WETLAND INVENTORY

EYRE PENINSULA

An assessment of selected inland wetlands for Eyre Peninsula, South Australia.

Environment Australia
Department of the Environment and Heritage
Department for Environment and Heritage
National Parks & Wildlife South Australia
Government of South Australia

This report may be cited as:
Seaman, R.L. (2002) *Wetland Inventory for Eyre Peninsula, South Australia*. Department for Environment and Heritage.

Author

Russell Seaman
Scientific Officer, Wetlands Management.
National Parks and Wildlife

Cartography and design

Russell Seaman

Photographs

Russell Seaman

Geographical Information System Data

Supplied by Geographical Analysis and Research Unit, Planning SA, Department for Transport, Urban Planning and the Arts.

and

The Department for Environment and Heritage, South Australia.

Funding Sources

Environment Australia

Support Organisation

National Parks and Wildlife SA

Acknowledgments

In the preparation of this report the expertise, advice and support of several people is greatly appreciated.

- Rob Walsh
- Roman Urban, DEH.
- Sandy Carruthers, Planning SA.
- Tim Croft, DEH.
- Liz Matthews

Executive Summary

The Wetland Inventory of Eyre Peninsula documents a representative sample of inland wetlands by recording their physical, chemical and biological attributes. Twenty-seven wetlands were surveyed, the majority of these comprised saline lake systems and brackish water bodies, with only one freshwater wetland being recorded during the survey.

The aquatic invertebrate fauna was notably scarce in many of the wetlands surveyed. This may be attributed to the high conductivity readings in the majority of wetlands, only four wetlands displayed good invertebrate diversity. The correlation between increasing salinity levels and decreasing biological activity was clear, and this decline is of concern for the health of many wetlands.

Several wetlands surveyed are considered to be nationally important as they meet the ANZECC criteria of being a good example of a wetland type occurring within a biogeographic region in Australia. These wetlands include the saline lake systems within Lincoln National Park and Lake Newland Conservation Park. Seven wetlands are recommended for monitoring, and include four wetlands in the District Council of Elliston and three wetlands managed by National Parks and Wildlife.

Figures

TABLES

PLATES

Maps

SECTION ONE WETLAND INVENTORY

1.0 INTRODUCTION

Eyre Peninsula contains unique and significant inland wetlands, the majority of which are saline lake systems with characteristic tea-trees forming circular bands around them. In spite of the high salinities, these lake systems contain excellent biodiversity values within the aquatic zone and adjacent terrestrial vegetation. This wetland inventory documents a representative sample of inland wetlands and records the physical, chemical and biological attributes of each waterbody. From this information, aquatic environments that contain high biodiversity are highlighted and threats affecting them documented. The inventory provides a snap shot of the condition and conservation value of wetlands on Eyre Peninsula. Those wetlands that meet one or more of the Australian and New Zealand Environment and Conservation Council (ANZECC) criteria for an important wetland will be nominated for inclusion into the National Directory of Important Wetlands in Australia.

The wetland database and inventory project is an initiative of the South Australian Department for Environment and Heritage, Conservation Strategies Section with support from Environment Australia, National Wetlands Program.

2.0 REPORT STRUCTURE

This report is divided into three sections, namely the wetland inventory, wetland assessment and wetland monitoring.

Section 1 - **Wetland Inventory**. Outlines the project aims, wetland risk assessment methodology and inventory methodology.

Section 2 - **Wetland Assessment**. Provides an analysis of the wetland inventory, which includes the identification of wetland values and threats.

Section 3 – **Wetland Monitoring**. Discusses frameworks for monitoring and recommends indicator species for monitoring and wetlands to monitor.

3.0 PROJECT SCOPE

The project scope consist of seven actions, these are to:

- Undertake wetland baseline surveys for the inland waters of Eyre Peninsula.
- Identify wetlands from surveys of conservation significance, according to ANZECC classification.
- Identify gaps in the data and prioritise the need for further surveys.
- Develop a South Australian wetland management database, format fields to be compatible with the Directory of Important Wetlands in Australia, and to allow for inclusion of data in the Directory and the Wetlands Inventory of Australia.
- Provide digital coverage of spatial boundaries of identified wetlands in ARC/INFO compatible format at appropriate scale, in consultation with Planning SA.
- Develop monitoring protocols for assessment of changes in ecological character of wetlands, and for recording results from this and future wetland related projects, based on the following key references.
- Produce a manual on monitoring protocols and a report on the biological values of wetlands on Eyre Peninsula.

4.0 OVERVIEW OF WETLAND INVENTORY TRENDS

The most comprehensive listing of wetlands in South Australia in terms of numbers and coverage is by Lloyd and Balla (1986). This study identified about 1500 wetlands and complexes state-wide.

The Lloyd and Balla listing was a desktop study that collated and recorded information within a standard format. This included:

- wetland type
- name
- location
- size
- catchment
- aquatic fauna
- aquatic and fringing vegetation
- wetland condition
- water regime
- landuse
- impacts
- tenure.

This report does provide a good starting point in understanding the extent and some attributes of South Australian wetlands. The study does however fall short in providing up to date information on invertebrate composition, water chemistry and basic landform information. The wetlands listed in Lloyd and Balla formed the basis for site selection in undertaking baseline surveys for this current study.

Since Lloyd and Balla's 1986 report, several studies have mirrored this kind of information and presentation of wetland information, but has not been collected within a standard format. However, good information has been generated for certain areas including the Murray River corridor. Thompson's (1986) study of River Murray Wetlands and Jensen *et al* (1996) *Wetland Atlas report of the South Australian Murray Valley* Wetlands made inroads into spatially capturing wetland locations through the use if GIS. The introduction of linking wetlands with GIS enabled the creation of a wetlands GIS database for the Murray Valley Wetlands. In 1997 a GIS database was also created for the South East wetlands. This database recorded wetland type, name, complex, watercourses and assigned a condition score and conservation value, Carruthers and Hille (1997). The benefits of collecting data and linking it to GIS became evident not only for environmental planning and information retrieval but also for reporting to Environment Australia on the extent of wetland resources.

In 1993 the Australian Nature and Conservation Agency published the first edition of '*A Directory of Important Wetlands in Australia'*. A second edition was complied in 1996, which included information on 68 wetlands in South Australia. Information was collected and put into a format which provided, for the first time, a detailed assessment of selected wetlands in South Australia.

It became apparent, that several regions within South Australia were lacking baseline wetland information. De Jong and Morelli (1996) suggested that there is a need for systematic inventories, biological surveys and research programs in many areas of the State. Wetland information in regions such as the Great Victoria Desert, Flinders and Olary Ranges, Eyre Peninsula, Yorke Peninsula, Kangaroo Island and Nullarbor is inadequate.

This project combines some of these key developments and recommendations, namely developing a GIS database and providing baseline information for nominated regions.

5.0 WETLAND RISK ASSESSMENT

The wetland risk assessment is a conceptual framework to assist in predicting and assessing change in the ecological character of wetlands. The framework has been adopted by Ramsar (resolution V11.10) and is now promoted as an integral component of the management planning processes for wetlands. The relevance of undertaking wetland inventories becomes apparent within this framework. A wetland inventory ultimately collects information for the wetland assessment framework. This information is also critical in order to develop monitoring programs.

5.1 Ecological Character

A central component of the wetland risk assessment is the ability to record the ecological character of a wetland. The first process comprises of the collection of information, the wetland inventory.

> *Ecological character is the sum of the biological, physical, and chemical components of the wetland ecosystem and their interactions that maintain the wetland and its products, functions, and attributes.*

Change in ecological character is the impairment or imbalance in any biological, physical, or chemical components of the wetland ecosystem, or in their interactions.

Van Dam *et al* (1999) outline five main causes of adverse change, namely:

1. changes to the water regime
2. water pollution
3. physical modification
4. exploitation of biological products
5. introduction of exotic species.

6.0 WETLAND INVENTORY METHODOLOGY

This section describes the approach and information collected for the wetland inventory. A wetland inventory can be defined as the collection of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities (Finlayson and Eliot, 2001). Costa *et al* (1996) also suggests that inventories have the attributes of set objectives over a given time-period with the aim of publishing and disseminating the information and making it available within a database.

6.1 Study area boundaries

The project boundary is defined by the Natural Heritage Trust administration boundaries for Eyre Peninsula. Refer to Map 1.

6.2 Site selection

The aim of the wetland selection process is to sample a broad range of wetlands within each region and where access was relatively simple. Factors such as time constraints and project budget was also a limiting factor in the number of wetlands selected.

Wetland sites identified by previous studies (eg Lloyd and Balla, 1986) and sites located in state and local government reserves were given priority for selection. These sites usually have information regarding the wetland and the surrounding natural resources.

6.3 GIS Database

This project builds on initiatives undertaken by Planning SA and the Department for Environment and Heritage. GIS databases are developed for the Murray River region Carruthers and Nicolson (1992) and published in the form of an Atlas, Jensen *et al* (1996). A GIS database exists for the South East region of the state and published in the form of a technical report (Carruthers and Hille 1997). One of the project scopes for this project is to provide a digital coverage of spatial boundaries of identified wetlands. This will provide a GIS database for Eyre Peninsula, Mount Lofty Ranges, Northern Agricultural Districts and Kangaroo Island. Gaps in coverage will occur simply due to project constraints, and it is suggested that these gaps be filled at a later stage.

A State-wide numbering system was developed for identifying wetlands which follows the system established for the Murray wetlands. The Murray region wetlands have been assigned the numbers S0001 to S0999. The South East region wetlands have been assigned the numbers S1000 to S1999, Northern Agricultural Districts S4000 to S4999, Kangaroo Island S5000 to S5999 and the Mount Lofty Ranges S2000 S2999. Eyre Peninsula is assigned numbers S3000 to S3999.
The system used to produce the wetlands data is the ESRI (Environmental Systems Research Institute) geographic information system (GIS) ARC/INFO. The GIS layer was created initially from the existing land cover layer that contained areas designated as swamps, vegetated swamps, lakes and vegetated lakes. This land cover layer was mapped from 1:40 000 colour aerial photography (Carruthers and Hille 1997).

6.4 Wetland inventory survey

In developing the wetland survey it was critical that information relevant to the wetland risk assessment framework was incorporated. This ultimately involves the collection of physical, biological and chemical parameters. Several survey methodologies were studied and incorporated; these included:

- Butcher R.J.(1999) *Assessing biodiversity in temporary and permanent wetlands.* Pp 50-53 in The Other 99%. *The Conservation and Biodiversity of Invertebrates*, ed by Ponder W and Lunney D, (1999). Transactions of the Royal Zoological Society of New South Wales

- Finlayson C.M. and Spiers A.G. (1999) *Techniques for enhanced wetland inventory and monitoring.* Supervising Scientist, Canberra

- Fairweather P.G. & Napier (1998) *Environmental indicators for national state of the environment reporting - inland waters.* Environment Australia

- Maher W & Liston P (1997) *Water quality for maintenance of aquatic ecosystems: Appropriate indicators and analysis. Australia: State of the Environment Technical Paper Series. (Inland waters).* Environment Australia

- Morelli J & de Jong M (1996) *A Directory of Important Wetlands in South Australia.* South Australian Department of Environment and Natural Resources, Adelaide

- Storey A.W., Lane J.A.K and Davies P.M. (1997) *Monitoring the ecological character of Australia's wetlands of international importance (RAMSAR Convention).* Western Australian Department of Conservation and Land Management and Biodiversity Group of Environment Australia.

6.5 Wetland survey template

For each wetland surveyed physical, biological and chemical information was collected. A brief outline is given below. The complete wetland survey descriptions are given in Appendix 1.

Physical parameters

- Wetland Reference Number
- Ramsar Site
- Land Use
- Land Element
- Wetland Name
- Description of Site
- Tenure
- Geology

Biological parameters

- Vegetation Associations
- Biological Threats
- Noteworthy Flora and Fauna
- Aquatic Vegetation Classes

Chemical parameters

- Dissolved Oxygen
- Conductivity
- Turbidity
- pH
- Temperature

7.0 INTRODUCTION

Wetland assessment involves the identification of the status of and threats to wetlands as a basis for the collection of more specific information through monitoring activities. In essence, Section Two of this report analyses the survey results by looking at each relevant survey parameter individually. This comprises a background discussion, analysis and discussion of results.

8.0 EYRE PENINSULA

8.1 Wetland overview

Eyre Peninsula contains excellent examples of inland saline lake systems found within South Australia. These wetland systems are confined mainly to the south-west of the Peninsula. There are also several areas with good quality coastal wetland systems consisting of mangroves and samphire flats; these are located within the numerous bays and tidial inlets around the Peninsula. The eastern portion of Eyre Peninsula contains many degraded saline lake systems and the occasional freshwater wetland. These remaining freshwater wetlands are quickly becoming saline due to the effects of dryland salinity. Threats to deteriorating water quality in wetlands include vegetation clearance contributing to increased salinisation, livestock grazing, introduced plants and animals, altered water regimes and introduction of industries dependant upon irrigation are affecting wetland areas on Eyre Peninsula.

There are several inland wetland areas on Eyre Peninsula that are listed in the Directory of important wetland for South Australia. These include Big Swamp, Little Swamp, Sleaford Mere, Lake Newland and Lake Hamilton.

A total of 27 wetlands were surveyed. Some are conserved within the South Australian reserve system, including Lake Newland in Lake Newland Conservation Park and Sleaford Mere and Pillie Lake within Lincoln National Park. Other wetland areas protected in the reserve system but not covered by the survey include Coffin Bay Conservation Park and Calpatanna Waterhole Conservation Park.

Refer to Map 2 for wetland survey localities.

9.0 WETLAND LAND USE

9.1 Background

On site and surrounding land uses can have major impacts on wetlands. The most common land uses on Eyre Peninsula include cropping and grazing. Land used for cropping can lead to bank erosion, depleted soil structure and loss of nutrients. Dryland salinity is significantly increased in areas where deep-rooted vegetation has been replaced by annual crops. Grazing by domestic stock affects wetlands by removing vegetation, breaking up of the soil surface, distributing weed species and increasing organic nutrients through faecal deposits. Land set-aside for conservation purposes either through the reserve system or on-farm conservation have the least impact but currently comprise the minority of wetland land uses.

9.2 Analysis

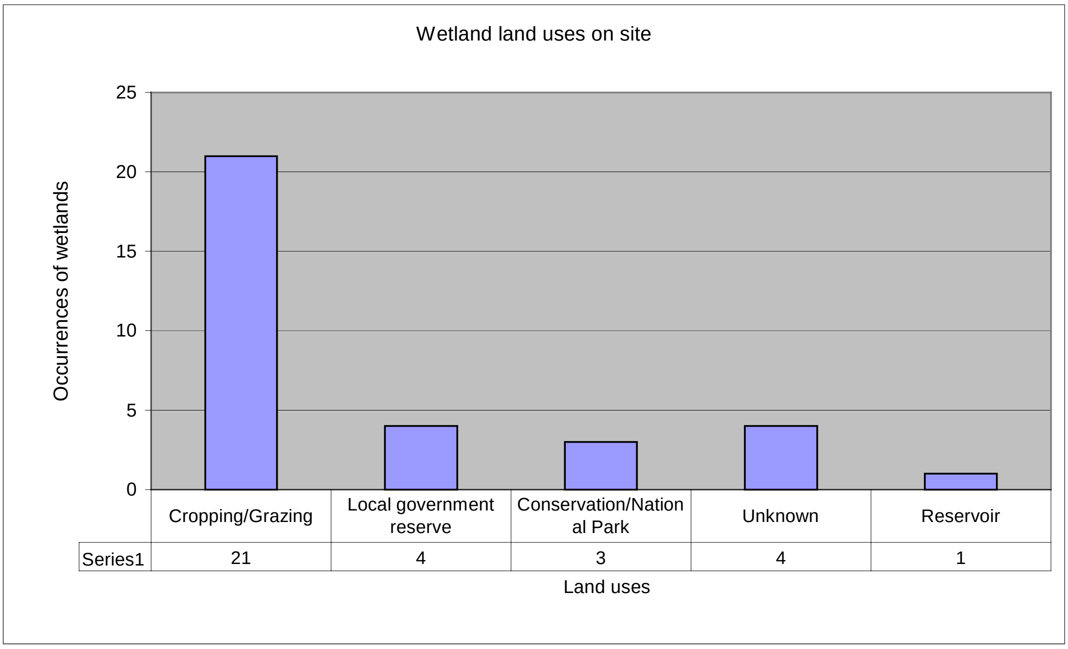


Figure 1. On site wetland land uses

Twenty-one occurrences of cropping and grazing were recorded as the main land uses within or adjacent to wetlands surveyed on Eyre Peninsula. Land uses for four wetlands were classified as unknown. These are areas that have been rested from primary industry or are roadsides or lands with no clear land use allocation. Wetlands located within NPWSA reserves were sufficiently protected from deleterious surrounding land uses.

10.0 TENURE AND MANAGEMENT AUTHORITY

10.1 Background

The type of management authority and tenure surrounding a wetland often dictates the type and level of protection and management for the wetland. An understanding of this parameter also allows consideration of different legislation and approaches concerning on-site management and planning for wetland areas.

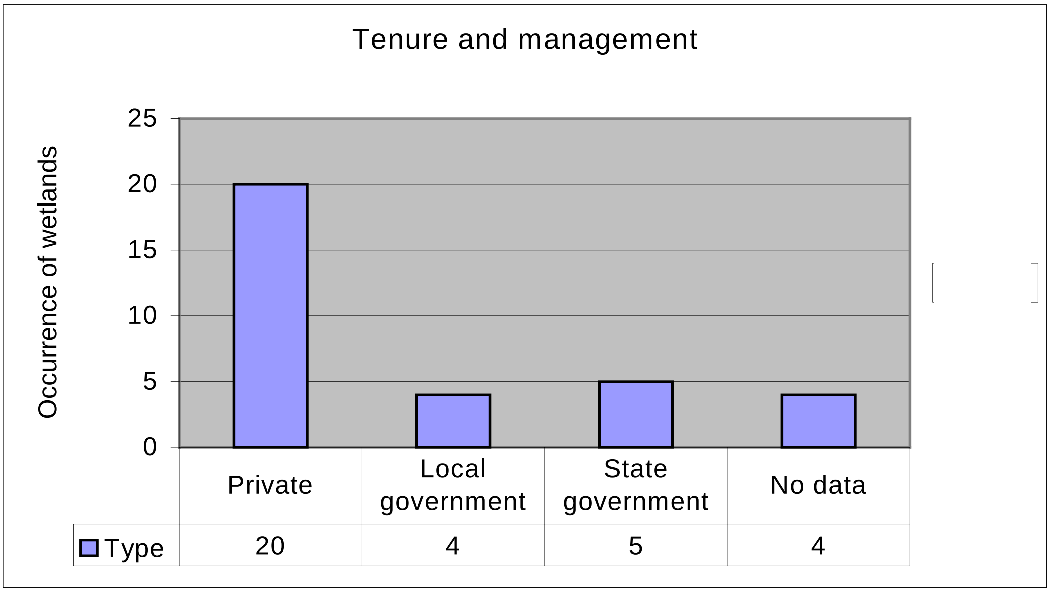


Figure 2. Tenure and management

10.2 Analysis

Private tenure and management was the most common occurrence with 20 sites recorded. This suggests that the management of wetlands surveyed on Eyre Peninsula lies with private landholders. This factor has implications for the management of wetlands for biodiversity, and highlights the importance of off reserve conservation programs.

11.0 ENVIRONMENTAL REGIONS

11.1 Background

Laut *et al* (1977) described and mapped South Australia hierarchically into Environmental Provinces, Environmental Regions and Environmental Associations. The three tiers are based on geological formations and vegetation type. Eyre Peninsula is part of the Eyre and Yorke Peninsula Province. This province is divided into six Environmental Regions, which are based on vegetation criteria. The wetland survey is contained within three of these regions.

The Southern Highlands and Plains Environmental Region encompasses the southern section of the uplands of the Koppio Hills and along the east coast of Eyre Peninsula, and the undulating to low hilly plains to the west. The western boundary represents a change from duplex soils on the hilly or undulating country to sands and calcarenite plains, the north is defined by inland dune landforms (Laut *et al* 1977).

