of great scientific research value and/or play a role in maintaining wetland ecosystems and foodwebs.

Description

DSE (2003) indicates that three flora and two fauna species recorded at the Gippsland Lakes Ramsar site are classified as nationally endangered under the EPBC Act, and four flora and ten fauna species as nationally vulnerable. More recent investigation of species lists have been undertaken as part of the current study and the following nationally or internationally threatened flora and fauna species are considered the key wetland dependent species of the site:

Threatened fauna species

- green and golden bell frog (*Litoria aurea*)
- growling grass frog (*Litoria raniformis*)
- Australian grayling (*Prototroctes maraena*)
- Australian painted snipe (*Rostratula australis*)
- Australasian bittern (*Botaurus poiciloptilus*)

Threatened flora species

- dwarf kerrawang (*Rulingia prostrata*)
- swamp everlasting (*Xerochrysum palustre*)
- metallic sun-orchid (*Thelymitra epipactoides*)

The majority of these species have already been discussed in the context of local populations that form critical components. The remaining species that are as yet undescribed include Australian grayling and the two cryptic wetland bird species, Australian painted snipe and Australasian bittern. These species have not been included as critical components on the basis that there are no or very minimal site records within the Ramsar site or otherwise there is poor information about the importance of the habitats within the site for these fauna.

Australian grayling

Australian grayling is listed as vulnerable under the EPBC Act and near threatened under the IUCN Red List (IUCN 2010), and is also listed as threatened under state legislation (Flora and Fauna Guarantee Act 1988). Confirmed records for these species exist for all major river basins that drain directly into the site, and given its apparent obligate estuarine juvenile life-history phase, it will need to use the site to complete its life-cycle. As identified above, there are records for Australian grayling for catchments that drain into the site. No information is available on the population dynamics and abundance of this species within these catchments or the Ramsar site.

The population status of Australian grayling in the river basins that drain into the site are highly likely to be dependent on the maintenance of suitable juvenile nursery habitat either within the estuarine sections of the site, or in the sea. It is thought that juveniles spend approximately six months of their life in estuarine/marine waters (approximately May to November), before migrating upstream into freshwaters, possibly in response to spring freshes (Backhouse et al. 2008). There are uncertainties regarding species habitat (structural and hydraulic) and water quality requirements during the juvenile stages.

There is no information on usage by the species within the site, although several drainages that flow into the site are considered to represent important habitats including Tambo, Mitchell, Avon and Thomson Rivers (Backhouse et al. 2008). Little is known about the population status of fish in these streams. Based on environmental flow assessments for the Thomson and Macalister Rivers, it was argued that abundances of this species were low and populations were unlikely to be self sustaining (Thomson Macalister Environmental Flows Task Force 2004), although it is uncertain how this conclusion was reached.

Painted snipe

Australian painted snipe (*Rostratula australis*) is listed as Vulnerable under the EPBC Act. This secretive, crepuscular species occurs on well vegetated shallow, permanent or seasonal wetlands (usually freshwater but occasionally brackish) (Geering et al. 2007). Occurrence is regarded as erratic and unpredictable (often in response to local rainfall), seldom remaining long in any locality and being absent from areas in some years and common in others (Marchant and Higgins 1993; Geering et al. 2007). This species requires dense vegetation cover for roosts (often tall grass) and forages on soft muds and in shallow water for seeds and invertebrates (Marchant and Higgins 1993; Geering et al. 2007).

The Birds Australia Atlas contains records of painted snipe in 1977 (three records), 1979 (one record) and 1980 (one record). The Birds Australia database (counts) and DSE Fauna databases do not contain any records of painted snipe at the site.

Australasian bittern

Australasian bittern (*Botaurus poiciloptilus*) – is listed as endangered under the IUCN Red List (IUCN 2010). This shy and cryptic bird roosts, feeds and breeds within dense vegetation cover of terrestrial and estuarine wetlands, though preferring permanent freshwater wetlands which support a combination of tall, dense vegetation (for example, bullrushes *Typha* spp. and spikerushes *Eleocharis* spp.) and short dense vegetation including sedges, rushes and reeds (Marchant and Higgins 1990;

Garnett and Crowley 2000). Garnett and Crowley (2000) consider that due to their comparatively specialised habitat requirements, this species may be more sensitive to overall habitat loss than are many wetland species.