The West Coast Environmental Region is comprised predominantly of undulating to hilly plains on calcarenite with local rises and the occasional steep-sided hills on quartzite on the west side of Eyre Peninsula. Dunes are restricted to the coastal fringe where they occur in association with lagoons and lakes (Laut *et* al 1977).

The Central Mallee Plains and Dunes and Environmental Region extends across Eyre Peninsula from its western extremity to Spencer Gulf. It is distinguished climatically by being more arid than regions to the south, and this is reflected in the vegetation. The northern margin is formed by the dunefields of the Great Victoria Desert and the eastern margin by the Gawler Ranges. The region is essentially an undulating plain with an extensive cover of dunes and sand sheets (Laut *et al* 1977).

11.2 Analysis

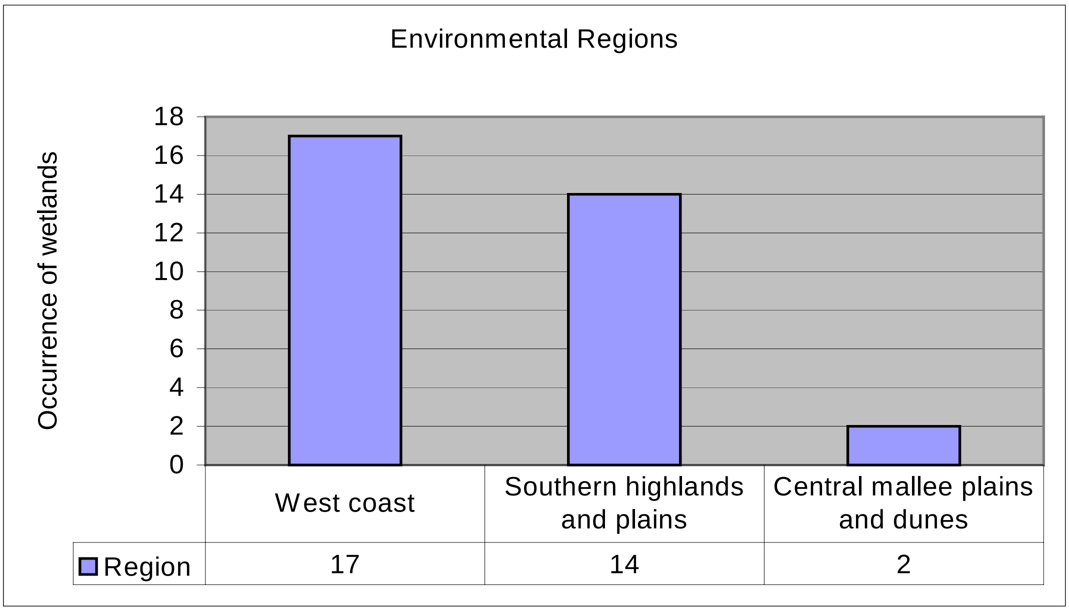


Figure 3. Wetlands within environmental regions

The West Coast and the Southern highlands and plains regions contained most of the wetlands surveyed. This suggests that more wetlands occur in these regions, which correspond to the geological characteristics of limestone or highland wetland formations.

12.0 KEY BIODIVERSITY AREAS

12.1 Background

Key Biodiversity Areas are used to define areas of high biodiversity on Eyre Peninsula. The ability of overlying wetlands surveyed within Key Biodiversity Areas assists in highlighting wetlands located in environmental significant areas. Two key biodiversity areas are identified in the *Biodiversity Plan for Eyre Peninsula* (Matthews, 2001). These are large remnant areas and threatened habitat areas which have been developed by combining the biological assets of Eyre Peninsula. Refer to Map 3 for Key Biodiversity Areas.

12.1.1 Large remnant areas

These areas have been identified on the basis that they contain large blocks of vegetation, good linkages, species diversity and populations of species with high conservation significance. Two large remnant areas have been identified on Eyre Peninsula, the ‘Central North-West linkage’ and the ‘Jussieu Peninsula to Coffin Bay Peninsula’.

Central North-West Linkage is almost a continuous vegetated band stretching from central Eyre Peninsula to approximately the Poochera district. Large areas are dedicated to the South Australian reserve system and private Heritage Agreement areas. A network of Heritage Agreements and reserves has formed an almost continuous linkage of habitat up to 200 kilometres long (Matthews 2001).

Jussieu Peninsula to Coffin Bay Peninsula is located south of Flinders Highway between Port Lincoln and Coffin Bay. The area includes two large National Parks (Lincoln and Coffin Bay) along with Kellidie

Bay, Sleaford Mere and Kathai Conservation Parks and a number of Heritage Agreements (Matthews 2001).

12.1.2 Threatened Habitat Areas

Threatened Habitat Areas have been identified on the basis that they are:

- selectively cleared and modified resulting in low remnancy of plant communities
- poorly conserved within reserve systems
- fragmented and contain regionally threatened plant communities
- contain large numbers of species of high conservation significance.

Five Threatened Habitat Areas have been identified on Eyre Peninsula. These are Koppio Hills, Cleve Hills, South-west, Sheoak Grassy Woodlands and the Far West Threatened Habitat Areas (Matthews 2001).

Koppio Hills Threatened Habitat Area contains small scattered remnants of highly significant vegetation communities such as the regionally threatened community of *E. camaldulensis* woodland (river red gum). The Koppio Hills cover an area of approximately 96,000 hectares with a total area of native vegetation of 18,000 hectares (Matthews 2001).

Cleve Hills Threatened Habitat Area has been identified as a Threatened Habitat Area due to a number of threatened and endemic species. The boundary of this area has been made on the southern and eastern boundary at approximately 200m above sea level (Matthews 2001).

South-West Threatened Habitat Area has been identified due to a number of significant biological features of this area. This area includes the plains to the south-east of Lake Hamilton, and includes the large areas of salt lakes including Lakes Malata and Greenly. The South-West Threatened Habitat Area comprises 172,000 hectares with a total of 25,000 hectares of native vegetation.

Sheoak Grassy Woodlands Threatened Habitat Area contains scattered sheoak populations, *Allocasuarina verticillata* and temperate native grasslands and grassy woodlands. Sheoak Grassy Woodlands comprises an area of 123,000 hectares with 27,000 hectares of native vegetation.

Far West Threatened Habitat Area has been identified due to a number of significant biological features of this area. This area contains several vegetation communities that have been identified as being rare or threatened. Unlike the other Threatened Habitat Areas the Far West extends down to the coast and incorporates high biodiversity coastal areas. Areas such as Tourville Bay contains mangroves and salt marshes for wading birds and other wetland species (Matthews 2001).

12.2 Analysis

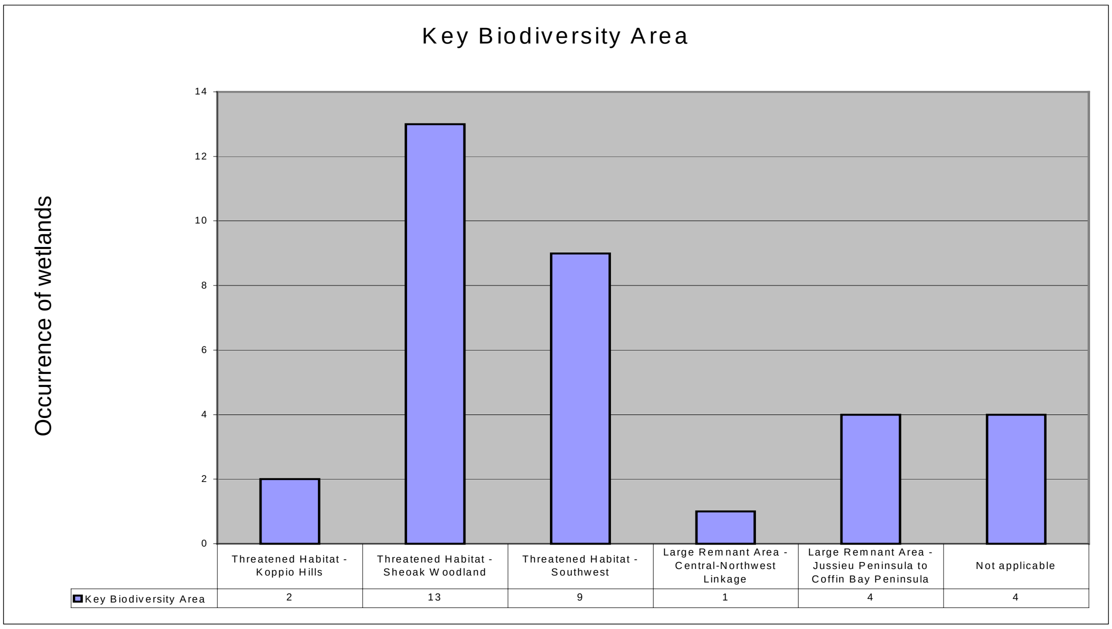


Figure 4. Wetlands within Key Biodiversity Areas.

The grouping of Threatened Habitat Areas has the highest wetland occurrence, especially within the subgroup of Sheoak Grassy Woodlands (13 sites). This is understandable due to the characteristic calcrete sheets formations which have formed wetland areas in weathered or cracked calcrete sheets. The South-West Threatened Habitat Area contains wetlands such as Lake Hamilton and Lakes Malata and Greenly. Again, geological formations (dune and calcrete) have dictated much of the distribution of wetlands in this area. Several wetland sites are located within the Large Remnant Area of the Central-Northwest Linkage, these wetlands are mostly located within Lincoln National Park and Coffin Bay National Park.

13.0 WETLAND AREA

13.1 Background

The area of wetlands was calculated by using ArcView GIS based on ISB/GAR Landcover – 1991 Photography, River/Lakes Layer 2000, Evaporation Basins 2000.

13.2 Analysis

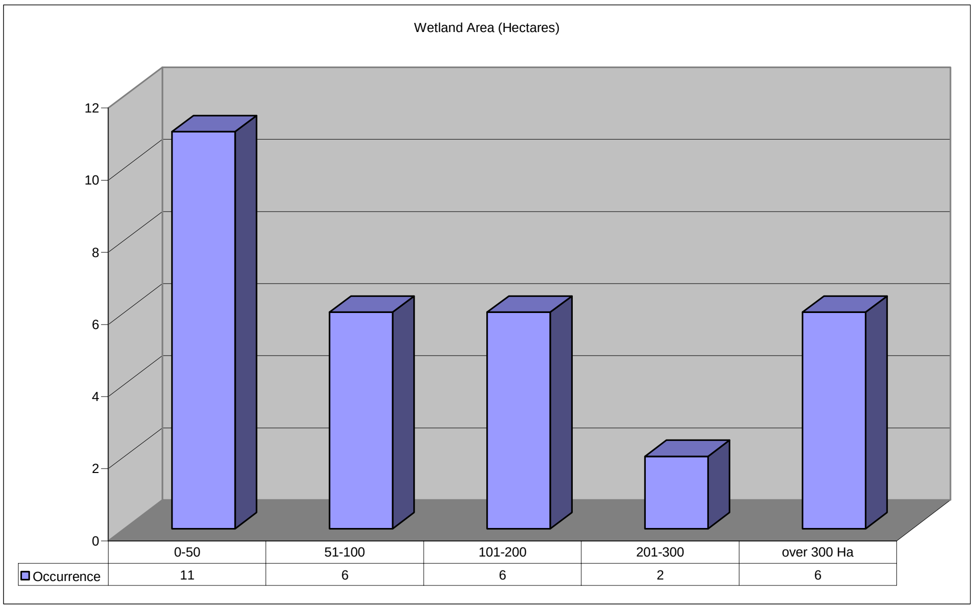


Figure 5. Wetland Area.

The total wetland area for Eyre Peninsula is approximately 64,000 hectares with a mean of 21 hectares and a maximum of 3,170 hectares. With only 13,000 hectares having baseline data, the opportunity exists for the other 51,000 hectares to be mapped and baseline data attributed to these wetlands.

Wetlands over 300 hectares in size include Sleaford Mere (707 ha), lake Hamilton (1,900 ha) and Lake Greenly (2,629 ha).

14.0 LANDFORM ELEMENT

14.1 Background

Landform element definitions have been adapted from Heard and Channon (1997) "Guide to a native vegetation survey using the biological survey of South Australia methodology, Section 3". Geographic Analysis and Research Unit, Department of Housing and Urban Development.

14.2 Analysis

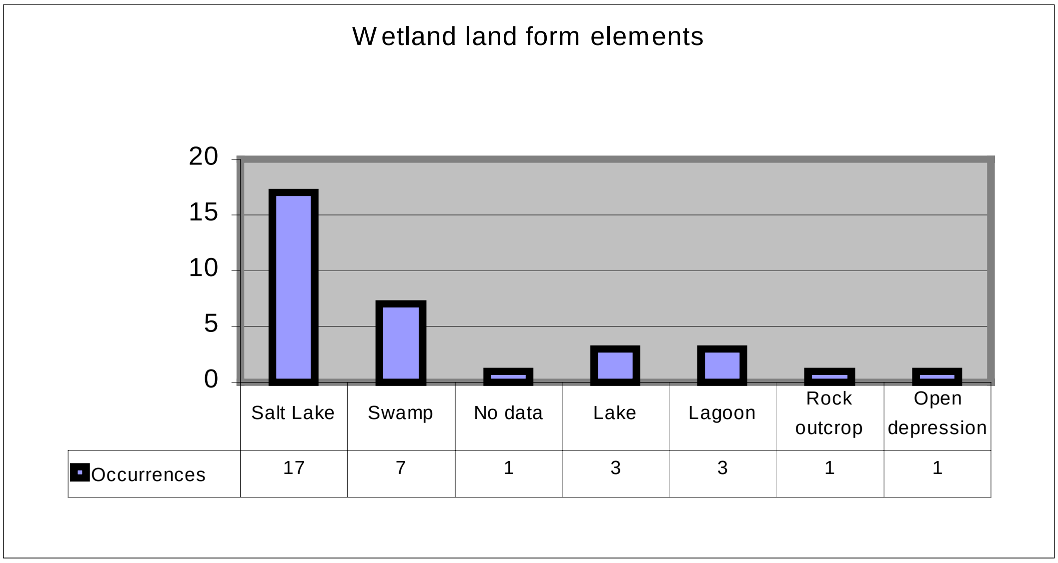


Figure 6. Wetland landform elements.

Salt lakes were the most common wetland sampled. Salt lakes are defined as lakes that contain a concentration of mineral salts (predominantly sodium chloride in solution as well as magnesium and calcium sulphate). Swamps were the next most common wetland landform with seven occurrences (eg Old Plough Swamp and Elliston Cemetery Swamp). Swamps are generally level or closed depressions with a seasonal or permanent water table at or above the surface; sometimes biological (peat) accumulation occurs.

15.0 GEOLOGY

15.1 Background

Eyre Peninsula is underlain by a basement of crystalline rocks, mainly granite and gneiss. The triangular shape of the peninsula is due to the intersection of two major fault zones. The Lincoln fault runs along the east coast, south-west from the vicinity of Port Augusta and another fault runs from the southern tip of the peninsula north-west to Elliston. The northern section of the peninsula is separated from the Gawler Ranges by the Corrobinnie depression. This depression also extends southwest from Minnipa and is characterised by a series of ephemeral salt lakes (Matthews 2001). The Corrobinnie depression contains old limestone formations, which forms series of sub-surface water areas. The Bridgewater Formation containing these limestone formations is a dominant geological band along the west coast. A number of basins are located within this area, namely the Lincoln, Uley South, Uley Wanilla and Polda Basins. Refer to Map 4 for the geology underlying the surveyed wetlands.

15.2 Analysis

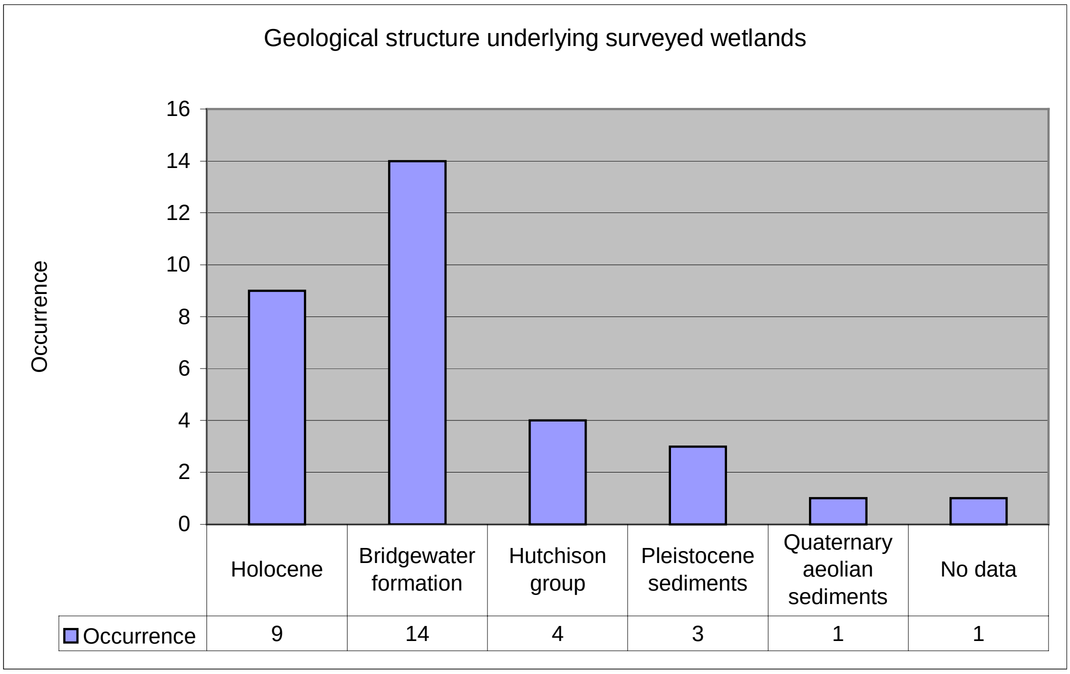


Figure 7. Geological structure underlying wetlands.

The majority of wetlands are located within the Bridgewater Formation (eg salt lakes near Elliston and Lake Hamilton). The Bridgewater Formation consists of partly cemented calcareous sand usually calcreted at the surface. This formation extends from south of Port Lincoln along the west coast to beyond Streaky Bay. Calcrete is formed by dissolution and replacement of shell fragments which gradually develops a nodular or sheet of hardened material (Parker *et al,* 1985). Several of the wetlands surveyed are underlaid by Holocene sediments (eg Round Lake and Sheringa Lagoon) these sediments form the base of the longitudinal sand dunes of the Corrobinnie Depression. The Holocene sediments are described in Map 4 as undifferentiated alluvial/fluvial sediments. The soil characteristics tended to reflect the underlying geological formations, hence the majority of soils ranged from calcareous sands to silty loams and clays.

16.0 HYDROLOGY

16.1 Background

The wetland survey recorded average annual rainfall for wetland areas and made observations on the main sources of water for the wetlands. The mean average annual rainfall varies from 550 mm to 500 mm on the south of the Peninsula to 400 mm in the north-western section near Elliston and 350 mm near Cleve in the north-east. Nearly all of the rainfall is during winter with Port Lincoln receiving an average rainfall of 260 mm and Elliston of 200 mm (Schwerdtfeger, 1985). Evaporation is high in summer throughout the region and mean monthly evaporation exceeds median monthly rainfall throughout the year except in southern areas in winter.

Surface water is the most common source of water for wetlands on Eyre Peninsula. The surrounding catchment plays a critical role in supplying and filtering water for the lower lying drainage depressions that form the wetlands. Extensive vegetation clearance in many areas has resulted in increases in dryland salinity which has increased water salinity levels. This has affected aquatic fauna composition, aquatic flora and surrounding terrestrial flora. Groundwater occurs in three geological environments which are Pre-cambrian, Tertiary and Quaternary ages. The most important of these is the Bridgewater Formation; refer to Map 4. This formation houses the three southern basins, Lincoln, Uley South and Uley Wanilla. Recharge for these basins is mainly from rainfall (Matthews, 2001).