The Birds Australia database contains one record of Australasian bittern at Lake Tyers in 1992, whereas the Birds Australia Atlas contains a record in 2006 at McLeod Morass (Birds Australia 2009). The DSE Fauna Database contains 15 records (years 1986, 1987, 1988, 1990, 1992, 1994, 1997, 1998), all of which were comprised of a single individual.

Natural variability

There are significant constraints to the assessment of Australasian bittern and Australian painted snipe due to their highly cryptic nature.

Nonetheless, maintaining the populations of these species (and the other threatened species) over time is most dependent on the following:

- Hydrology - Maintenance of natural patterns of freshwater inundation and prevention of increases in saline intrusion.
- Biological/Biophysical Processes - Maintenance of natural vegetation patterns, extent, condition, and habitat interconnectivity. Maintenance of key biological processes occurring at the site such as growth, reproduction, recruitment, feeding and predation.
- Water Quality - Maintenance of water quality in key habitats (nutrients, dissolved oxygen, salinity).

3.8.2 Critical Service 2 - Fishery Resource Values

Reasons for selection as 'critical'

Gippsland Lakes supports important fisheries resources in the form of fisheries habitats. These include feeding 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).

In the context of this service, black bream is considered a key indicator of the fisheries habitat values of the site. Selection of this species as a key indicator is based on the fact that recreational and commercial fishing focuses heavily on this species and there has been reasonable catch data collected over time for analysis.

Description

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.

Table 3-10 shows that important fisheries species (that is, those species listed in Table 3-11) 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 flexible habitat requirements, and are typically found in a variety of habitat types. In general terms, most of the species listed in the table below spend their juvenile stages in shallow nearshore waters, particularly around seagrass and mangroves, whereas most species tend to spawn in inshore waters, particularly near the surf zone. Adults of most species tend to utilise a variety of habitats. There are exceptions to these general patterns; dusky flathead, river garfish and black bream spawn entirely in estuaries, with dusky flathead and river garfish typically spawn near seagrass and/or shoals, whereas black bream is thought to spawn in upper estuaries near the fresh and brackish water interface (Ramm 1986).

Table 3-10 Key fisheries species present in the Gippsland Lakes 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*	Inshore 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.			
river garfish	Juv., Ad.	Juv., Ad., Spw.	Juv., Ad.		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.			
estuary perch		Juv.		Juv. Ad.	Juv. Ad.	Spw (estuary mouth)			
carp					Juv., Ad.				
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 (Hindell 2008);

blue shading = habitats not represented in the site

Natural variability

Patterns in fish (and shellfish) community structure may vary across a range of spatial and temporal scales. Presently, there are no available data describing these life history functions for species within the site. As a decline in spawning or recruitment success would be expected to result in a reduction in relative abundance of juvenile and possibly adult fish, fish abundance data may provide a broad proxy indicator for this service.

Relative abundance data of high fisheries value species can be broadly determined based on commercial fish catch data (refer Table 3-11), which provides catch data for marketable fish. These data are strongly biased towards adults, are not based on systematic standardised catch methods and have limited spatial resolution. Furthermore, there are only four years of data for the period up to and including site declaration in 1982. There are also no suitable fisheries independent catch data to validate commercial catch data.

Notwithstanding these limitations, the commercial catch data presented in Figure 3-19 show:

- Black bream commercial catches displayed a marked decline, which was especially notable post-1986. This species does however remain one of the most abundant species in commercial catches within the Ramsar site. Overall declines were also observed for yelloweye mullet and tailor, although these species remained at a constant rank in terms of total catch within the site.
- European carp displayed a marked increase in numbers over time, particularly during the mid- to late-1990's.
- Overall, the post-1983 catch of other species was fairly similar to the pre-1983 catch, and the rank in terms of total catch within the site remained within one or two positions for most species.