16.2 Analysis

All of the wetlands surveyed had annual rainfall ranges between 400 and 500 mm. Limited information is available on the groundwater connections to the wetlands surveyed. The Polda Basin near Elliston may have some impact on surrounding wetlands and the Lincoln Basin probably influences Big Swamp and Sleaford Mere. The majority of the information available regarding water resources on Eyre Peninsula is focused on water supplies for human consumption and use by stock; there is a need for investigations regarding water requirements for biodiversity.

17.0 PLANT ASSOCIATION SUMMARY

17.1 Background and Analysis

A large proportion of the wetlands surveyed within the three regions are considered to be saline (>3000EC). Aquatic flora was noticeably scarce in most water bodies, especially in hyper-saline water bodies (>100 000EC). Those species that tend to dominate saline areas are mainly terrestrial-aquatic species. Genera of the family Chenopodiaceae are common including Halosarcia and Sarcocornia (glassworts or samphires). Several species of submerged aquatic genera (Ruppia and Lepilaena) also occur within saline water bodies. These genera tend to form the understorey and ground cover within the structural vegetation formation surrounding wetlands.

The most common canopy vegetation type is *Melaleuca halmaturorum ssp*. *halmaturorum. Melaleuca halmaturorum ssp*. *halmaturorum* tall shrubland is considered rare on Eyre Peninsula. The wetland survey recorded 13 sites with *Melaleuca halmaturorum* as the dominant vegetation association and four sites recorded *Melaleuca halmaturorum* over *Gahnia filum* (which is recognised as a threatened plant community on Eyre Peninsula). Several sites recorded Eucalyptus species (*E. camaldulensis* at three sites and one site with *E. diversifolia*). The remaining sites recorded introduced grasses either with or without *Melaleuca halmaturorum* forming the canopy.

The ecological role of *Melaleuca halmaturorum* as a fringing saline wetland species is very important. *Melaleuca halmaturmorum* often forms an effective buffer for water bodies from increased sediment loads and nutrient concentrations. Greenway (1997) discusses some further direct benefits from *Melaleuca halmaturorum.* These include:

Hydrological benefits

- Improved water quality by filtering suspended particles and by removing, recycling, or immobilising contaminants and nutrients, thereby preventing deterioration of downstream aquatic ecosystems

- Provide a protective buffer zone between shorelines, estuaries and river systems protecting these waterways from siltation, nutrient runoff and erosion

- Provide flood mitigation by storing and detaining precipitation and runoff thus reducing flow rates and peak floods

- Provide groundwater recharge and a water source for people and wildlife.

Ecological benefits

- Melaleuca trees are highly productive at recycling nutrients and function as long-term biomass sinks

- During major flood events, particulate matter is washed into the rivers and estuaries to provide a food source for heterotrophic mirco-oranisms and detritivores

- Provide both temporary and permanent habitats for a variety of flora and fauna, including roosting and breeding areas for wildlife, some Melaleuca swamps support large ibis and egret colonies

- Provide refuges for wildlife during periods of drought

- Melaleuca trees flower prolifically and provide a source of nectar for resident and migratory birds, bats, possums, bees and other insects. Their nectar is a particularly valuable food source for migratory honey eaters and parrots during the autumn/winter months.

Threats

There are several key threatening processes which affect the majority of remnant *Melaleuca halmaturorum* woodlands. Drainage or water extraction, which influences soil chemistry, is common and can cause acid sulphate soils.
Increased nutrients moving into the water due to catchment clearance may result in vegetation dieback and change in water chemistry. *Melaleuca halmaturorum* requires fresh water flushing on a seasonal basis to stimulate regeneration of seedlings and maintenance of existing specimens.

Plate 1. *Melaleuca halmaturorum* tall shrubland over *Halosarcia* sp.
Low open shrubland. Hamp Lake near Elliston.

Melaleuca halmaturorum in full flower providing excellent nectar source for insects.

North of Wanilla, Eyre Peninsula.

Plate 2. *Melaleuca halmaturorum*

Typical example of a wetland with introduced grasses as the dominant vegetation.

Meadow Pool, central west region, Eyre Peninsula.

Plate 3. Introduced grasses

Example of a wetland with Gahnia sp. as the dominant vegetation association.

Orana Swamp, central west region, Eyre Peninsula.

Plate 4. Gahnia sp.

18.0 DEGRADATION AND DISTURBANCE

18.1 Background

Disturbances or threats are defined as any direct or indirect human activities at the site or in the site or in the catchment area that may have a detrimental effect on the ecological character of the wetland. The effect may be a low level disturbance such as low stocking rates or major threats from water diversion schemes.

18.2 Analysis

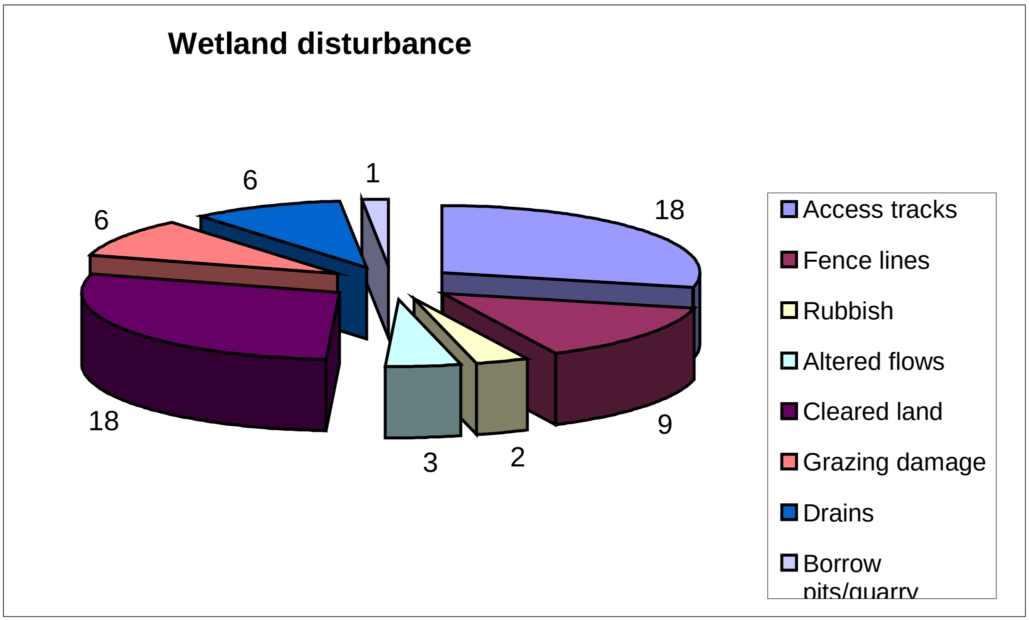


Figure 8. Wetland disturbance

Many wetlands were found to have a number of disturbances at the one site, the two most frequent disturbances recorded were access tracks and cleared land. The majority of wetlands are located on private property where cleared land for cropping and access tracks are a necessity. Many of the tracks are located adjacent to wetlands and clearance for cropping occurs to the wetland edges. Drains, grazing and fence lines are also common disturbances. Rubbish dumping occurred within two wetlands, both on private property. Altered flows commonly involved extracting water for irrigation or the construction of levy banks for vehicle access and drainage.

Flinders Highway dissecting the central and northern lagoons of Big Swamp.

Plate 5. Flinders Highway

19.0 AQUATIC VEGETATION CLASSES

19.1 Background

Parameters for seven classes of aquatic vegetation were included in the survey. These records can indicate the types of producers within the wetland system. The diversity of classes recorded may indicate a level of aquatic biodiversity present, or lack of plants recorded indicates limited primary production within the wetland system.

The vegetation classes consisted of:

- Algal
- Aquatic Moss
- Rooted Vascular
- Floating leaved
- Floating vascular
- Submergents
- Surface vegetation
-

Algal and aquatic moss commonly comprise Charophyta (stoneworts) and Chlorophyta (green algae) which forms macroscopic mats either attached to plants or in open water. Algal forms the basis for photosynthetic basis for the open water food sources in many inland waters (Boulton and Brock, 1999). For green algae images see: http://www.nmnh.si.edu/botany/projects/algae/Imag-Chl.htm.

Floating vascular/leaved plants have part or all of the leaves at the waters surface. Examples include *Azolla* species floating ferns that host bacteria that fix nitrogen (Romanowski,1998), *Lemna*, *Spirodela* and *Wolffia* (duckweeds) and members of the family Utricularia (bladderworts). Members from the family Potamogetonacea (pondweeds) are also common floating plants and can be found in a variety of habitats. All these plants are able to provide habitat for invertebrates, provide shelter for fishes and produce oxygen.

Rooted vascular plants are those rooted in the sediments with either a major proportion of material above water (reeds, rushes and sedges) or totally under water (*vallisneria* spp.). Many of these plants play a key role in nutrient cycling and provide habitat for birds, insects and aquatic invertebrates. Typical genera include Baumea, Bolboschoenus, Carex, Cyperus, Gahnia, Schoenus, Juncus, Triglochin and Myriophyllum. Myriophyllum is a distinctive wetland genus that provides food, shelter and spawning or nesting sites for a variety of animals, from invertebrates to fish, frogs and birds, (Romanowski,1998).

19.2 Analysis

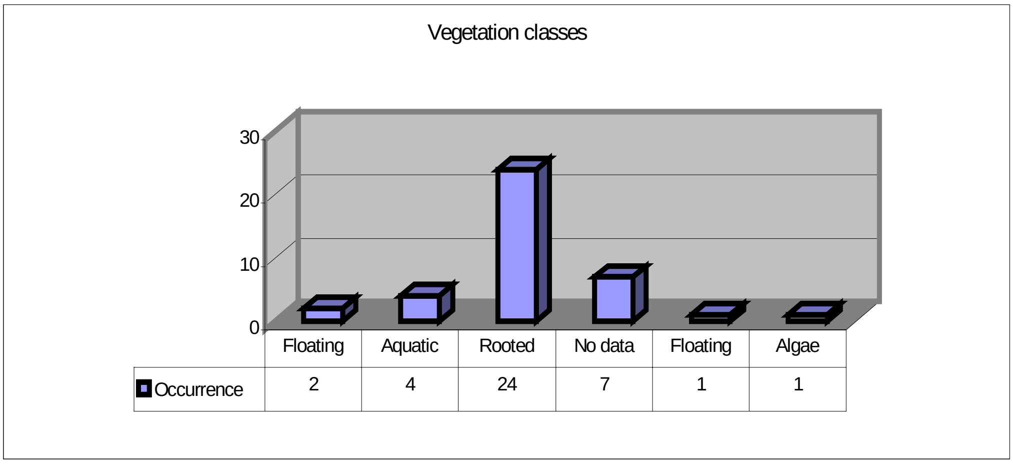


Figure 9. Aquatic vegetation classes recordeded.

The aquatic class of rooted vascular is the most common form of vegetation class within the wetlands surveyed. Genera such as Myriophyllum, Halosarcia and Sarcocornia were frequently recorded within those wetlands that are not hyper-saline. The genus Gahnia was also recorded at some sites with fresh to saline waters. Vegetation composition and abundance is strongly linked with salinity levels, many saline wetlands surveyed had very little aquatic vegetation abundance or diversity. The majority of vegetation was in the form of terrestrial-aquatic species such as samphires.

20.0 AQUATIC INVERTEBRATE ANALYSIS

20.1 Background

Macro and micro invertebrates are an essential component of the wetland food web. They are responsible for a significant proportion of the secondary production occurring in wetlands, and form two interconnected wetland food chains, a grazing food chain and a detrital food chain, Davis and Rolls (1987). Invertebrates comprise much of the diet of waterfowl populations the diversity and abundance of waterfowl can be a direct consequence of the invertebrate food supply.

20.1.1 Ecological benefits

Yen and Butcher (1997) provide some examples of direct ecological benefits that invertebrates contribute.

Tangible direct benefits:

1. Plant pollination
2. Effects on soil; soil formation and fertility.
3. Decomposition; fragmentation and recycling of dead plant and animal material.
4. Position in the food web; invertebrates are the principle food for many vertebrates. They form a basic element in food chains and networks which underlie the general balance of nature
5. Preditation and parasitism; involved in the natural regulation of populations of other species through predation and parasitism; and thus form the basis of biological control.

Indirect ecological benefits:

- *Ecosystem stability:* the loss of species from highly interrelated systems is likely to cause a cascade of further losses.

- *Evolutionary time*: diversity within ecosystems maintains greater diversity.

20.1.2 Trophic dynamics

Standing water communities are dynamic systems which reflect change in many variables. The trophic state of a wetland depends on nutrient inputs from the catchment and within the wetland (Boulton and Brock 1999). If samples from all trophic groups are collected, this could suggest that the aquatic ecosystem is a reasonable state of equilibrium. The top of the food chain is occupied by vertebrate predators, including fish, water rats and water birds. Terrestrial predators can be considered to be on the top of the aquatic food chain, and provide a pathway for export of nutrients and other material from the wetland ecosystem (Boulton and Brock 1999).

Primary producers

Primary producers form two groups those that are suspended or floating and those attached to substrate or other plants. Attached macrophytes includes frindging reeds and submerged plants and periphyton (the biota attached to submerged surfaces). Suspended or floating forms generally consist of the phytoplankton and algae groups. Phytoplankton form the basic photosynthetic basis for the open water food web in most standing waters

Consumers

There are two main types of consumers based on diet: grazers that consume plants and predators that consume other animals.

Grazers

Grazers consist of aquatic snails (Gastropoda) and some mayfly nymphs (Ephemeroptera), caddisfly larvae (Trichoptera) and beetles (Coleoptera). These groups are usually found near the edges of the water body. Within the open water, some of the important grazers are zooplankton, including rotifers, water fleas (Cladocera) and copepods (Calanoida and Cyclopoida).

Vertebrate Grazers

Vertebrate grazers generally consist of groups such as tadpoles, fish and waterbirds. Vertebrate grazers can influence the food web considerably when attracted to water bodies in times of flood or in types of drought.

Predators

Predators include dragonfly larvae (Odonata) which tend to ambush prey and invertebrates that hunt in open water such as diving beetles (Dytiscidae, Coleoptera) (Boulton and Brock 1999). Areas such as the littoral zone tend to have high biodiversity of grazers which in turn attracts many invertebrate predators.

20.2 Salt Lake Systems

Freshwater organisms in Australia generally tolerate salinities up to about 3 gL (3000 EC), and beyond this there are changes in community composition, with decreased richness and increased abundance (Williams, 1998; Skinner *et al* 2001). The biological process in salt lakes can resemble those of fresh water bodies despite the differences in physical, chemical and biological attributes (Boulton and Brock 1999). The beds of many salt lakes are covered with benthic microbial mats dominated by photosynthetic producers, and lake crusts contain propagules of decomposers, producers and consumers. Boulton and Brock (1999) comment that little is known about the microbial loop in salt lakes.

A high diversity of invertebrates can occur within salt lakes, examples include rotifers, anostracan, cladocerans, calanoid copepods and ostracods. Fishes are usually absent from saline lake systems and the top consumers are mostly water birds.

In general, invertebrate species richness in salt lakes declines with increasing salinity, but at intermediate salinities where many species tolerances are broad, other factors such as biological interactions, pH will affect community composition (Skinner *et al,* 2001; Williams 2000). Studies by Skinner *et al* (2001) indicates that salinization shifts invertebrate community structure and algae tends to also become dominant at the higher salinity levels. This could lead to insufficient food for animals higher in the trophic level, including fish and waterfowl.

20.3 Temporary Wetlands

Many of South Australia's inland wetlands are temporary and display slightly different invertebrate fauna composition from other wetland systems (saline lakes or permanent waters) Williams (2000) makes four general conclusions from his study of temporary wetlands.

1. Faunal diversity is high and often higher than in many permanent wetlands.
2. A wide range of fauna groups occurs, the particular assemblage depending largely upon time from filling. Many species are restricted to temporary wetlands, for example all notostracan, conchostracan and anostracan species are restricted to temporary wetlands.
3. Local differences in hydrology, filling frequency, basin shape and other factors often result in differences between wetlands in the same area and same time.
4. Considerable continental and regional endemism prevails. Most macofaunal species are endemic to Australia.

The filling or flooding of temporary water bodies realises a pulse of nutrients that, together with light and water, provide the resources for germination and growth of both micro and macro photosynthesizers. Habitat for consumers and decomposers soon follows. The invertebrate sediment egg bank with desiccation-resistant stages seems to be the initial source of colonists. The groups that tend to be first in temporary waters include rotifers, ostacods, copepods and cladocerans.

When the water body starts to dry a 'predator soup' results, and terrestrial predators (eg birds) come to the water to feed during the drying process. This process forms a critical trophic link between aquatic and terrestrial systems (Boulton and Brock, 1999).

20.4 Analysis

Thirty-three sites were surveyed with 18 sites returning invertebrate sample results. The remaining 15 sites did not have invertebrates present; these are hyper saline wetlands that do not support micro invertebrates, or had water levels that were to low too retrieve samples. Overall species composition, richness and trophic structure is quite deficient in wetlands surveyed on Eyre Peninsula.

20.4.1 Invertebrate abundance

Table 1 illustrates the invertebrate abundance sampled within the 18 survey sites. Twenty-three species were recorded in total. The average abundance of species within each wetland is approximately four species. Abundance levels varied from one species to 14 species, with three species showing substantially higher frequency of occurrence than the other 15 species. Two of these species are from the family Ostracoda (*Candonocypris* sp. and *Diacypris* cf. *spinosa*) and the other *Daphniopsis pusilla* is from the family Cladocera. Both families are widely distributed and common, occurring within inland waters fresh and saline. Ostracods vary in form, some being swimmers, clingers, climbers or burrowers. Cladocerans usually live on the substrate where they feed on fine particulate matter, others are mainly free-swimming and constitute an important part of the plankton of the open water (Williams 1980). Cladocerans are also an important food for zooplanktivorous fish. Their nutritional value is high, they are in particular rich in essential highly unsaturated fatty acids and natural anti-oxidants.

Table 1. Invertebrate abundance

Invertebrate identification	**Number of records**
Acanthocyclops sp.	2
Alona sp.	2
Atherinosoma sp.	1
Austrachiltonia australis	4
Bennologia australis	2
Boeckella triatriculata	5
Calamoecia cilitellata	4
Calamoecia salina	5
Candanocypris sp.	14
Chydorus cf.sphaericus	1
Coxiella striata	1
Cypricercus sp.	5
Daphnia cf. carinata	4
Daphniopsis pusilla	8
Diacypris cf. spinosa	10
Liyodromus sp.	6
Macrothrix spp.	6
Mesochra cf. baylyi	2
Mesocyclops spp.	1
Metacyclops cf. mortoni	6
Mytilocypris	4
Parartemia cf. zietziania	3
Simocephalus cf. elizabethae	1

Plate 6. Diacypris cf. spinosa.

Diacypris cf. *spinosa*. (family Ostracoda) 40X
Ten records were recorded.

Plate 7. Daphniopsis pusilla

Daphniopsis pusilla (family Cladocera)
40X. Eight records recorded.

20.4.2 Invertebrate diversity

Figure 10 illustrates invertebrate diversity by wetland site. Two wetlands stand out as having high diversity; these are S3033 (Old Plough Swamp) and S3006 (Big Swamp). Both sites have different landform characteristics, vegetation and water regimes, but with the same occurrence of invertebrate diversity. Wetland sites S3023 (Lake Tungketta) and S3022 (Middle Lake) are very similar, both being typical salt lake systems with invertebrate species common to both sites. Genera common to both sites includes *Mytilocypris*, *Austrachiltonia*, *Calamoecia*, *Diacypris* and *Ilyodromus*.