Notwithstanding the above, Gippsland Lakes continues to represent an important habitat for black bream and other commercially significant species.

These above-described changes over time are likely to relate to a combination of changes in fishing effort and/or market demand, changes in actual abundance of these species and/or other factors controlling fishing effort (for example, fishing regulations, weather conditions, etc.). It is important to note, for example, there has been a reduction in number of license holders (and therefore fishing effort) due to Government buy-backs in the 2000's. Furthermore, it is noted that Lake Tyers was closed to commercial fishing in April 2003, coincident with a major reduction in black bream catches. However, even excluding data from the period when the Lake Tyers fishery was closed, the median black bream catch for the period 1982-83 to 2001-02 (174 tonnes) was still less than the 20th percentile catch for the period 1978-79 to 1981-82 (190 tonnes). Analysis by Ecos (unpublished) shows that fish effort has also declined since listing (Figure 4.1; Section 4.1.2), however there was a period in the mid 1980's to 1990's where catch declined but effort was equivalent to pre-1982 levels.

Catch per unit effort data were unavailable to the study team, hence it is not possible to make a definitive determination of whether changes in fishing effort or other factors were responsible for changes in commercial catch over time. Based on catch per unit effort data presented in Ecos (unpublished) for black bream catch (Figure 3-20), it is apparent that commercial catch has tended to decline in time in the period 1978 to 2003. Based on these data, the baseline catch per unit effort

(tonnes/number of vessels) for the period 1978 to 1982 was 7.9 (median), and the 10th percentile baseline catch per unit effort was 6.1.

Table 3-11 Commercial production (tonnes) for Gippsland Lakes summary statistics (20th, 50th and 80th percentile values)

Species	Pre-listing (<i>n</i> = 4)			Post 1982 (<i>n</i> = 26)
	20 th	50 th	80 th	50 th
Australian anchovy	3	13	33.8	3.5
Australian salmon	3	3.5	4	13
black bream	189.6	212.5	240.6	156
European carp	183.4	211	286.6	376
dusky flathead	9.6	17.5	24.2	11.5
river garfish	0.6	4	24.6	2
leatherjacket	0.6	2.5	5.6	1
luderick	13	17	23.8	20.5
sea mullet	5.4	9.5	22	10.5
yelloweye mullet	87	98.5	114	78
blue Mussel	0	0	0	1
estuary perch	0	0	0	1
tailor	41.8	48	52.6	23
silver trevally	11.8	13.5	15.2	16
other	19	27.5	35.6	27.5

(Data source: DPI 2008). Red = 20th percentile 'baseline' greater than median post-1982 value