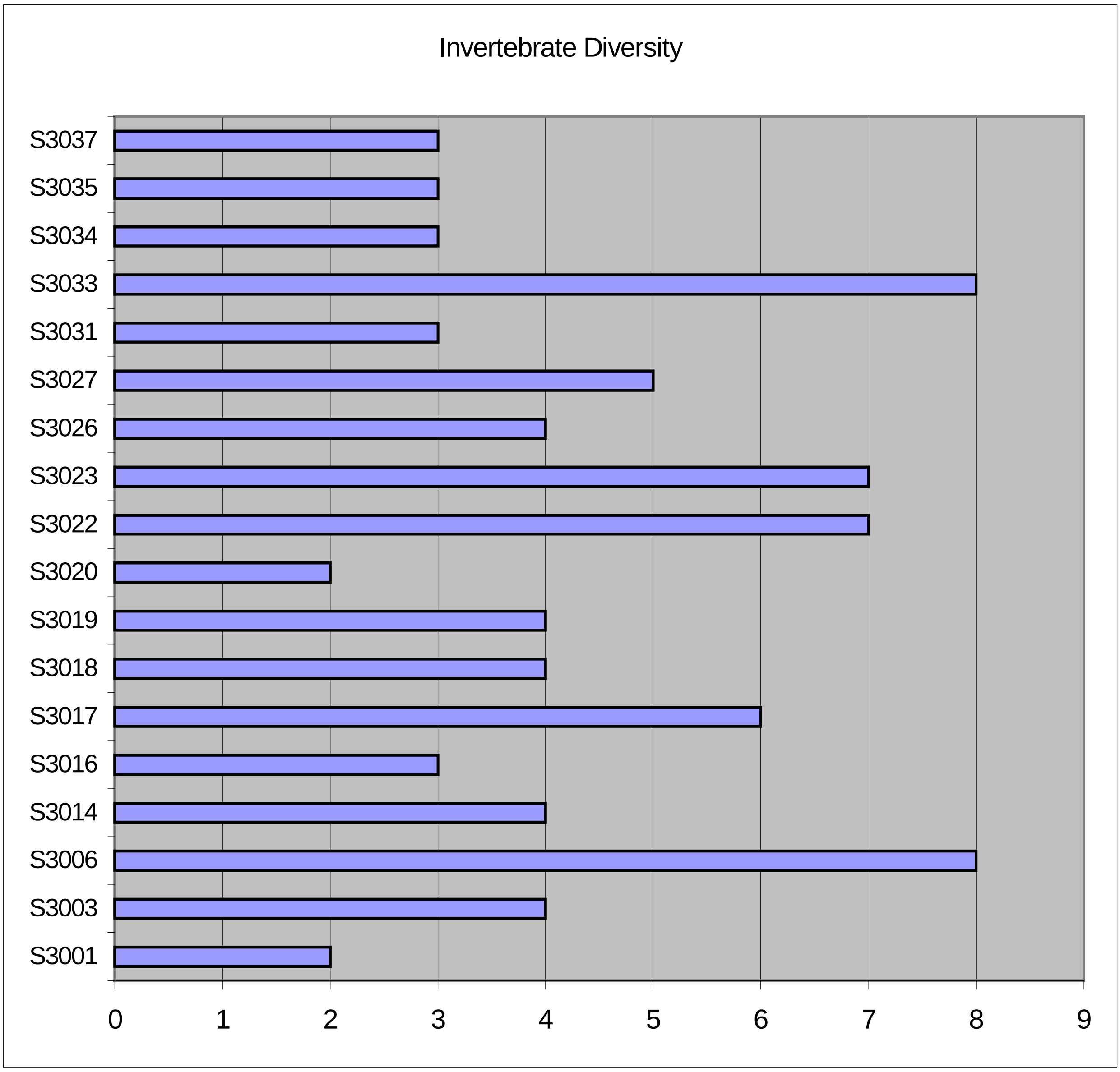


Figure 10. Invertebrate diversity by wetland site.

Plate 8. Old Plough Swamp.

Old Plough Swamp. Temporary water regime located within agricultural land.

Plate 9. Big Swamp

Big Swamp. Permanent water regime located within a largely agricultural catchment. Established aquatic and fringing vegetation exists.

Invertebrate family structure is quite similar between Old Plough Swamp and Big Swamp wetlands both comprising of copepods, cladocerans and ostracods. The differences at each site are on a species level with each comprising six different species and two common species. One conclusion is that the genera found in Old Plough Swamp are adapted to temporary waters (*Daphnia*, *Diacypris*, *Metacyclops* and *Calamoecia*) while those found in Big Swamp are adapted more to a permanent water regime (*Alona*, *Coxiella*, *Cypricercus* and *Simocephalus*).

Plate 11. Middle Lake

Plate 12. Lake Tunketta

Middle Lake and Lake Tungketta are good examples of salt lake systems, both sites recorded seven different taxa.

21.0 WATER CHEMISTRY

Chemical processes in permanent and temporary waters are extremely complex. The chemistry of the water directly influences the biological process (such as photosynthesis) the physical features of the wetland also has a strong influence on both the chemical and biological processes. These three factors (chemical, physical and biological) are constantly in a state of movement and change. Changes in these parameters are most apparent in temporary wetlands where a wetting and drying cycle occurs. The majority of wetlands on Eyre Peninsula have seasonal water regimes, filling during winter and remaining dry throughout spring, winter and autumn.

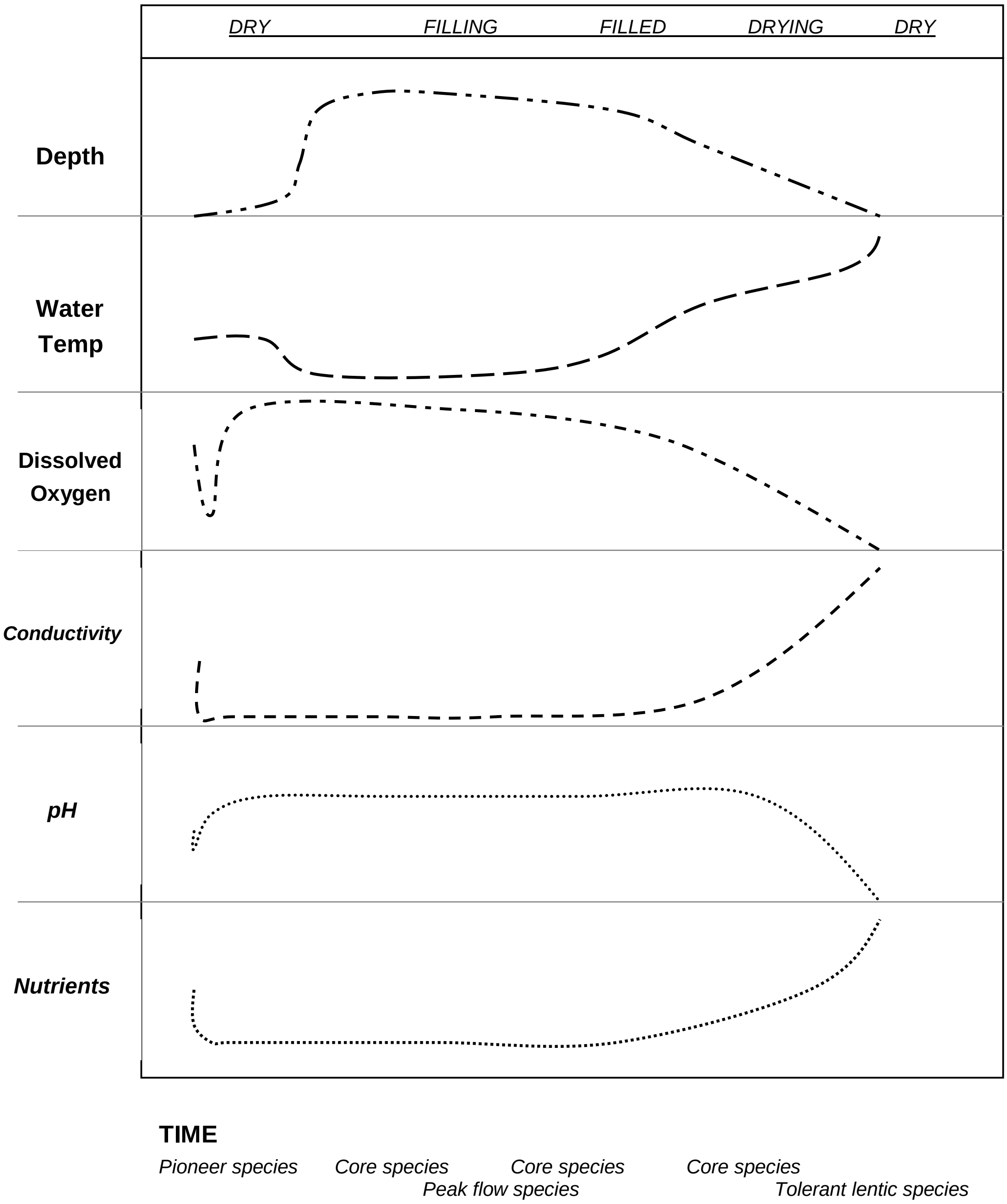


Figure 11. Temporary wetland cycles

Brock and Boulton (1999) state that changes in water quality during drying and filling depend on factors including:

1. sediment properties (composition, nutrients and organic content)
2. type of drawdown (gravity or evaporative)
3. severity of drying (rate of drying, temperature, weathering)
4. conditions of refilling (origin of water, degree of sediment disruption).

Figure 11 describes the changes in chemical variables over time during the phases of filling and drying in temporary wetlands. Seasonal changes in invertebrate composition is also noted.

21.1 pH

21.1.1 Background

The pH value of water indicates how acidic or alkaline it is on a scale 1-14. Acids have a low pH of about 2 for a strong acid like sulphuric acid and about 4 for a weak one like lactic acid. Alkalis have a high pH of about 12 for sodium hydroxide. Pure distilled water has a pH of 7 which is neutral. From pH 7 to 0, a liquid becomes increasing acidic and from pH 7 to 14, a liquid becomes increasingly alkaline.

Generally in South Australia, the pH of natural water ranges between 6.0 and 8.5 with most water bodies in the range 7.0-8.0. The higher pH of natural water bodies is caused by high bicarbonate levels in the water and can raise the pH during the day and lower pH at night. Chemicals entering the water can also affect the pH.

PH is an important environmental indicator. At extremely high or low pH values, the water becomes unsuitable for most organisms.

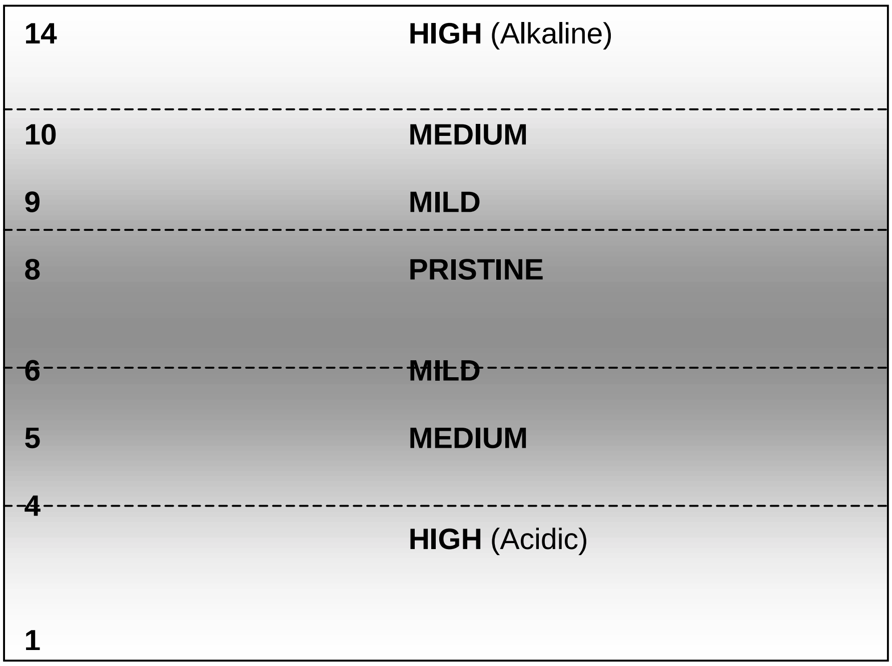


Figure 12. pH values

21.1.2 Analysis

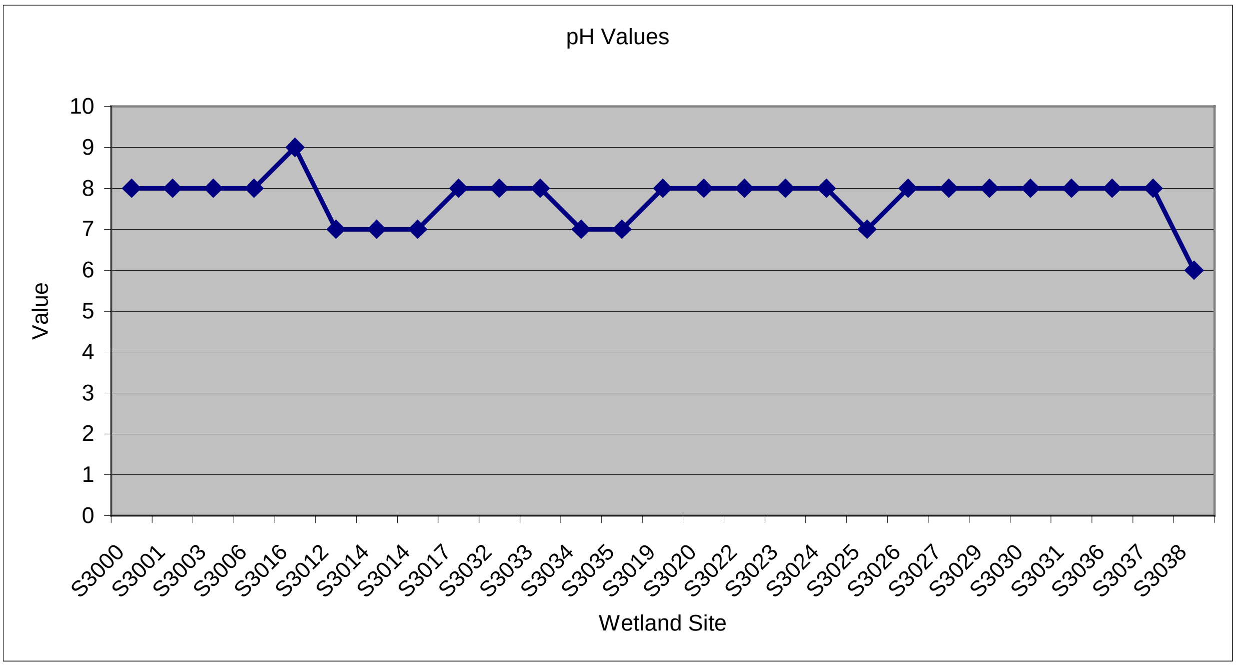


Figure 13. Wetland pH values for surveyed sites on Eyre Peninsula.

The average pH of the wetlands surveyed ranged between pH 7 and 8, which falls into a neutral pH value. This suggests that aquatic species diversity within the wetlands surveyed are not severely affected by pH levels. Wetland site S3038 (Samphire Flat) recorded the highest acidic reading with a pH of 6; opposing this was wetland site S3016 which recorded the highest alkaline reading of 9. These two sites had very different conductivity readings. Site S3038 was hyper-saline (185 Ms) and site S3016 was slightly saline (14 Ms). Turbidity readings were also quite different with site S3038 having extremely high turbidity (15 NTU's) and site S3016 had a turbidity reading of zero. These results suggest that pH is closely linked to conductivity and turbidity levels. pH readings are regarded as a useful secondary chemical indicator of water quality rather than a primary one.

21.2 Conductivity

The majority of wetlands studied within the three regions are affected by salt either through natural processes or by secondary salinisation processes. In closed drainage basins (typical throughout Yorke Peninsula, Eyre Peninsula and Kangaroo Island) salt is retained and accumulated over long periods. This natural accumulation of salt in closed basins results in the development of salt lakes, and this process is primary or natural salinisation. Natural salinisation has caused almost 45% of global surface waters to become more saline (Williams 2001).

Secondary salinisation primarily results from human activities. Disturbances have increased the number of salt lakes and the levels of salt in freshwater wetlands. The main causes of secondary salinisation include:

- Clearance of native deep-rooted vegetation from catchments and its replacement by pasture and other agricultural crops.
- Drainage of saline waste water from irrigated regions.
- Rising saline ground waters and saline intrusions.
- Diversion of inflows from salt and freshwater lakes for irrigation.
- Construction of impoundments on rivers.
- Construction of salt harvesting basins
- Brine discharges from mining activities (Williams 2001).

Effects on biodiversity

Secondary salinisation causes various serious biological effects, these include;

- Changes to the natural character of water-bodies
- Loss of biodiversity
- Less salt-tolerant species are replaced by more tolerant species.

These effects can cause permanent degradation and ecosystem collapse. Williams (2001) comments that the loss of biodiversity is probably greater than generally realised since recent work in semi-arid and arid regions indicates they have much greater biodiversity than was thought. Salinisation also leads to significant decreases in water quality for irrigation and water supply (leading to high economic costs), the loss of amenity and aesthetic values, extensive habitat loss and reduced conservation values (Williams 2001).

Survey results indicate that up to 18,000 hectares of inland water bodies are affected by increases from primary and secondary salinity and pose risks to wetland biodiversity. Approximately another 120,000 hectares of water bodies exist on Kangaroo Island, Eyre Peninsula and Yorke Peninsula (based on wetland mapping, Planning SA, 2000). Extrapolating preliminary results from the 18,000 hectares surveyed, it is likely that salinity poses a risk to biodiversity in the remaining 120,000 hectares of wetlands within these regions.

21.2.1 Analysis

Conductivity within the wetlands surveyed tended to fall within the highly saline range, often being equal to or higher than conductivity levels in sea water. High salt levels occur in some water bodies such as saline lake systems but other wetland systems are obviously being affected by increasing dryland salinity. Wetland number S3038 (Samphire Flat), west of Kyanatta, is an example of a water body suffering from increased dryland salinity with a reading of 185 mS/cm. Wetland S3025 (Hamp Lake), near Elliston, is a good example of a wetland with salinity levels reaching the same salinity as sea water (approximately 64.0 mS/cm); healthy stands of *Melaleuca halmaturorum* are also present. Some of the freshest waterbodies sampled are located within seasonally flooded pasture and small rocky outcrops. They include wetland sites S3037 (Meadow Pool) and S3036 (Taddie Pool), both located on the western section of Eyre Peninsula.

Limited data is available for assessing the risk of adverse effects of salinity in different ecosystem types, particularly wetlands. The Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality (1999) tables wetlands with ‘no data’ related for assessing adverse effects of salinity. A criteria of 8.0 mS/cm (8000 EC) above which irrigation water may be detrimental to a wide range of vegetable, fruit, ornamental and pasture crops. This level has also been adopted by the Murray-Darling Basin Commission as an interim objective to be met at Morgan in South Australia to ensure that reasonable water quality is available to all users.

Figure 14 is based from the salt measurement conversions guide from the Land Management Society Inc.

Salinity in milli-siemens per cm	**Water definition**	**Surveyed wetlands**
0 – 0.9	Fresh 0 = distilled water	Meadow Pool.
1.0 – 2.7	Marginal Maximum for hot water systems, dam water starts to go clear, maximum for people.	Big Swamp, Taddie Pool.
3.0 – 9.1	Brackish Maximum for milking cows and poultry, crop losses start.	Little Swamp, Todd Reservoir.
9.5 – 15.0	Salt 9.5 = Yabbie growth starts to slow, maximum for horses. 14.5 = Yabbie growth ceases	Pillie Lake, Orana Swamp, Pillana Swamp, Old Plough Swamp.
15.5 – 22.5	Salt This range includes the maximum for beef cattle, sheep and many trees.	Sheringa Lagoon.
23.0 – 64.0	Salt Sea water at 64.0	Sleaford Mere, Malata Complex, Round Lake, Middle Lake, Lake Tungketta, Elliston Cemetery Swamp, Elliston Myrtle Swamp, Three Lakes One, Three Lakes Three, Three Lakes Four, Greenly Complex.
64.0 – 649.0	Salt Limit for salt bush at 100.0 and saturated NaCl salt lakes at 649.0	Elliston hamp lake, Lake Newland, Lake greenly, Big lake malata, Samphire flat.