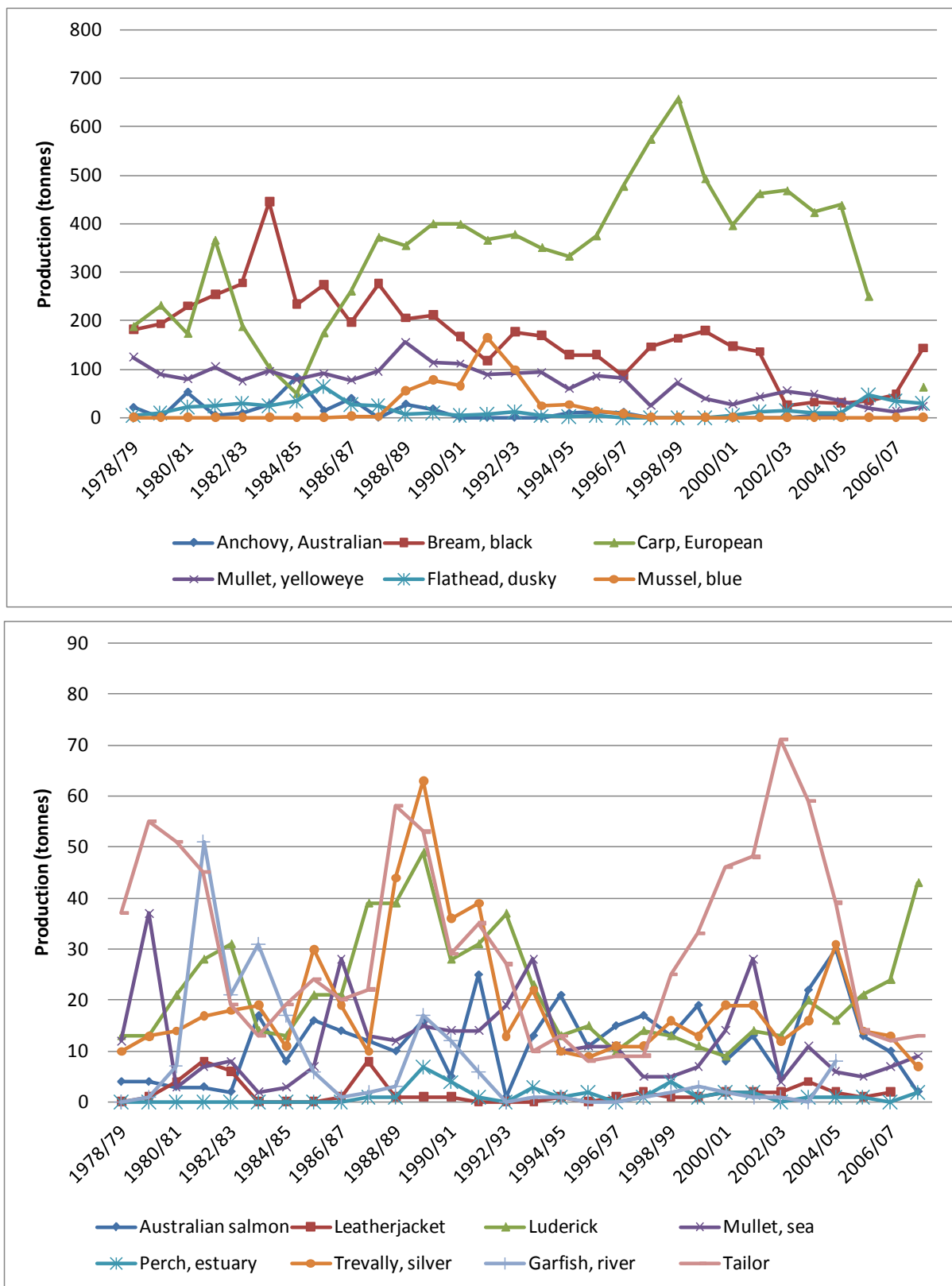


Figure 3-15 Commercial fisheries catch data between 1978-2008 (Source: DPI 2008)

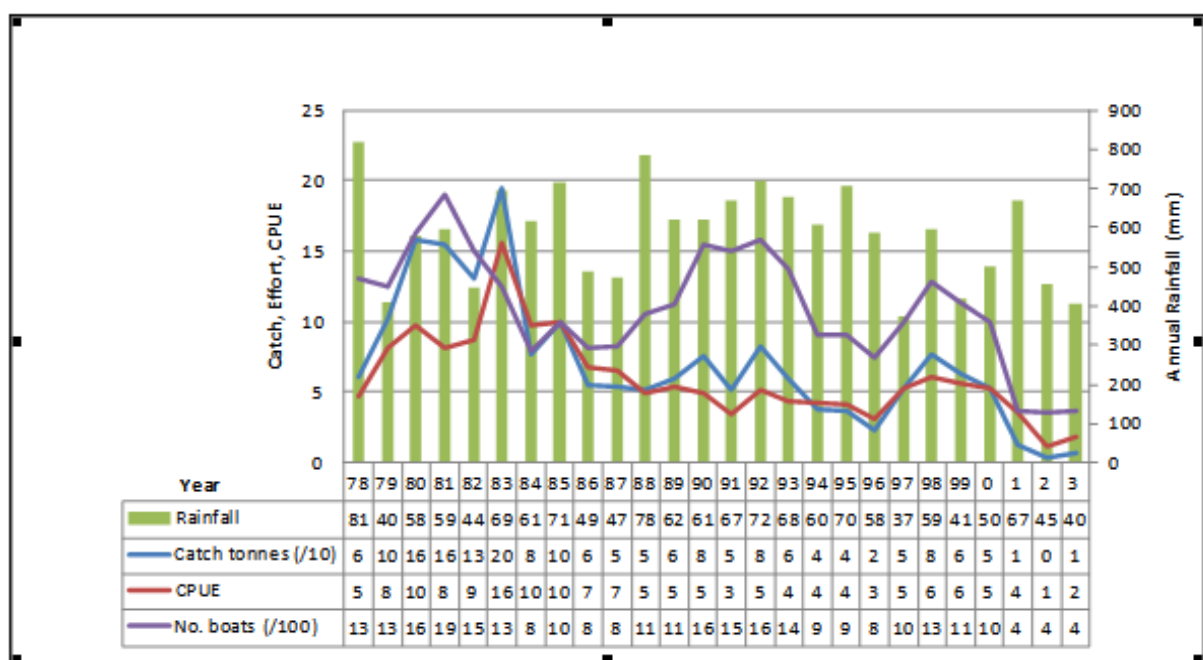


Figure 3-16 Black bream commercial catch, effort (number of boats) and catch per unit effort (catch divided by number of vessels) at Gippsland Lakes (Data source: Ecos unpublished)

3.9 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.

3.9.1 Recreation and Tourism Values

Description

Tourism and recreation are among the most important uses of the Gippsland Lakes, and have a major impact on employment and the economic wealth of the region. In this context, a supporting service/benefit of the site is its tourism and recreational use including recreational fishing.

Tourism and recreational use

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 Main 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).

Visitors undertake a wide range of recreational activities on and around the Lakes including bushwalking, boating and sailing, fishing, swimming, camping, hunting, bird watching, horse riding, picnicking and sight-seeing. Boating and fishing are, however, the main recreational activities with most visitors attracted to the Lakes for angling and boating opportunities (DSE 2003).

Coastal towns in the Gippsland region are subject to large seasonal population fluctuations usually in summer which are directly related to tourist influx into the region's motels, hotels, caravan parks and holiday homes for holidays. Maintenance of coastal environmental values (that make the Gippsland Lakes region attractive to visitors) is therefore a key to economic sustainability of many of these areas.

The visual attraction of the area is underpinned by the fact that the National Trust of Australia has classified the Gippsland Lakes area as being of special regional landscape significance. Of prime visual importance is the contrast of land and water, particularly due to the sandy barrier system which formed the coastal lagoons comprising the Gippsland Lakes and several geomorphic sites of international, national and state significance already discussed (DSE 2003).

Commercial tour operators run tours and make use of Gippsland Lakes and its parks, particularly Gippsland Lakes Coastal Park and The Lakes National Park (DSE 2003). National Parks, Coastal Parks and reserves in the Gippsland Lakes contain about 300 campsites, 150 picnic and other visitor areas, boating facilities (including private jetties that provide some 300 – 400 berths) and more than 60 toilet blocks (DSE 2003).

Based on the region's market profile prepared by Tourism Victoria, 84 per cent of overnight visitors to Gippsland were sourced from the intrastate market, followed by 12 per cent from interstate and three per cent from the international market (Tourism Victoria 2007). The region has 13 per cent market share of all domestic visitors to regional Victoria.

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.

Recreational fishing

Approximately 43 per cent of Victorian recreational fishing in 2000-2001 occurred in bays, inlets and estuaries such as the Gippsland Lakes (Fisheries Victoria 2007). Recreational fisheries are an important aspect of the Gippsland Lakes region, contributing significantly to regional economy and tourism. Recreational fishing supports the tourism and recreational industries in the region which surrounds the Ramsar site which has a major impact on the economic health of the region (DSE 2003). Approximately 1.3 million hours per year are spent by recreational fishers (DCNR 1995) with similar fish being targeted as the commercial fishery, including black bream, flathead, snapper, whiting and squid. There is interdependence between the commercial and the recreational sectors with the recreational sector relying on bait collected by commercial operators. Lake Tyers was declared a recreational fisheries reserve in 2004 to improve recreational fishing opportunities in the region.