Figure 14. Salinity guidelines.

The majority of wetlands fall within the 23.0 to 100.0 mS/cm range, with the remaining wetlands scattered across the marginal, brackish and salt ranges. More research is required to understand the effects of salinity upon flora and fauna, in particular invertebrate fauna. Little is known regarding the range of tolerance levels that invertebrate's display, and research into these aspects would enable the development of biological indicators.

Plate 12. Hamp Lake

Hamp Lake (S3025) 69.1 ms/cm

Plate 13. Taddie Pool

Taddie Pool (S3036) 2.25 ms/cm

Plate 14. Meadow Pool

Meadow Pool (S3037) .515 ms/cm

Plate 15. Samphire Flat

Samphire Flat (S3038). 185 ms/cm Insert: crystalised salt.

21.3 Turbidity

Turbidity is a measure of water clarity and can be affected by the amount of suspended particles of clay, silt, plankton, industrial wastes and sewage in water. Turbidity is caused by small particles suspended in water which are too small to settle out, but big enough to scatter light. At higher levels of turbidity, water loses its ability to support a diversity of aquatic organisms, and it becomes warmer as suspended particles absorb heat from the sun. Turbidity leads to less light penetrating the water, thereby decreasing photosynthesis, which in turn reduces dissolved oxygen concentrations. Suspended particles may also clog aquatic invertebrate and fish gills, reduce growth rates, and prevent egg and larval development. Particles in suspension can carry heavy metals, pesticides, nutrients and bacteria. Different components of ecosystems are adapted to different levels of light. The plant community structure and biomass in an ecosystem are determined by the light regime, in conjunction with nutrients and temperature. Changes in water clarity may produce changes in the dominant phytoplankton groups. A common result from increased clarity tends to reduce the primary productivity of systems. Changes to the primary producers will also effect the other trophic components of the ecosystem (Liston and Maher, 1997).

Turbidity can have a significant effect on the microbiological quality of drinking-water, its presence can interfere with the detection of bacteria in drinking-water. Turbid water has been shown to stimulate bacterial growth since nutrients are adsorbed on to particulate surfaces, thereby enabling the attached bacteria to grow more rapidly than those in free suspension. The major problem associated with turbidity is its effect on disinfection, high levels have been shown to protect microorganisms from the action of disinfectants and to increase the chlorine and oxygen demand,
(http://www.who.int/water_sanitation_health/GDWQ/Chemicals/turbidity.htm).

Turbidity in water is measured in units called NTU's, or Nephelometric Turbidity Units. It is calculated by measuring the dispersion of a light beam passed through a sample of water.
Fine particles, silt, and suspended matter will cause a light beam passing through the water to be scattered. It has been found that the amount of scattering is proportionate to the amount of turbidity present. Therefore, this process gives a good indication of the relative turbidity of a water sample.

The measurement of NTU does not give the *sizes* of the particles, nor does it indicate the amount of particles present. It is a qualitative, rather than quantitative way of measuring turbidity.

21.3.1 Analysis

To understand the results fully, information about the natural levels of turbidity within all the survey regions at various times of the year is required. This is important because normal levels of turbidity can vary greatly in wetlands from clear flowing zones to murky areas. Natural variations are also related to flow events such as floods, winter rains, road run-off which can increase levels dramatically.

The *Australian Water Quality Guidelines for Fresh and Marine* Waters do not set a guideline for turbidity to protect aquatic ecosystems, but recommend that increases in suspended solids should be less than 10% of the seasonal mean NTU. Bek and Robinson (1991) also suggest that turbidity below 50 NTU is suitable for protecting aquatic animals and plants.

The New South Wales EPA has developed the following general guidelines for turbidity:
- good (< 5 NTU)
- fair (5-50 NTU)
- poor (> 50 NTU)

Refer to: http://www.epa.nsw.gov.au/soe/97/ch3/11.htm

The National Advisory Committee to Water on the Web has developed regional trends of fresh water fish activity with turbidity values and time. See figure 15.
(See: http://wow.nrri.umn.edu/wow/under/parameters/turbidity.html)
These trends correspond well with those guidelines developed by the NSW EPA mentioned above.

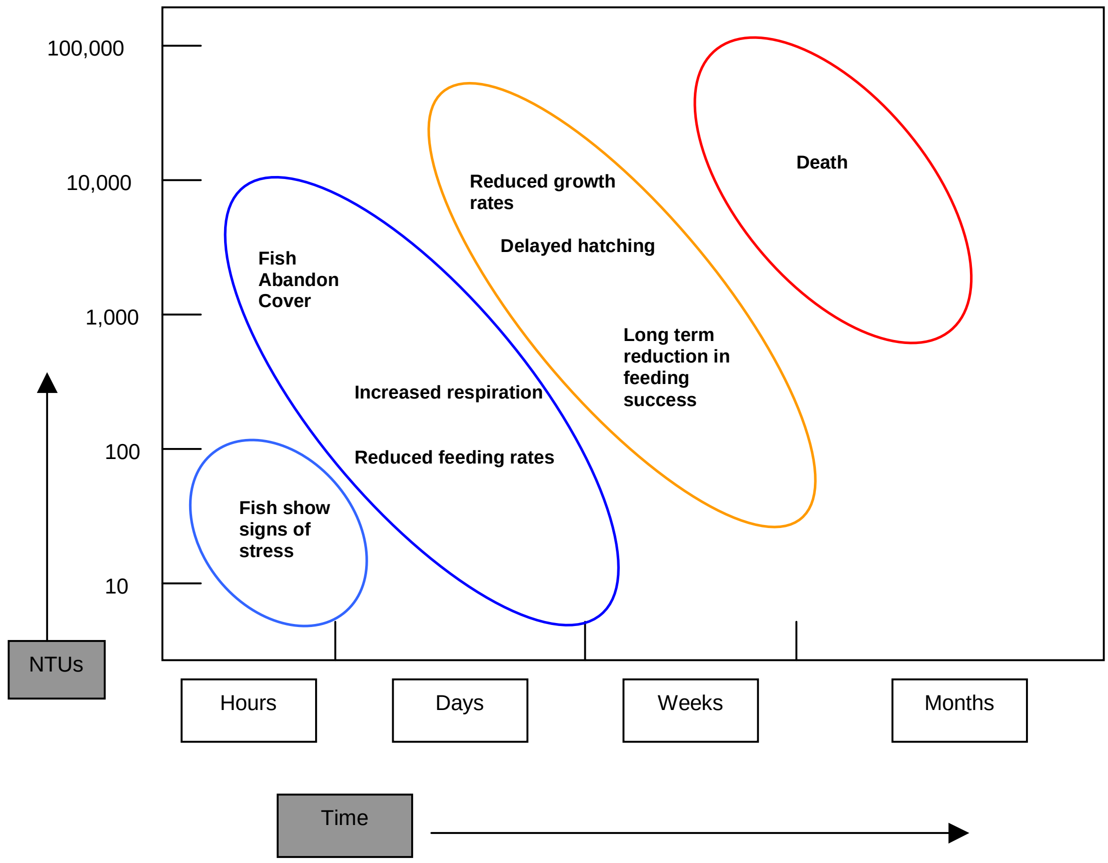


Figure 15. Fish activity against turbidity values and time

Survey Results

Turbidity values were generally below 30 NTUs with the exception of two sites, S3034 (lake Greenly) with a reading of 1000 NTUs and S3035 (Big Lake Malata) with 721 NTUs. Both of these sites displayed fine silty clay particles that obviously clouded the water column. The water depth was less than 15 cm and the land surrounding the waterbody was generally cleared. It is assumed that the combination of these factors, particularly the soil characteristics, contributed to these high NTU readings.

Many sites that contained moderate to high salinity levels tended to record a very low turbidity reading, generally zero. To put the survey readings in perspective the guidelines used by the NSW EPA have been adopted. Interpreting these results should be done with caution, as other water chemistry factors play a part in the overall health of a wetland.

Table 2. Turbidity guidelines.

Guideline	NTUs	Number of Wetlands
Good	**<5**	**15**
Fair	**5-50**	**9**
Poor	**>50**	**2** (lake Greenly and Big Lake Malata)

21.4 Water Temperature

Many of the physical, biological and chemical characteristics of a wetland are directly affected by temperature. Temperature affects the solubility of oxygen in water with warmer water holding less oxygen than cooler water. These factors affect the rate of photosynthesis by algae and larger water plants, with warm water temperatures being susceptible to eutrophication and therefore algal blooms. The sensitivity of organisms to toxic waste, parasites and diseases is also related to water temperature. Organisms can become stressed as temperatures rises and become less resilient to other stresses, this results in most aquatic organisms having a narrow temperature range in which they can function effectively.

Most aquatic organisms are cold-blooded which means they are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms. To a point, the higher the water temperature, the greater the biological activity. Fish, insects, zooplankton and other aquatic species all have preferred temperature ranges. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are few, or none.

The most obvious reason for temperature change in lakes is the change in seasonal air temperature water level. Daily variation also may occur, especially in the surface layers, which are warm during the day and cool at night. In deeper lakes (typically greater than 5 m for small lakes and 10 m for larger ones) during summer, the water separates into layers of distinctly different density caused by differences in temperature, this process is called thermal stratification.

When the surface water cools again in the fall to about the same temperature as the lower water, the stratification is lost and the wind can turbulently mix the two water masses together because their densities are so similar. A similar process also may occur during the spring as colder surface waters warm to the temperature of bottom waters and the lake mixes. The lake mixing associated with a turnover often corresponds with changes in many other chemical parameters and this can affect biological communities (The National Advisory Committee to Water on the Web 2001).

For aquatic systems the maximum recommended increase in the natural temperature range of any inland or marine water is 2^0C (Waterwatch Manual 1994). Because the surveys have recorded the first readings for many wetlands, this natural temperature range is largely unknown. As a general guide, temperatures between zero and 20 degrees are acceptable limits for Mediterranean climates, while temperatures over 20 degrees can start impacting on aquatic fauna and fauna (Waterwatch Manual 1994).

24.4.1 Analysis

The average water temperature was 19 degrees, with temperature variations between 11degrees (Elliston Hamp Lake) and 26 degrees being recorded. The influencing factor in wetland temperatures on Eyre Peninsula is that the majority of water bodies are very shallow, usually no more than 60 cm in depth. The time of sampling will also effect temperature ranges, readings taken early in the morning will be much different from temperatures in the afternoon. Temperature readings are required over several time periods and during different seasons to attain a true indication of temperature regimes.

22.0 RAPID ASSESSMENT

The rapid assessment component of the survey provides a quick snap shot of the condition within different riparian habitats. Generally the score is a subjective one given by the observer, it is an estimate of percentage of intact native vegetation and the diversity and abundance of aquatic flora and fauna.

22.1 Aquatic Fauna

This is a subjective score according to the abundance and diversity of invertebrates, fish and birds located within or on the water body.

- Low (1) refers to no fish or birds with little or no invertebrate presence,
- Moderate (3) refers to some bird presence and good vertebrate abundance, fish usually are not present,
- High (5) indicates good bird and invertebrate diversity and abundance with the presence of fish.

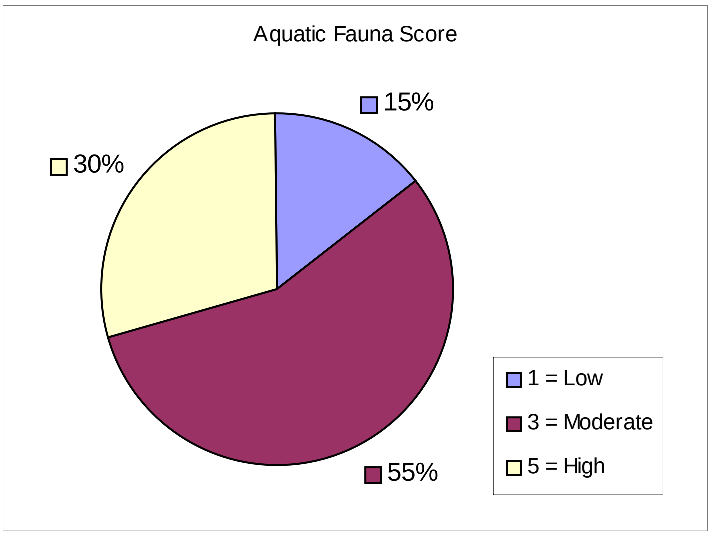


Figure 16. Aquatic Fauna Rapid Assessment

Four sites received a low score (Pillie Lake, Old Plough Swamp, Lake Greenly and Samphire Flat). Fifteen sites scored a moderate score and eight sites scored a high score (eg Orana Swamp).

22.2 Aquatic flora

This records the abundance and diversity of aquatic vegetation. Low (1) indicates no or very little aquatic vegetation, moderate (3) indicates some aquatic vegetation cover either in the form of floating or rooted vegetation, high (5) indicates good diversity of aquatic vegetation with a range of rooted vegetation such as reeds and rushes and floating vegetation such as water ribbons.

Eleven sites received a low score, 16 sites a moderate score and no sites received high scores.

23.0 RIPARIAN VEGETATION RAPID ASSESSMENT

Riparian native vegetation is assessed in three zones. These are the toe of bank (low water – high water), bank (high water mark – buffer) and buffer (top of the bank to the buffer which can extend between 10 metres and 100 metres). The vegetation association for each zone consists of the dominant or co-dominant over storey species and understorey species. The vegetation association for each zone is scored considering the level of disturbance and vegetation cover within each zone.

The vegetation association scoring system consists of:

- Degraded or no vegetation (1) with less than 30% vegetation cover, with high level of disturbance,
- Natural (3) between 30 – 75% vegetation cover, with little disturbance
- Intact (5) over 75% vegetation cover with little or no disturbance.

Table 3. Riparian vegetation Rapid Assessment.

	Degraded	Natural	Intact
Toe of bank	10	10	7
Bank	11	8	8
Buffer	13	11	5

24.0 WETLAND CONDITION SCORE

The wetland score reflects the previous rapid assessment scores for aquatic fauna, aquatic vegetation and riparian vegetation values. The combination of these values and the interpretation of others parameters recorded during the survey (such as land degradation and water chemistry) form the basis of the wetland condition score.

The wetland score consists of:

- Degraded (1) those sites that have a high level of disturbance and received low rapid assessment scores.
- Natural (3) those sites that have little disturbance, received moderate to high rapid assessment scores and that are sites usually protected within the reserve system or by private conservation.
- Pristine (5) those sites with no obvious sign of disturbance, scored very highly in the rapid assessment and are formally conserved within the State reserve system.

Wetland condition scores are very subjective. Although 17 sites received a natural score, significant disturbances are present at most sites. Nine sites scored as degraded and no sites received a pristine score.

25.0 RAPID ASSESSMENT TOTAL SCORE

The total score provides an indication of the environmental value of wetlands surveyed. These values are an interpretation of the biological, chemical and physical parameters.
This score consist of a tally from all the rapid assessment scores and the values are scored as follows:

- 0 – 6 low wetland values
- 7 – 18 moderate wetland values
- 19 – 30 high wetland values

These scores provided a quick means of identifying wetlands with low to high environmental attributes based on the survey parameters. Those wetlands that fall into the moderate to high wetland scores should be more closely examined in terms of land ownership, placement within the landscape and the likely success of monitoring and protective measures. Three sites received a low score, 16 sites a moderate score and eight received high wetland value scores.

25.1 Wetlands with high values

Table 4. Wetlands with high rapid assessment scores.

Wetland site number	Wetland name	Management Authority
S3000	Sleaford Mere	National Parks and Wildlife
S3014	Orana Swamp	DC Cummins
S3032	Greenly Complex	Private
S3025	Elliston Hamp Lake	DC Elliston
S3026	Elliston Myrtle Swamp	DC Elliston
S3027	Three Lakes One	Private
S3029	Three Lakes Four	Private
S3031	Lake Newland	National Parks and Wildlife

25.2 Moderate wetland values

Table 5. Wetland with moderate rapid assessment values.

Wetland site number	Wetland name	Management Authority
S3001	Pillie Lake	National Parks and Wildlife
S3003	Little swamp	Multiple private land holders and the Department of Correctional Services
S3006	Big Swamp	Private
S3012	Tod Reservoir	SA Water
S3016	Pillana Swamp	Private
S3017	'Malata Complex'	Private
S3018	Lake Hamilton	Private
S3019	Round Lake	Private
S3020	Sheringa Lagoon	DC Elliston
S3022	Middle Lake	Private
S3023	Lake Tungketta	Private
S3024	Elliston Cemetery Swamp	DC Elliston
S3030	Three Lakes Four	Private
S3035	Big Lake Malata	Private
S3036	Taddie Pool	DC Elliston
S3037	Meadow Pool	Private

25.3 Low wetland values

Table 6. Wetlands with low rapid assessment values.

Wetland site number	Wetland name	Management Authority
S3033	Old Plough Swamp	Private
S3034	Lake Greenly	Private
S3038	Samphire Flat	Private

26.0 ANZECC WETLAND CRITERIA

These criteria are used for determining nationally important wetlands in Australia, and form the bases for the inclusion in the Directory for Important Wetlands. These criteria were agreed to by the ANZECC Wetlands Network in 1994.

A wetland may be considered nationally important if it meets at least one of the following criteria:

1. *It is a good example of a wetland type occurring within a biogeographic region in Australia.*

2. *It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.*

3. *It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.*

4. *The wetland supports 1% or more of the national populations of any native plant or animal taxa.*

5. *The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.*

6. *The wetland is of outstanding historical or cultural significance.*

Many of the sites in the Directory meet more than one of the criteria. Application of the criteria to individual wetland sites involves a degree of subjectivity. Aspects of a site’s significance can be interpreted differently by different surveyors, and information gaps often exist which make it difficult to judge whether or not a site meets a particular criterion. This is especially true in the case of this wetland survey of Eyre Peninsula, more studies of nominated wetlands are required to apply the ANZECC criteria with greater certainty.

The Interim Biogeographic Regionalisation for Australia (IBRA) is used as the framework for applying Criterion 1, which identifies wetlands that are unique or representative within a biogeographic region in Australia. This framework has limitations due to its broad coverage of some areas, for example Yorke Peninsula and Eyre Peninsula are not defined as different regions. The use of IBRA subregions for South Australia provides much greater definition in identifying wetlands that are unique or representative for each sub region.

26.1 Analysis

Of the 27 wetlands surveyed,13 sites recorded an ANZECC wetland criteria. Two of these sites received multiple values. Criteria one, two and three all recorded a wetland with these values, while criteria four, five and six were not recorded.

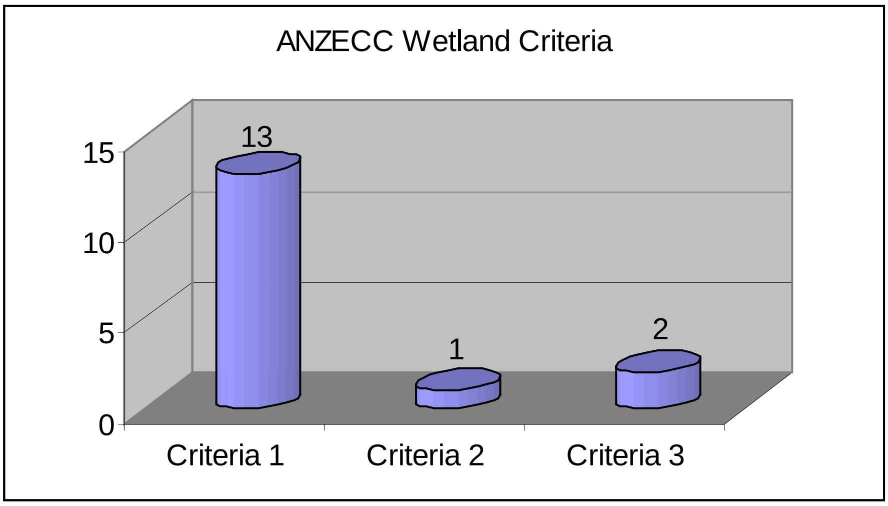


Figure 17. ANZECC Criteria.