3.9.2 Scientific Research

Description

Scientific investigations of the Gippsland Lakes in the past have focussed on water quality monitoring as a result of major algal outbreaks, which have occurred about every ten years but have intensified following the recent flood and fire events. State agencies also carry out regular water quality monitoring, data of which has been considered as part of the current study (see Appendix B). Other studies include long term assessment of seagrass assemblages (by Roob and Ball 1997; and more recently by Hindell 2008) and fisheries monitoring (Fisheries Victoria 2007). Extensive research into the loss of *Phragmites* and succession of *Melaleuca* vegetation communities in Dowd Morass have been undertaken by Boon et al. (2008) but the same level of study has not been undertaken for the other fringing wetlands of Lake Wellington. The Strategic Management Plan also notes that the Victorian Wader Study Group is active on the site monitoring the success and numbers of breeding little tern (DSE 2003).

Based on the literature reviewed as part of this study, the site is seen as an important site for expanding scientific knowledge with respect to several key features including the various sites of geomorphic significance, the zoological significance of Lake Reeve, the long term study of algal blooms in Lake Wellington.

Sites of geomorphological significance

The sites of geologic and geomorphological significance on the site range from sites of national, state and regional significance. These sites are well documented by Rosengren (1984). Of particular note is the Mitchell River Delta which is deemed as a site of international geomorphological significance as it is one of the finest examples of a classic digitate delta in the world (DSE 2003). The other sites of significance (as mapped by DPI) include:

- Rotomah Island (National Significance)
- Boole Boole Peninsula (National Significance)
- Sperm Whale Head (National Significance)
- Cunninghame Arm (National Significance)
- Red Bluff (State Significance)
- Barrier Dunes – Ninety Mile Beach (State Significance)
- Lake Reeve and Outer Barrier - Paradise Beach (State Significance)
- Outer Barrier near Seaspray (State Significance)
- Cuspate Forelands at Lakes Entrance (State Significance)
- Tambo River Delta (State Significance)
- Macleod Morass (State Significance)

- Point Turner - Banksia Peninsula (State Significance)
- McLennan Isthmus and McLennan Strait (State Significance)
- Latrobe Delta (State Significance)

Zoological/botanical significance of Lake Reeve

The Lakes National Park and Gippsland Lakes Coastal Park Management Plan (1998) (Parks Victoria 1998), identifies Lake Reeve being of 'international significance and is a site of special scientific interest' based on the site's unique geomorphology, remnant vegetation communities that have been disturbed elsewhere throughout most of their range, species diversity and extensive waterbird usage as breeding, roosting and feeding habitat.

Long term study of water quality and algal blooms

There have been a number of significant studies into the water quality of Gippsland Lakes including most notably the Gippsland Lakes Environmental Audit (CSIRO 1998), the Gippsland Lakes Environmental Study (CSIRO 2001) and more recent work by the Water Studies Centre (Cook et al. 2008). Long term monitoring of water quality has also been undertaken by the Victorian EPA.

Through these studies, a sound understanding has been developed of the triggers for different algal blooms and nutrient flux issues within the Lakes. A major knowledge gap recognised in the studies is how these algal blooms affect the ecology of the Lakes which are currently being explored at least in part by continuing baseline seagrass and fish surveys by the Arthur Rylah Institute (Chris Barry (GCB) pers. comm. 2009).

As discussed previously, it should be noted that water quality is not degraded in all parts of the Gippsland Lakes Ramsar site. Lake Tyers in particular provides a useful reference site for measuring water quality at a regional scale given its predominantly undeveloped catchment and near-pristine water quality conditions.

3.10 Conceptual Models

The broad interaction of critical and supporting components, process and services/benefits at a whole-of-site level is shown in Figure 3-21. As shown in the figure, there are three broad processes identified (climate, geomorphology and regional-scale hydrodynamic and hydrological processes) that together have shaped the local 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 3-21).