Table 7. Wetlands with ANZECC Criteria

Wetland Number	Wetland Name	ANZECC Criteria
S3000	Sleaford Mere	1,3
S3001	Pillie Lake	1
S3006	Big Swamp	1,2,3
S3014	Orana Swamp	1
S3016	Pillana Swamp	1
S3020	Sheringa Lagoon	1
S3024	Elliston Cemetery Swamp	1
S3025	Elliston Hamp Lake	1
S3026	Elliston Myrtle Swamp	1
S3027	Three Lakes One	1
S3029	Three Lakes Three	1
S3030	Three Lakes Four	1
S3031	Lake Newland	1

27.0 WETLAND TYPES

The definition of a wetland used in the survey is one adopted by the Ramsar Convention under Article 1.1.

> *"Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent of temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."*

Within this definition, the wetland classification system used in the Directory of Important Wetlands identifies 40 different wetland types in three categories: A-Marine and Coastal Zone wetlands, B-Inland wetlands, and C-Human-made wetlands. This wetland survey does not include Category A – Marine and Coastal Zone wetlands .
The system is based on that used by the Ramsar Convention in describing Wetlands of International Importance, but was modified slightly to suit the Australian situation.

A – Marine and Coastal Zone wetlands

1. Marine waters - permanent shallow waters less than six metres deep at low tide, includes sea bays straits
2. Subtidal aquatic beds, includes kelp beds, sea-grasses, tropical marine meadows
3. Coral reefs
4. Rocky marine shores, includes rocky offshore islands, sea cliffs
5. Sand, shingle or pebble beaches, includes sand bars, spits, sandy islets
6. Estuarine waters, permanent waters of estuaries and estuarine systems of deltas
7. Intertidal mud, sand or salt flats
8. Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
9. Intertidal forested wetlands, includes mangrove swamps, nipa swamps, tidal freshwater swamps forests
10. Brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea
11. Freshwater lagoons and marshes in the coastal zone
12. Non-tidal freshwater forested wetlands

B – Inland wetlands

1. Permanent rivers and streams includes waterfalls
2. Seasonal and irregular rivers and streams
3. Inland deltas(permanent)
4. Riverine floodplains, includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
5. Permanent freshwater lakes (8 ha) includes large oxbow lakes
6. Seasonal/intermittent freshwater lakes (>8 ha) floodplain lakes
7. Permanent saline /brackish lakes
8. Seasonal/intermittent saline lakes
9. Permanent freshwater ponds (<8 ha) marshes and swamps on inorganic sols, with emergent vegetation waterlogged for at least most of the growing season
10. Seasonal/intermittent freshwater ponds and marshes on inorganic soils includes sloughs, potholes, seasonally flooded meadows, sedge marshes
11. Permanent saline/brackish marshes
12. Seasonal saline marshes

13. Shrub swamps, shrub dominated freshwater marsh, shrub carr, alder thicket on inorganic soil
14. Freshwater swamp forest, seasonally flooded forest, wooded swamps, on inorganic soils
15. Peatlands, forest, shrubs or open bogs
16. Alpine and tundra wetlands: includes alpine meadows, tundra pools, temporary waters from snow melt
17. Freshwater springs, oasis and rock pools
18. Geothermal wetlands
19. Inland, subterranean karst wetlands

C- Human-made wetlands

1. Water storage areas; reservoirs, barrages, hydro-electric dams, impoundment's (generally over 8 ha).
2. Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3. Aquaculture ponds; fish ponds shrimp ponds
4. Salt exploitation, salt pans, salines
5. Excavations; gravel pits; borrow pits, mining pools.
6. Wastewater treatment areas; sewage farms, settling ponds, oxidation basins.
7. Irrigated land; includes irrigation channels and rice fields, canals, ditches
8. Seasonally flooded arable land, farm land
9. Canals

27.1 Analysis

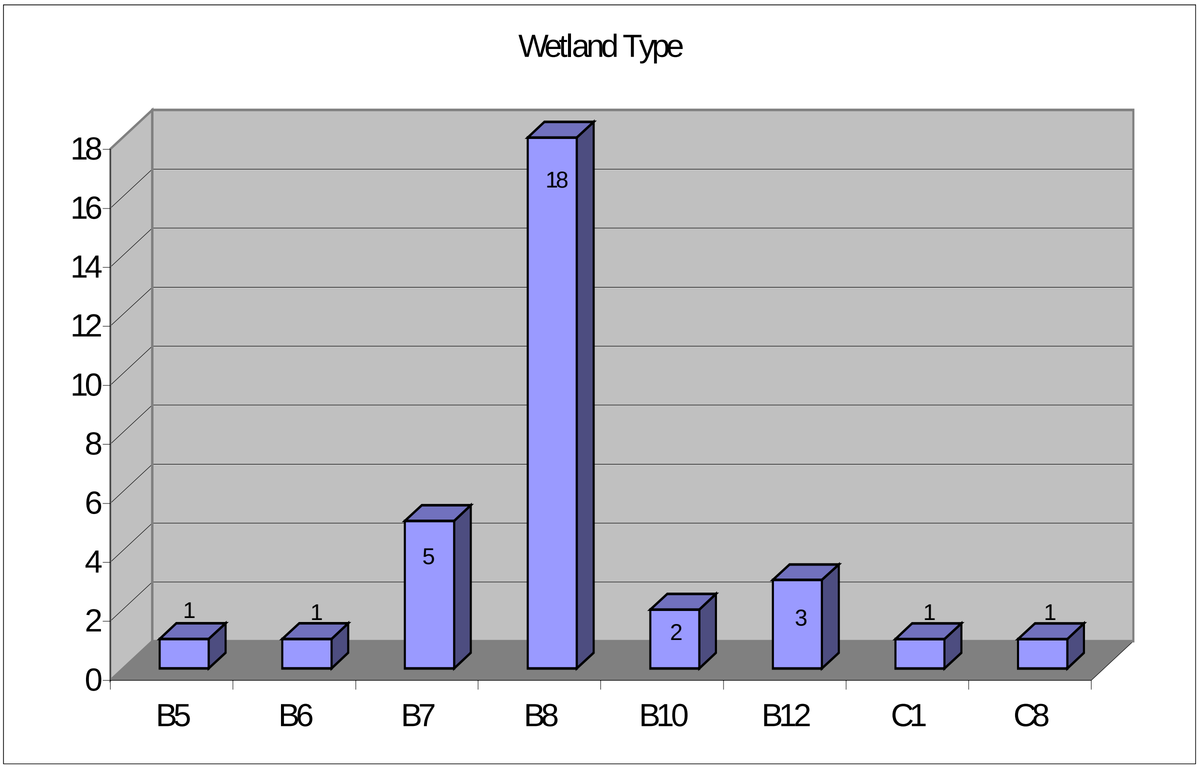


Figure 18. Wetland Type.

Seasonal/intermittent saline lakes (B8) were the most frequently recorded surveyed wetland type on Eyre Peninsula (18 sites), with permanent saline /brackish lakes being the next most common wetland type recorded (5 sites). One site (Little Swamp) is recorded as being a permanent freshwater lake (B5) and one site (Big Swamp) as an intermittent freshwater lake (B6). Two sites recorded wetland types as seasonal/intermittent freshwater ponds (B10), three sites as seasonal saline marshes (B12), one site as a water storage area (C1) and one site as seasonally flooded arable land and farm land. Refer to Table 8.

Table 8. Wetland types.

Wetland Reference Number	Wetland Name	Wetland Type
S3000	Sleaford Mere	B7
S3001	Pillie Lake	B8
S3003	Little Swamp	B5
S3006	Big Swamp	B6
S3012	Todd Reservior	C1
S3014	Orana Swamp	B12
S3016	Pillana Swamp	B8
S3017	'Malata Complex'	B8
S3018	Lake Hamilton	B8
S3019	Round Lake	B8
S3020	Sheringa Lagoon	B7
S3022	Middle Lake	B8
S3023	Lake Tungketta	B8
S3024	Elliston Cemetery Swamp	B12
S3025	Elliston Hamp Lake	B12
S3026	Elliston Myrtle Swamp	B8
S3027	Three Lakes One	B8
S3029	Three Lakes Three	B8
S3030	Three Lakes Four	B8
S3031	Lake Newland	B7
S3032	Greenly Complex	B8
S3033	Old Plough Swamp	C8
S3034	Lake Greenly	B8
S3035	Big Lake Malata	B8
S3036	Taddie Pool	B10
S3037	Meadow Pool	B10
S3038	Samphire Flat	B8
S3039	Driver Salt Lake	B8
S3040	Duck Ponds	B8
S3041	Lake Wangary	B7
S3042	Lake Baird	B8
S3043	Duck Lake	B7

28.0 INTRODUCTION

There are three important steps in developing monitoring protocols that can be applied effectively within the South Australian wetland management context.

These consist of:

1. Identification of wetland values (collating and collecting existing information and undertaking baseline surveys)
2. Identification of wetland threats (from the analysis of wetland values)
3. Development of monitoring indicators that highlight early changes in ecological Character.

> *"Monitoring essentially means the keeping of a continual record of certain parameters, advising whether they are being maintained within prescribed limits and warning if undesirable changes occur" (Hart 1980).*

Finlayson and Eliot (2001) expand on this definition by emphasising that the information derived from monitoring provides a platform on which management actions are both based and judged.

Finlayson and Mitchell (1999) identified the following five major reasons for monitoring wetlands:
- To characterise variations in responses of wetlands to natural variability in the environment;
- To collect baseline data on wetlands as part of inventory processes;
- To record ecological changes that may be occurring as a result of specific natural or anthropogenic events;
- To measure progress toward set objectives of a management program; and
- To audit the performance of management agencies and land users.

28.1 Ecological change

The third dot point mentions ecological change, the Ramsar Convention for Internationally Important Wetlands states that in order to record ecological change, the ecological character needs to be defined. Once defined it is possible to monitor for changes in ecological character.

Ecological character is the combined biological, physical, and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions and attributes. The change in ecological character is the impairment or imbalance in any biological, physical, or chemical components of the wetland ecosystem, or in their interactions, which maintain the wetland and its products, functions and attributes. (www.ramsar.org/key_guide-list-e.html)

The Ramsar Convention provides detailed guidelines for monitoring the ecological character of wetlands. These include guidelines for initiating and conducting a risk assessment framework. The Ramsar risk assessment framework consists of six steps and these are:

Step 1 - Identification of the problem. This is the process of identifying the nature of the problem and developing a plan for the remainder of the risk assessment based on this information. It defines the objectives and scope of, and provides the foundation for, the risk assessment. In the case of a chemical impact, it would include obtaining and integrating information on the characteristics (for example, properties, known toxicity) and source of the chemical, what is likely to be affected, and how is it likely to be affected, and importantly, what is to be protected.

Step 2 - Identification of the adverse effects. This step evaluates the likely extent of adverse change or impact on the wetland. Such data should preferably be derived from field studies, as field data are more appropriate for assessments of multiple impacts, such as occur on many wetlands. Depending on the extent of adverse change and available resources, such studies can range from quantitative field experiments to qualitative observational studies. For chemical impacts, on-site ecotoxicological bioassays constitute appropriate approaches, whereas for changes caused by weeds or feral animals, on-site observation and mapping may be all that is required.

Step 3 - Identification of the extent of the problem. This step estimates the likely extent of the problem on the wetland of concern by using information gathered about its behaviour and extent of occurrence elsewhere. In the case of a chemical impact, this includes information on processes such as transport, dilution, partitioning, persistence, degradation, and transformation, in addition to general chemical properties and data on rates of chemical input into the environment. In the case of an invasive weed, it might include detailed information on its entry into an ecosystem, rate of spread and habitat preferences. While field surveys most likely represent the ideal approach, use of historical records, simulation modeling, and field and/or laboratory experimental studies all represent alternative or complementary methods of characterising the extent of the problem.

Step 4 - Identification of the risk. This involves integration of the results from the assessment of the likely effects with those from the assessment of the likely extent of the problem, in order to estimate the likely level of adverse ecological change on the wetland. A range of techniques exist for estimating risks, often depending on the type and quality of the likely effects and their extent. A potentially useful technique for characterising risks in wetlands is via a GIS-based framework, whereby the results of the various assessments are overlaid onto a map of the region of interest in order to link effects to impact. In addition to estimating risks, such an approach would also serve to focus future assessments and/or monitoring on identified problem areas.

Step 5 - Risk management and reduction**.** This is the final decision-making process and uses the information obtained from the assessment processes described above, and it attempts to minimize the risks without compromising other societal, community or environmental values. In the context of the Ramsar Convention, risk management must also consider the concept of *wise use* and the potential effects of management decisions on this. The result of the risk assessment is not the only factor that risk management considers; it also takes into account political, social, economic, and engineering/ technical factors, and the respective benefits and limitations of each risk-reducing action. It is a multidisciplinary task requiring communication between site managers and experts in relevant disciplines.

Step 6 - Monitoring**.** Monitoring is the last step in the risk assessment process and should be undertaken to verify the effectiveness of the risk management decisions. It should incorporate components that function as a reliable early warning system, detecting the failure or poor performance of risk management decisions prior to serious environmental harm occurring. The risk assessment will be of little value if effective monitoring is not undertaken. The choice of endpoints to measure in the monitoring process is critical. Further, a GIS-based approach will most likely be a useful technique for wetland risk assessment, as it incorporates a spatial dimension that is useful for monitoring adverse impacts on wetlands.

29.0 MONITORING PROTOCOLS AND INDICATORS

The underlying concept of early warning indicators is that effects can be detected before actual environmental impacts. While such a ‘early warning’ may not necessarily provide firm evidence of larger scale environmental degradation, it provides an opportunity to determine whether intervention or further investigation is warranted.

Early warning indicators can be defined as:

> *"The measurable biological, physical or chemical responses to a particular stress, preceding the occurrence of potentially significant adverse effects on the system of interest".*
> (http://ramsar.org/key_guide_risk_e.htm)

Typically, indicators are ecological communities or assemblages of organisms, habitat or keystone-species. Indicators are usually closely linked to ecosystem-level effects. In selecting an indicator it is important that the ecological character of a wetland which includes the biological, chemical and physical components of the ecosystem. Therefore, it may be useful to select early warning indicators according to which of the above three components are considered more susceptible to change (Finlayson and Spiers, 1999).

The concepts of early warning and ecological relevance can conflict. The types of biological responses that can be measured, and their relationship to ecological relevance and early warning capability. As an example, biomarker responses can offer exceptional early warning of potential adverse effects. However, there exists very little evidence that observed responses result, or culminate in adverse effects at an individual level, let alone the population, community or ecosystem level (Finlayson and Spiers 1999). If the primary assessment objective is that of early detection, then it is likely that it will be at the expense of ecological relevance (Finlayson and Spiers 1999).

To have potential as an early warning indicator, a particular response should be:

1. **anticipatory**: it should occur at levels of organisation, either biological or physical, that provide an indication of degradation, or some form of adverse effect, before serious environmental harm has occurred;

2. **sensitive**: in detecting potential significant impacts prior to them occurring, an early warning indicator should be sensitive to low levels, or early stages of the problem;

3. **diagnostic**: it should be sufficiently specific to a problem to increase confidence in identifying the cause of an effect;

4. **broadly applicable**: it should predict potential impacts from a broad range of problems;

5. **correlated to actual environmental effects/ecological relevance**: an understanding that continued exposure to the problem, and hence continued manifestation of the response, would usually or often lead to significant environmental (ecosystem-level) adverse effects;

6. **timely and cost-effective**: it should provide information quickly enough to initiate effective management action prior to significant environmental impacts occurring, and be inexpensive to measure while providing the maximum amount of information per unit effort;

7. **regionally or nationally relevan**t: it should be relevant to the ecosystem being assessed;

8. **socially relevant**: it should be of obvious value to, and observable by stakeholders, or predictive of a measure that is socially relevant;

9. **easy to measure**: it should be able to be measured using a standard procedure with known reliability and low measurement error;

10. **constant in space and time**: it should be capable of detecting small change and of clearly distinguishing that a response is caused by some anthropogenic source, not by natural factors as part of the natural background (that is, high signal to noise ratio);

11. **nondestructive**: measurement of the indicator should be nondestructive to the ecosystem being assessed.

Attributes of indicators developed by van Dam et al (in press) in Finlayson and Spiers (1999).

The importance of the above attributes cannot be over-emphasized, since any assessment of actual or potential change in ecological character will only be as effective as the indicators chosen to assess it. However, an early warning indicator possessing all the ideal attributes cannot exist, as in many cases some of them will conflict, or will simply not be achievable (Finlayson and Spiers 1999).

29.1 Early warning indicators

Finlayson and Spiers (1999) outline a number of early warning indicators, these are placed into three broad categories:

1. rapid response toxicity tests;
2. field early warning tests; and
3. rapid assessments.

Each of the techniques may meet different objectives in water quality assessment programs. Although the majority of early warning indicators are of a biological nature, physico-chemical indicators do exist and often form the initial phase of assessing water quality (Finlayson and Spiers, 1999).

29.1.1 Toxicity tests

These represent rapid and sensitive responses to one or more chemicals. They provide an indication that there may be a risk of adverse effects occurring at higher levels of biological organization (for example, communities and ecosystems). Laboratory toxicity tests are of particular use for a chemical or chemicals yet to be released into the aquatic environment (for example, a new pesticide or a pre-release waste water). They provide a basis upon which to make decisions about safe concentrations or dilution/release rates, thereby eliminating, or at least minimizing, adverse impacts on the aquatic environment. However, there are major differences in the ecological relevance of responses that can be measured (Finlayson and Spiers 1999).

29.1.2 Field early warning indicators

These comprise of a range of techniques that are grouped together because they are used to measure responses or patterns in the field and thus provide a more realistic indication of effects in the environment. In contrast to rapid response toxicity tests, early warning field tests predict and/or assess the effects of existing chemicals. Some of the techniques can also be applied to biological and physical problems (Finlayson and Spiers, 1999).

29.1.3 Rapid Assessments

Rapid assessment is essentially the method used for this wetland inventory, and has the appeal of enabling ecologically-relevant information to be gathered over wide geographical areas in a standardised fashion and at relatively low costs. The trade-off is that rapid assessment methods are usually relatively ‘coarse’ and hence are not designed to detect subtle impacts.

Attributes of rapid assessment include:

1. measured response is widely regarded as adequately reflecting the ecological condition or integrity of a site, catchment or region (that is, ecosystem surrogate);
2. approaches to sampling and data analysis are highly standardised;
3. response is measured rapidly, cheaply and with rapid turnaround of results;
4. results are readily understood by non-specialists; and
5. response has some diagnostic value (Finlayson and Spiers 1999).

The most powerful impact assessment programs will generally be those that include two types of indicator, namely those associated with early warning of change and those (regarded as) closely associated with ecosystem-level effects. The 'ecosystem-level'-type indicator might include ecologically important populations (for example, keystone species) or habitat, or communities of organisms that serve as suitable ecosystem 'surrogates'. Indicators used in rapid assessment would also normally serve this role. With both types of indicators measured in a monitoring program, information provided by 'ecosystem-level' indicators may then be used to assess the ecological importance of any change observed in an early detection indicator.

30.0 RECOMMENDED INDICATORS FOR MONITORING SURVEYED WETLANDS

Monitoring **water chemistry** is recommended as an **early warning indicator** and monitoring **invertebrate composition** as an **ecosystem level indicator**.

Before these indicators can be used effectively in a monitoring program, more research and surveys are required. The wetland surveys undertaken on Eyre Peninsula, Kangaroo Island and Yorke Peninsula recorded information rapidly at one location and at one time of the year. Significantly more work is required to establish creditable baseline data that records wetland values over time. An understanding of the natural levels of water chemistry and invertebrate composition for each region also needs to be established before effective monitoring can occur. For the interpretation of water chemistry parameters and ecosystem based parameters, refer to Section Two – Wetland Assessment under the relevant background discussions.

30.1 Early warning indicators – Water chemistry

The collection of water chemistry parameters is suggested as the means for monitoring for early change in wetlands. Parameters essential to collect include conductivity, dissolved oxygen, temperature, turbidity and pH. Conductivity will probably play an important indicator providing the first early warning change within wetlands.