The interaction of the critical ecosystem components, processes and services/benefits are shown in conceptual models for the site in Figure 3-23, Figure 3-24 and Figure 3-25. The models are based on the three broad wetland habitat groupings identified previously and utilise the numbering system for the critical components (C1 to C8), processes (P1 and P2) and services/benefits (S1 and S2) already presented.

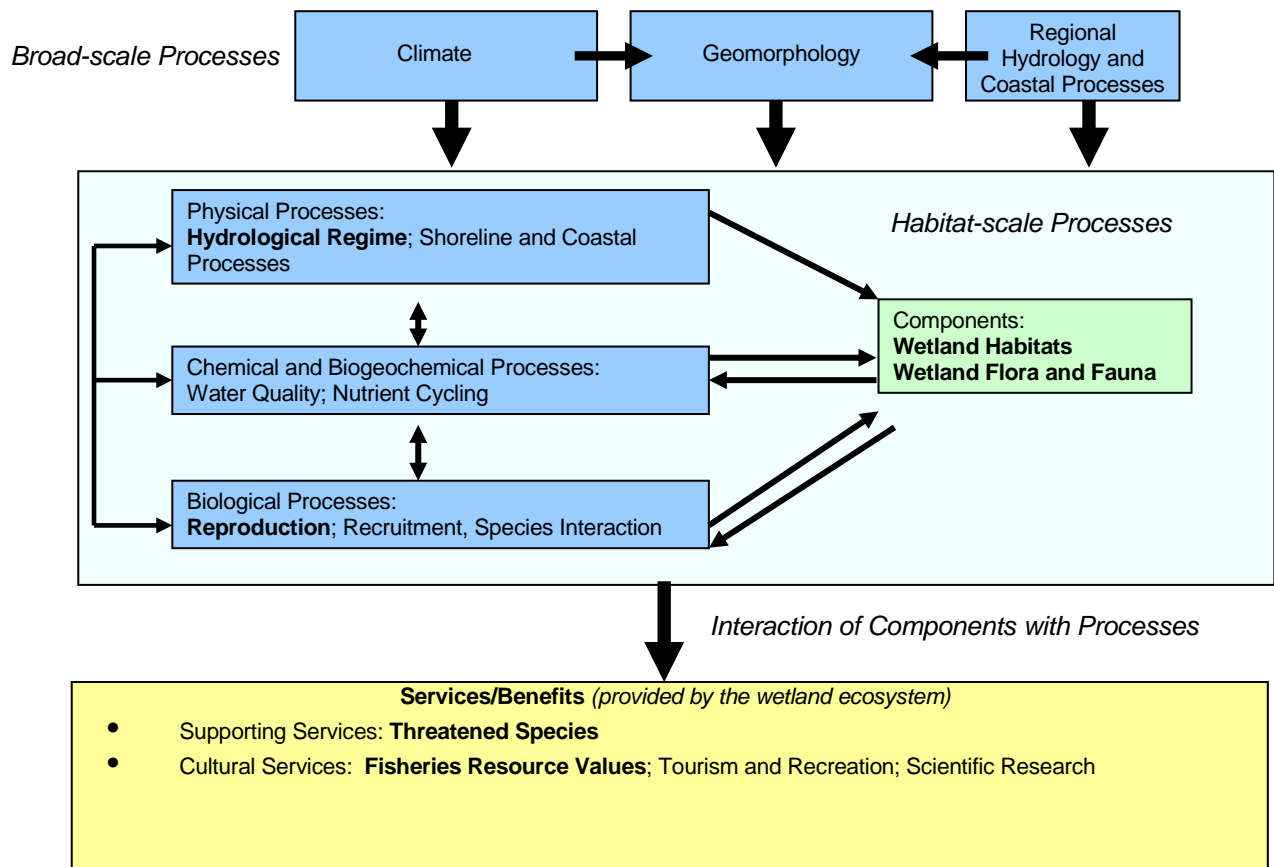


Figure 3-17 Conceptual model showing interaction of ecosystem components, processes and services/benefits (bold font indicates critical element)