30.2 Ecosystem based indicator

Invertebrates are recommended as the ecosystem based indicators for monitoring. The important features of invertebrates which make them useful as indicators include:

1. Invertebrates are ecologically and functionally important
2. Invertebrates are diverse, providing a good range from which to choose suitable taxa
3. Many species are habitat specific
4. Many species are abundant and are relatively simple to collect (Yen and Butcher, 1997)

Indicator taxa should be selected on a regional basis and that are sensitive species to environmental change, whose presence indicates the probability of disturbance.
Indicator species should also be selected that have been identified as keystone species. These species play critical ecological roles, and their loss from a particular system will result (directly or indirectly) in the disappearance of other species (Soule and Kohm 1989); (Lawton 1991).

Research is required towards developing these indicators. Yen and Butcher (1997) suggest research in the following areas:

- The link between invertebrate biodiversity and ecosystem functioning
- The value of using guilds or functional groups to monitor ecosystem processes
- Identifying keystone taxa
- The existence of redundant species.

The interaction between invertebrate composition and water chemistry also requires much research. Without an understanding of the dynamics between these two parameters, interpretation of ecological change will be hindered.

An example of how the invertebrate monitoring program can be applied to detect change in ecological character is to study the trophic dynamics or functional groups. The presence of both invertebrate grazers and predators indicates functional invertebrate dynamics. The loss of either group quickly indicates change in the ecological character of the wetland.

The development of keystone indicator species requires further research especially within saline lake systems. However, as a starting point there are several families that can be used in starting to develop these indicators. Representative grazers and predators are important to include as indicators due to their importance in the trophic chain.

Keystone species to monitor include:

Grazers: zooplankton, including cladocera, copepods, Calanoida and Cyclopoida.

Predators: dragonfly larvae (Odonata) and families Dytiscidae, Coleoptera.

30.3 Other considerations

Monitoring also is required for many other parameters. Programs need to include whole of catchment parameters that cause change in the ecological character of wetlands. Monitoring of threats to wetland such as land clearance, drainage, land ownership changes and land use changes all need to be documented and included in the monitoring program. Ideally an action plan to alleviate and manage threats should be developed for nominated wetlands in conjunction with a monitoring program.

31.0 RECOMMENDED WETLANDS TO MONITOR

Those wetlands that received a high to moderate wetland score (refer to Section Two – Wetland Assessment) are used as the first criteria for inclusion. The second criteria is the management authority. Those wetlands that are under public ownership are targeted as preferential sites to monitor unless significant wetland values are identified on private lands. The reasoning behind this is that wetlands within the community land classification or under State government ownership may be easier to access and manage a monitoring program. At this early stage of developing a monitoring program these sites will assist in refining techniques and develop monitoring protocols.

Once monitoring techniques have been developed and tested, the opportunity to expand monitoring to other wetlands with high value on private property is feasible. Other protection measures can be developed for wetlands on private property before monitoring occurs. Actions such as buffering wetlands with revegetation, fencing, removing rubbish and the development of wise use of wetland programs for landowners are currently required to manage wetland threats. The recording of baseline data before such actions is necessary to assist in the development of an on-going monitoring program in the future.

31.1 Recommended priority wetlands

Table 9. Recommended priority wetlands for monitoring.

Wetland site number	Wetland name	Management Authority
S3000	Sleaford Mere	National Parks and Wildlife
S3031	Lake Newland	National Parks and Wildlife
S3001	Pillie Lake	National Parks and Wildlife
S3025	Elliston Hamp Lake	DC Elliston
S3026	Elliston Myrtle Swamp	DC Elliston
S3020	Sheringa Lagoon	DC Elliston
S3024	Elliston Cemetery Swamp	DC Elliston

31.2 Second priority wetlands

Table 10. Second priority wetlands to monitor.

Wetland site number	Wetland name	Management Authority
S3027	Three Lakes One	Private
S3006	Big Swamp	Private

32.0 RECORDING MONITORING PARAMETERS

The wetland inventory template (refer to Section One) should be used for the collection of baseline data. Once collected, analysis of the results is required to determine the values of the wetland, threats and possible key indicator groups. The format of such analysis can be based on Section Two – Wetland Assessment. Routine collection of information is required in order to establish which factors to monitor and then compare data from previous monitoring to identify ecological change. Defining acceptable limits of change will be difficult in the absence of a detailed knowledge of individual wetland sites. The suggested wetlands to monitor will also be of value in developing reference sites for the region.

BIBLIOGRAPHY

A.N.Z.E.C.C (1999). *Draft Overview of the National Water Quality Management Strategy*., Australian and New Zealand Guidlines for Freshwater and Marine Water Quality.

Arthington, M. K. (1997). *Review of impacts of displaced/introduced fauna associated with inland waters*. Canberra, Department for Environment: 69.

Barritt, M. (1982). *A rapid appraisal survey of some natural areas on kangaroo Island, South Australia*. Adelaide, Nature Conservation Society.

Bek, P. A.. Robinson, G. (1991). *Sweet Water or Bitter Legacy-Water Quality in New South Wales*, Water Quality Unit, Department of Water Resources, Sydney.

Biological Database of SA; *Reserves and plant populations*; Flora. Source for status; SA = NPWSA Act 1972, Updated Schedule 1999, REG = Lang and Kraehenbuehl, 2001.

Brock, M.(1999). *Australian freshwater ecology: processes and management*, Gleneagles Publishing.

Brown, W.(1979). *An inventory of research and available information on wetlands in Western Australia*, Department of Conservation and Environment, WA.

Butcher, R. (1999). *Assessing biodiversity in temporary and permanent wetlands*, Pp 50-53 in The Other 99%. The Conservation and Biodiversity of Invertebrates, ed by W. Ponder and D. Lunney, 1999. Transactions of the Royal Zoological Society of New South Wales, Mosman.

Butcher, Y.(1997). *An overview of the conservation of non-marine invertebrates in Australia*.Canberra, Environment Australia.

Cadwallader, B.(1983). *A guide to the freshwater fish of Victoria*, FD Atkinson Government Printer.

Curruthers, S. and Hille, B. (1997). *South East Wetlands GIS Database*, Geographic Analysis and Research Unit, Information and Data Analysis Branch, Planning Division, Department of Housing and Urban Development.

Davis, M.(1998). *Wetlands for the future*, Gleneagles Publishing, SA.

Defaye, D.(1995). *Copepoda, Introduction to the Copepoda*, SPB Academic Publishing.

DEH (2001) *Provisional listing of threatened ecosystems of the Agricultural Regions for South Australia.*

Department of Conservation and Environment (1980*). Guidelines for the conservation and management of wetlands in Western Australia*., Department of Conservation and Environment, Western Australia.

Department of Housing and Urban Development, (1997). *Guide to a native vegetation survey using the biological survey of South Australia methodology, Section 3*, Geographic Analysis and Research Unit.

Dowall., R.(1980). *Freshwater fishes of South-Eastern Australia*, A.H. & A.W. Reed PTY LTD.

Dussart, B. H.(2001). *Introduction to the Copepoda*, Backhuys Publishers.

Environment Protection and Biodiversity Conservation Act, 1999

Environmental Protection Authority (1993). *A guide to wetland management in the Swan coastal plain area*., Environmental Protection Authority, Perth, Western Australia.

Fairweather, P.G. & Napier (1998). *Environmental indicators for national state of the environment reporting - inland waters.* Environment Australia.

Farinha, N.(1996). *Mediterranean Wetland Inventory: A Reference Manual*., MedWet/Instituto da Coservacao da Natureza/Wetlands International Publication, Volume 1, Lisbon and Slimbridge, UK.

Finlayson, C.M. and Spiers, A.G. (1999). *Techniques for enhanced wetland inventory and monitoring.* Supervising Scientist, Canberra.

Finlayson, C.M. and Eliot, I. (2001). "*Ecological Assessment and monitoring of Coastal Wetlands in Australia's Wet Dry Tropics: A Paradigm for elsewhere*?" Coastal Management 29: 105-115.

Finlayson, C. M. and Mitchell, D.S. (1999). "*Australian wetlands: The monitoring challenge*." Wetlands ecology and management 7: 105-112.

Geneva, W. H. O (1996). Guidelines for drinking-water quality, 2nd ed. Vol. 2. Health criteria and other supporting information pp. 370-373.

Greenway, M. (1997) Wetlands in a Dry Land: Understanding for Management, Albury, New South Wales, 29-30. Environment Australia.

Hart, B. T. (1980). Environmental surveys. *An Ecological Basis for Water Resource Management*, Australian National University Press.

Heard and Channon (1997) *Guide to a native vegetation survey using the biological survey of South Australia methodology*, Section 3. Geographic Analysis and Research Unit, Department of Housing and Urban Development.

Jackson, J.(1997). *State of Habitat Availability and Quality in Inland Waters*. Australia: State of the Environment Technical Paper Series (Inland Waters), Environment Australia.

Jensen, A.(1996). *Wetlands Atlas of the South Australian Murray Valley*, Department for Environment and Heritage.

Liston and Maher, (1997). *Water quality for maintenance of aquatic ecosystems: Appropriate indicators and analysis.* Australia: State of the Environment Technical Paper Seriers. (Inland waters)., Environment Australia.

Lloyd, B.(1986). *Wetlands & Water Resources of South Australia*. Appendix 1. Part 3: South Australian Gulf Drainage Division., Conservation Projects Branch. Department of Environment & Planning.

Maher, W. & Liston, P. (1997). *Water quality for maintenance of aquatic ecosystems: Appropriate indicators and analysis. Australia: State of the Environment Technical Paper Series. (Inland waters).* Environment Australia.

Matthews, E. (2000). (Draft) *Biodiversity Plan for Eyre Peninsula*, Department for Environment and Heritage, SA.

McComb, P.(1988). *The Conservation of Australian Wetlands*, Surrey Beatty & Sons Pty Limited, NSW.

Morelli, J. and DeJong, M.(1996). *A Directory of Important Wetlands in South Australia*. Adelaide, South Australian Department of Environment and Natural Resources.

Nogrady, T.(1993). *Rotifera, guides to identification of the Micro Invertebrates of the Continental Waters of the World*., SPB Academic Publishing.

NLWRA (National Land and Water Resources Audit) 2001, *Australian Dryland Salinity Assessment 2000. Extent, impacts, processes, monitoring and management options*, National Land and Water Resources Audit, Australia.

Paijmans, K.(1978). *A Reconnaissance of four wetland pilot study areas*., CSIRO Division of Land Use Research, Canberra.

Parker A.J and C.M. Fanning, R. B. F. (1985). *Geology in Natural History of Eyre Peninsula*, Editors C.R. Twidale, M.J. Tyler and M.Davis, Royal Society of South Australia.

Pressey, R. L.(1987). *A Survey of wetlands of the lower Macleay Floodplain*, NSW, NSW National Parks and Wildlife.

Raines, J.(1993*). Nomination of wetlands of outstanding ornithological importance for the Register of the National Estate*. Royal Australasian Ornithologist Union Database, Western Australia.

Ramsar (*Ramsar Resolution VII.10 and Annex on Wetland Risk Assessment Framework*). Ramsar. Rivier, I. K.(1998). *The predatory Cladocera (Onychopoda: Podonidae, Polyphemidar, Cercopagidae) and Leptodorida of the world*., Backhuys Publishers.

Robinson, P.(1991). *Sweet Water or Bitter Legacy-Water Quality in New South Wales*, Water Quality Unit, Department of Water Resources, Sydney.

Rolls, D. (1987). *A baseline biological monitoring programme for the urban wetlands of the Swan Coastal Plain*, WA. Perth, Environmental Protection Authority.

Sainty, G. R. (1981). *Waterplants of New South Wales*, Water Resources Commission NSW.

Sainty, G. R.(1994). *Waterplants in Australia*, South China Printing Co.

Schwerdtfeger, P.(1985). *'Climate' in Natural History of Eyre Peninsula*, by C.R. Twidale, M.J. Tyler and M. Davis, Royal Society of South Australia.

Sheldon, F. and Walker, K.(2001). *“Propagules in dry wetland sediments as indicators of ecological health: effects of salinity*.” Regulated rivers:Research and Management 17: 191-197.

Smet, W.(1997). *Rotifera, Volume 5: The Dicranophoridae (Monogononta*), SPB Academic Publishing.

Smirnov (1992). *The Macrothricidae of the world*, SPB Academic Publishing.

Sonneman, A.(1988). *Freshwater Algae in Australia*, Sainty and Associates.

Stanton, J. P. (1975). *A Preliminary Assessment of Wetlands in Queensland*, CSIRO Division of Land Use Research, Canberra.

Storey, A.W. Lane, J.A.K. Davies, P.M. (1997). *Monitoring the ecological character of Australia's wetlands of international importance (RAMSAR Convention).* Western Australian Department of Conservation and Land Management and Biodiversity Group of Environment Australia.

Streever, W.(1996). *Preliminary example of a sampling design assessment method for biomonitoring studies that rely on ordination. INTECOL'S V International Wetlands Conference*., University of Western Australia, Gleneagles Publishing.

The National Advisory Committee to Water on the Web (2001) http://wow.nrri.umn.edu

Thompson, M. B.(1986). *River Murray Wetlands:their characteristics, significance and management*., Nature Conservation Society of South Australia and the Department of Environment and Planning, Adelaide.

Walker S.J. and Goonan P.M.(2000) *Frog Census 2000*, Environmental Protection Agency, DEH. South Australia.

Walker, G. van der Wel, B. & Leaney, R. Jolly, I.(2000). *Assessing the impacts of dryland salinity on South Australia's water resources*. South Australia, CSIRO Land and Water: 60.

Waterwatch Manual (1996). *Waterwatch Manual for South Australia*, South Australian Government Printer.

Weatherley, A. H.(1967). *Australian inland waters and their fauna*, Australian National University Press, Canberra.

Williams, W. D.(1980). *Australian Freshwater Life*, Globe Press, Victoria.

Williams, W. D.(1998). *Wetlands in a dry land: understanding for management*., Environment Australia, Biodiversity Group, Canberra.

Williams, W.D. (2000). “*Biodiversity in temporary wetlands of dryland regions*.” Limnology 27: 141-144.

Williams, W.D.(2001). *Salinisation:unplumbed salt in a parched landscape*.

Web Sites referenced

http://www.ea.gov.au/parks/nrs/ibraimcr/ibra_95/index.html

http://www.nmnh.si.edu/botany/projects/algae/Imag-Chl.htm

http://www.who.int/water_sanitation_health/GDWQ/Chemicals/turbidity.htm

http://www.epa.nsw.gov.au/soe/97/ch3/11.htm

http://wow.nrri.umn.edu/wow/under/parameters/turbidity.html

www.ramsar.org/key_guide-list-e.html

http://ramsar.org/key_guide_risk_e.htm

Other useful web sites

Water Watch
http://www.sa.waterwatch.org.au/

Environment Australia
http://www.ea.gov.au/water/wetlands/

Wetland Care Australia
http://www.wetlandcare.com.au/

Environmental Protection Agency
http://www.environment.sa.gov.au

AusRivas
http://ausrivas.canberra.edu.au/

Catchment Water Management Boards
http://www.catchments.net/

Invertebrates
http://www.umesci.maine.edu/ams/inverts.htm

APPENDIX 1 Wetland Inventory descriptions

Wetland Reference Number*:* The wetland reference number is critical for clearly defining wetland locations within regions of the State. The wetland reference number acts as the primary key for records for each wetland, this enables data transfer between databases and GIS tables.

Wetland Name*:* The name of the site.

Ramsar Site**:** If the wetland is listed as a Ramsar site.

Description of Site*:* A general description of the location features, closest roads or landmarks.

Current Land use

> ***On site****:* Current human use of the designated wetland area.
>
> ***Surrounding area****:* Human use on land adjacent to the wetlands, and more broadly in the surrounding catchment.

Tenure/ownership

> ***On site****:* Details of land ownership of the wetland site if possible.
>
> ***Surrounding****:* Details of the tenure type that is dominant in the surrounding areas if possible.

Jurisdiction and management authority*:* The name of the body or bodies responsible for management of the wetland.

Complied by: Name of person undertaking data collection.

Organisation: Organisation that is managing the data collection

Date/time*:* Date and time of data collection.

Region: Geographical region (eg Eyre Peninsula, Yorke Peninsula and Kangaroo Island)

Environmental Regions: This refers to broad environmental regions within South Australia as described by Laut P (1977), or regions described within the Regional Biodiversity Plans developed by the Department for Environment and Heritage (2000 – 2001).

Key Bio diversity Areas*:* The Department for Environment and Heritage has developed key biodiversity areas within the Regional Biodiversity Plans for South Australia. The key biodiversity areas have been developed by analysis of biological assets of the area and information from community groups. There are six key biodiversity areas identified within the three wetland study regions; these are: coastal wetland habitat areas, fragmented habitat areas, grassland habitat, large remnant area, ridgeline systems, threatened habitat area.

GPS reading*:* Taken in Latitude and Longitude or easting and northing.

Map Sheet and Reference*:* Record of map sheet name and number with grid reference if required.

Approximate Area*:* usually recorded after of before survey by GIS query.

Elevation: in meters above sea level. Preferably recorded from GPS and compared with map sheet elevation values.

***Landform Element**:* Landform element definitions have been adapted from Heard and Channon (1997) Guide to a native vegetation survey using the biological survey of South Australia methodology, Section 3. Geographic Analysis and Research Unit, Department of Housing and Urban Development.

Sandy Plain: Large, very gently inclined or level element composed of fine grains of weathered rocks of quartz.

Limestone plain: Large, very gently inclined or level element of hard almost horizontally bedded limestone, which contains at least 80% of the carbonates of calcium or magnesium.

Rock outcrop: Any exposed area of rock that is inferred to be continuous with underlying bedrock on a large, very gently inclined or level element.

Drainage depression: Level to gently inclined, long, narrow, shallow open depression with smoothly concave cross-section, rising to moderately inclined side slopes, eroded or aggraded by sheet wash.

Open depression: Landform element that extends at the same elevation, or lower, beyond the locality where it is observed.

Closed depression: Landform element that stands below all points in the adjacent terrain.

Flat: Planar landform element that is neither a crest nor a depression and is level or very gently inclined (<3% slope).

Swale: Linear, level-floored open or closed depression excavated by wind, or left relict between ridges built up by wind or waves, or built up to a lesser height than them. Or long, curved open or closed depression left relict between scrolls built up by channelled stream flow.

Lagoon: Closed depression filled with water that is typically salt or brackish, bounded at least in part by forms aggraded or built up by waves or reef building organisms.

Hill crest: Very gently inclined to steep crest, smoothly convex, eroded mainly by creep and sheet wash. A typical element of mountains, hills, low hills and rises.

Hill slope: Gently inclined to precipitous slope, commonly simple and maximal, eroded by sheet wash, creep, or water-aided mass movement.

Gully: Open depression with short, precipitous walls and moderately inclined to very gently inclined floor or small stream channel, eroded by channelled stream flow and consequent collapse and water-aided mass movement.

Stream channel: Linear, generally sinuous open depression, in parts eroded, excavated, built up and aggraded by channelled stream flow. This element comprises stream bed and banks.

Flood out: Flat inclined radially away from a point on the margin or at the end of a stream channel, aggraded by over bank stream flow, or by channelled stream flow associated with channels developed within the over-bank flow part of a covered plain landform pattern.

Fan-alluvial: Large gently inclined to level element with radial slope lines inclined away from a point, resulting from aggradation, or occasionally from erosion, by channelled, often braided, stream flow, or possibly by sheet flow.

Estuary: Stream channel close to its junction with a sea or lake, where the action of channelled stream flow is modified by tide and waves. The width typically increases downstream.

Lake: Large water-filled closed depression.

Salt lake: Lake, which contains a concentration of mineral salts, (predominantly sodium chloride in solution as well as magnesium and calcium sulphate).
Swamp: Almost level closed, or almost closed depression with a seasonal or permanent water table at or above the surface, commonly aggraded by over-bank stream flow and sometimes biological (peat) accumulation.

Perched swamp: A tract of land that is permanently saturated with moisture and is positioned on an elevated landform.

Playa/pan: Large, shallow, level-floored closed depression, intermittently water-filled, but mainly dry due to evaporation, bounded as a rule by flats aggraded by sheet flow and channelled stream flow.

Geological formation name*:* Name of geological formation defined from the physical geography data sets available from http://www.atlas.sa.gov.au/

*Soil types***:** Soil type definitions have been adapted from Heard, L and Channon, W (1997) Guide to a native vegetation survey using the biological survey of South Australia methodology, Section 3. Geographic Analysis and Research Unit, Department of Housing and Urban Development.
To determine soil texture take a small handful of soil below the crust and add water working the soil into a an elongated ball (bolus) until it just fails to stick to the fingers. The behaviour of the bolus and of the ribbon produced by shearing (pressing out) between the thumb and forefinger characterise the texture. The behaviour and feel, smoothness or graininess, during bolus formation are also indicative of its texture.

Sand: Coherence nil to very slight, cannot be moulded. Sand grains of medium size, single sand grains adhere to fingers. Commonly less than 5% clay content.

Loam: Bolus coherent and rather spongy, smooth feel when manipulated but with no obvious sandiness. May be somewhat greasy to the touch if organic matter in present. Will form a ribbon of about 25mm.

Clay Loam, Sandy: Coherent plastic bolus with medium size sand grains visible within a finer matrix, forms a ribbon between 40-50mm. Clay contents between 30% – 35%.

Medium clay: Smooth plastic bolus, can be moulded into rods without fracture. Will form a ribbon of 75 mm or more. Clay contents between 45% - 55%.
Medium heavy clay: Same properties as medium clay but with a higher clay content of 50% or more.

Loamy sand: Slight coherence, sand grains of medium size, can be sheared between thumb and forefinger to give minimal ribbon of about 5 mm. Approximate clay content of about 5%.

Silty loam: Coherent bolus, smooth, often silky when manipulated, will form a ribbon of about 25mm. Clay content between 25% with 25% or more of silt.
Silty clay loam: Coherent smooth bolus, plastic and often silky to the touch, will form a ribbon of 40-50mm. Clay contents between 30%-35% and with silt 25% or more.

Clayey sand: Slight coherence, sand grains of medium size, sticky when wet, many sand grains stick to fingers. Will form a minimal ribbon of 5-15 mm, discolours fingers with clay stain. Clay contents between 5%-10%.
Sandy clay loam: Strongly coherent bolus, sandy to touch, medium size grains visible in finer matrix, will form ribbon of 25 – 40mm. Clay contents between 20% - 30%.
Light clay: Plastic bolus, smooth to touch, slight resistance to shearing between thumb and fore finger, will form ribbon of 50 – 75 mm. Clay content between 35% - 40%.

Heavy Clay: Smooth plastic bolus, handles like stiff plasticine, can be moulded into rods without fracture, has firm resistance to ribboning shear. Will form a ribbon of 75 mm or more. Clay contents of 50% or more.

Sandy loam: Bolus coherent but very sandy to touch, will form a ribbon of 15-25 mm, dominant sand grains are of medium size and are readily visible. Clay contents between 10% - 20%.

Clay loam: Coherent plastic bolus, smooth to manipulate and will form a ribbon of 40 – 50 mm. Clay contents between 30% and 35%.

Light medium clay: Plastic bolus, smooth to touch, slight to moderate resistance to ribboning shear, will form a ribbon of about 75 mm.

Peat: Brownish or blackish fibrous substance produced by anaerobic decay of vegetation and found in boggy areas.

Comments: Any comments regarding soil structure, surface materials, rock contents or other soil attributes.

Source of water supply*:* The main sources of water that enter the water body, most commonly a combination of catchment run-off, ground-water and rainfall.

Rainfall estimate*:* Isohyet information gained from the Bureau of Meteorology for annual average rainfall. Also easily accessed by overlaying GIS isohyet information on the wetlands.

Dominant riparian vegetation association*:* Describes the dominant or co-dominant over storey species and understorey species.

Significance – why the wetland is important*:* Details any significance of the wetland within its regional setting or ecological function.

Noteworthy flora*:* Threatened species: threatened flora at national or State level that occur on the site (includes any threatened species identifies under national or State legislation, ANZECC lists or action plans). Composition information on the composition of any plant species or communities for which the wetland is particularly important.

Noteworthy fauna*:* Threatened species: list of threatened fauna at national or State level that are present at the site. (includes any threatened species identifies under national or State legislation, ANZECC lists or action plans). Composition: information regarding composition of important fauna that may inhabit the wetland permanently or seasonally including migratory species. An indication of population sizes, breeding colonies, migration stopovers is also given where available.

Land Degradation*:* disturbances or threats are defined as any direct or indirect human activities at the site or in the site or in the catchment area that may have a detrimental effect on the ecological character of the wetland. The effect may be a low level disturbance (eg low level grazing) or a major threat (eg water diversion schemes). Examples include disturbance by stock, water extraction, river regulation, siltation, salinity, urban development, drainage, pollution, excessive human activity, and impact of invasive species. There are several typical types of land degradation that may affect wetlands; these are listed as a standard template within the survey.

- Access tracks
- Cleared land
- Fire breaks
- Off-Road vehicles
- Rubbish dumping
- Pollution
- Pest vertebrate presence
- Altered water flows
- Borrow pits/Quarry
- Drains
- Fence lines
- Power lines
- Slashing/clearance
- Watering points
- Grazing damage
- Wetland drainage

Comments*:* Clarification of the severity of the threats and other comments.

Potential disturbances*:* Any threats that could impact on the wetland in the future, for example, a planned change in adjoining land use.

***Conservation measures taken and measures proposed**:* Details of conservation measures being undertaken at the site (for example, fencing or revegetation) and the names of any protected areas established at or around the wetland. Details of management plans for the site and status of the site in terms of National Estate, Ramsar or World Heritage listing can also be included.

***Current scientific research**:* Outline any research activities by scientific bodies such as CSIRO or universities or other recognised research organisations.

***Current conservation education**:* Documents the existence of interpretive facilities, use of the area by school groups or other organisations.

***Recreation and tourism**:* Records recreation facilities present on the site and if there are tourism uses or values with the site.

***Social and Cultural Values**:* Documents pre-European and European historical and social values of the site.

***References**:* Lists relevant references associated with the site.

Aquatic Vegetative Classes

This parameter provides a snap shot of aquatic vegetation structure, vegetation classes recorded include:

- Algal
- Aquatic moss
- Rooted vascular
- Floating leaved
- Floating vascular
- Unknown submergent
- Unknown surface

Aquatic Flora Sample

Records any aquatic vegetation sample collected with the wetland number, wetland name, GPS location, and habitat location. Samples should be placed into a snap lock plastic bag with water and labels placed inside and outside the bag. If field trips are longer than for one day, samples should be dried and pressed that day. Pressed samples will need the paper changed every other day to avoid the specimen rotting. The Plant Biodiversity Centre can assist with plant identification and a good reference books for aquatic plant identification include *Waterplants in Australia* by G.R. Sainty (1994) and *Aquatic and wetland plants* by Nick Romanowski (1998).

Aquatic Fauna Sample

Collecting Sample Material: This is achieved by two methods.

1. **Plankton Net**. This is a small round net of approx. 200-250um pore size. Attached to the net is a length of string. One end of the string is tied to the plankton net. The other should be tied to the user of the net. The net is thrown into the water and is pulled through the water, towards the user. This procedure is done several times until sufficient sample material is collected.

If the water is too shallow then the net may be used by holding the metal rim and scooped through the water until sufficient sample material is collected in the plastic vial at the end of the net.

The sample material is then transferred from the sample vial to another vial, and 40% formalin is added to the sample to make up a mixture of approx.10% Formalin and 90% sample fluid.

2. **Hand Net**. The use of the hand net is a simple method. This is used in weedy habitats or shallow areas where the plankton net may become stuck or lost on objects. The net is used to prod at the base of vegetation and is run closely to the bottom of shallow water bodies. This is done over approx. 10-20 metres distance to obtain a representative sample from the water body.

The material in the net then is transferred to one or two sample vials.

Washing the Nets: This is done between sampling of each site in an attempt to clean the net of invertebrates to stop cross “contamination” of samples between sites. Cleaning of the net between sites is achieved by simply washing the net in the water of the site, without the sample vial attached. Ideally this should be done before and after a sample is taken.

Labelling Sample Vials: This is extremely important and should be done in a legible manner. The label should clearly and legibly be written upon and information recorded should be clearly stated.

Information recorded includes:

- Wetland number
- Name of wetland
- Date of Sample
- Grid Reference of site
- Method of collection (hand net or plankton net).

Material preservation of sample: material collected should be preserved with approximately 10% formalin as soon as possible after the sample is collected. This stops decomposition of the sample and also many of the invertebrates from eating each other. Formalin is used as many of the microinvertebrates become soft and mushy, denaturing in the 70% alcohol solution, used to preserve macroinvertebrates and vertebrates.

The formalin supplied is 40% by volume. This should be added to the sample material to make up approximately 10% formalin and 90% sample material. This is only a guide and should be used by the sampler with a degree of care.

Formalin is a dangerous chemical and is a fixative. Do not inhale it and wash your hands after use thoroughly. Read instructions on the label before use.

Water phys-chemistry

Five standard water chemistry parameters are collected; these are described below.

PH : is recorded using a Hanna HI 9025 pH meter. The meter is placed into the water body (ensuring that the probes do not touch the substrate). The reading is then given on the display. Calibration and maintenance of the pH unit is often needed, these procedures are outlined in the pH manual supplied with the unit.

Conductivity: is recorded using a Hanna HI 9635 meter. This meter can measure in the 0 to 199 µS/cm range. It can be used to measure any sample from deionised water to highly saline water. The meter is placed in the water body ensuring that the probe does not touch the substrate and the reading is given on the display when stable. Calibration and maintenance procedures required are outlined in the manual.

Turbidity: is recorded using a Hanna HI 93703 portable microprocessor turbidity meter. The unit is designed to perform measurements according to the ISO 7027 International Standard. The instrument functions by passing a beam of light through a vial containing the sample being measured. A sensor, positioned at 90º with respect to the direction of light, detects the amount of light scattered by the undissolved particles present in the sample. These readings are given in NTU units. The manual accompanying the unit outlines measurement, calibration and maintenance procedures.

Dissolved O^2: is recorded using a Hanna HI 9142 dissolved oxygen meter. Dissolved oxygen is indicated in tenths of parts per million (ppm=mg/l). The dissolved oxygen probe has a membrane covering the polarographic sensors and a built in thermistor for temperature measurements and compensation. The thin permeable membrane isolates the sensor elements from the testing solution, but allows oxygen to enter. When a voltage is applied across the sensor, oxygen that has passed through the membrane reacts causing current to flow, allowing the determination of oxygen content.

Water Temperature: Water temperature is read from the pH or Dissolved Oxygen meter.

Rapid assessment (conservation values)

The rapid assessment component of the survey provides a quick snap shot of the vegetation associations and condition within different riparian habitats. Other parameters such as aquatic fauna and wetland condition is also recorded.

Aquatic Fauna*:* is a subjective score according to the abundance and diversity of invertebrates, fish and birds located within or on the water body.

- Low (1) refers to no fish or birds with little or no invertebrate presence.
- Moderate (3) refers to some bird presence and good vertebrate abundance, fish usually are not present.
- High (5) indicates good bird and invertebrate diversity and abundance with the presence of fish.

Aquatic Vegetation*:* records the abundance and diversity of aquatic vegetation.

- Low (1) indicates no or very little aquatic vegetation.
- Moderate (3) indicates some aquatic vegetation cover either in the form of floating or rooted vegetation.
- High (5) indicates good diversity of aquatic vegetation with a range of rooted vegetation such as reeds and rushes and floating vegetation such as water ribbons.

Riparian Vegetation

Riparian vegetation is assessed at three zones, these are the
- toe of bank (Low water – High water),
- bank (high water mark – buffer) and
- buffer (top of the bank to the buffer which can extend between 10 meters and 100 meters).

The vegetation association for each zone consists of the dominant or co-dominant over storey species and understorey species. The vegetation association for each zone is scored considering the level of disturbance and vegetation cover within each zone.

The vegetation association scoring system consists of:
- Degraded or no vegetation (1) with less than 30% vegetation cover, with high level of disturbance.
- Natural (3) between 30 – 75% vegetation cover, with little disturbance.
- Intact (5) over 75% vegetation cover with little or no disturbance.

Wetland Condition

The wetland score should reflect the previous rapid assessment scores for aquatic fauna, aquatic vegetation and riparian vegetation values. The combination of these values and the interpretation of others parameters recorded during the survey (such as land degradation and water chemistry) form the basis of the wetland condition score.

The wetland score consists of:
- Degraded (1) those sites that have a high level of disturbance and received low rapid assessment scores.
- Natural (3) those sites that have little disturbance, received moderate to high rapid assessment scores and that are sites usually protected within the reserve system or by private conservation.

- Pristine (5) those sites with no obvious sign of disturbance, scored very highly in the rapid assessment and are formally conserved within the reserve system.

Photographic records

Photographic records for this survey have been recorded by digital camera in JPEG and BITMAP format. The following records should be kept when using a digital camera. It is recommended that a Laptop computer be taken on surveys for ease of cataloguing photographs.

All pictures need the following information recorded:

- Picture number and wetland number
- Direction and features if relevant
- Photographer name and date.

ANZECC wetland criteria

This criteria is used for determining nationally important wetlands in Australia, and form the bases for the inclusion in the Directory. These criteria are those agreed to by the ANZECC Wetlands Network in 1994.

A wetland may be considered nationally important if it meets at least one of the following criteria:

- It is a good example of a wetland type occurring within a biogeographic region in Australia.

- It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.

- It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.

- The wetland supports 1% or more of the national populations of any native plant or animal taxa.

- The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.

- The wetland is of outstanding historical or cultural significance.

Many of the sites in the Directory meet more than one of the criteria. Application of the criteria to individual wetland sites involves a degree of subjectivity. Not only may certain aspects of a site's significance be interpreted differently by different investigators, but information gaps often exist which make it difficult to judge whether or not a site meets a particular criterion.
The Interim Biogeographic Regionalisation for Australia (IBRA) is used as the framework for applying Criterion 1, which identifies wetlands that are unique or representative within a biogeographic region in Australia.

Wetland type

The definition of a wetland used in the survey is one adopted by the Ramsar convention under Article 1.1.

> *"Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent of temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."*

Within this definition, the wetland classification system used in the Directory of Important Wetlands identifies 40 different wetland types in three categories: A-Marine and Coastal Zone wetlands, B-Inland wetlands, and C-Human-made wetlands. This wetland survey does not include Category A – Marine and Coastal Zone wetlands .

The system is based on that used by the Ramsar Convention in describing Wetlands of International Importance, but was modified slightly to suit the Australian situation.

A – Marine and Coastal Zone wetlands

- Marine waters - permanent shallow waters less than six metres deep at low tide, includes sea bays straits
- Subtidal aquatic beds, includes kelp beds, sea-grasses, tropical marine meadows
- Coral reefs
- Rocky marine shores, includes rocky offshore islands, sea cliffs
- Sand, shingle or pebble beaches, includes sand bars, spits, sandy islets
- Estuarine waters, permanent waters of estuaries and estuarine systems of deltas
- Intertidal mud, sand or salt flats
- Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
- Intertidal forested wetlands, includes mangrove swamps, nipa swamps, tidal freshwater swamps forests
- Brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea
- Freshwater lagoons and marshes in the coastal zone
- Non tidal freshwater forested wetlands

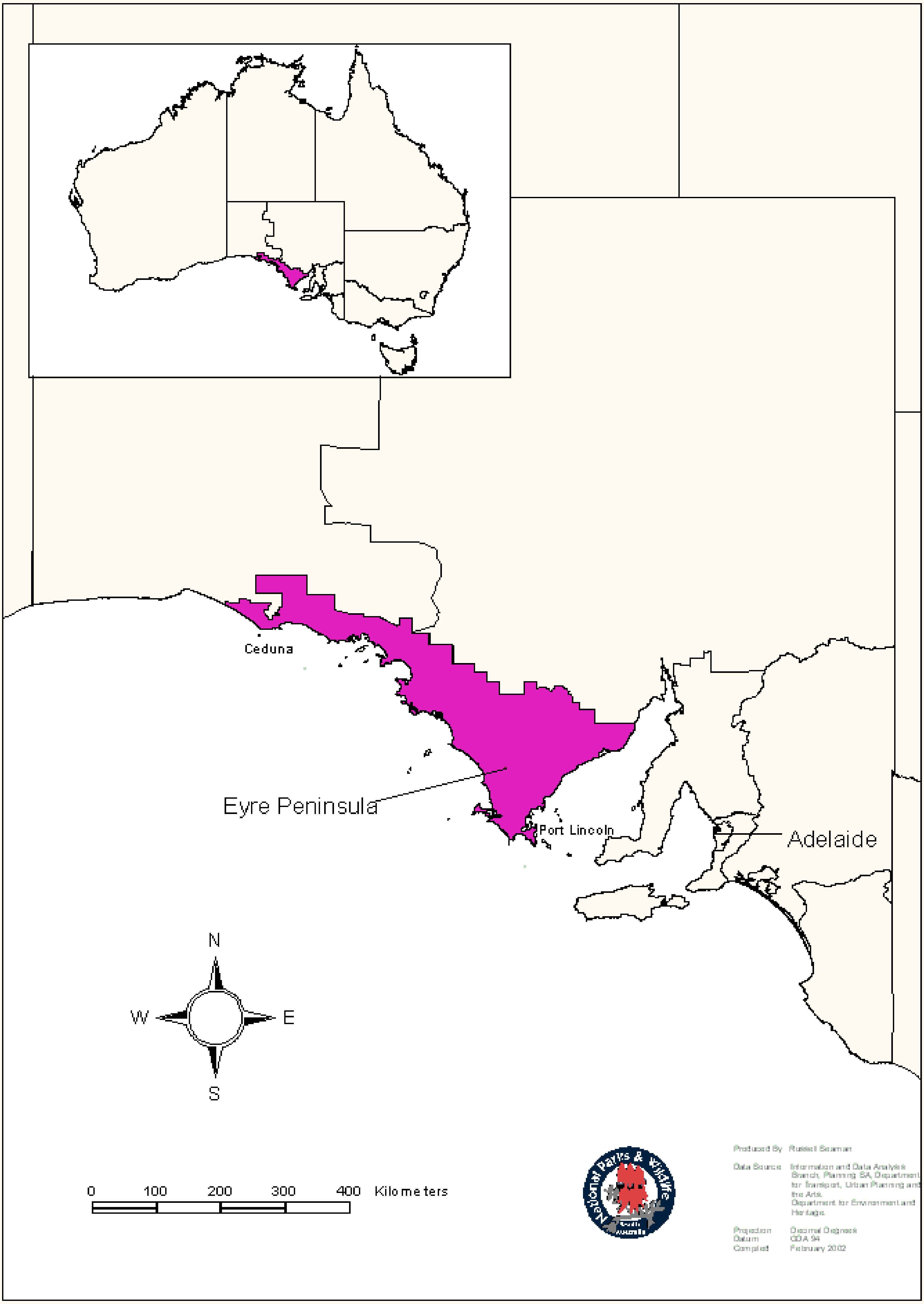
B – Inland wetlands

- Permanent rivers and streams includes waterfalls
- Seasonal and irregular rivers and streams
- Inland deltas(permanent)
- Riverine floodplains, includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
- Permanent freshwater lakes (8 ha) includes large oxbow lakes
- Seasonal/intermittent freshwater lakes (>8 ha) floodplain lakes
- Permanent saline /brackish lakes
- Seasonal/intermittent saline lakes
- Permanent freshwater ponds (<8 ha) marshes and swamps on inorganic sols, with emergent vegetation waterlogged for at least most of the growing season
- Seasonal/intermittent freshwater ponds and marshes on inorganic soils includes sloughs, potholes, seasonally flooded meadows, sedge marshes
- Permanent saline/brackish marshes
- Seasonal saline marshes
- Shrub swamps, shrub dominated freshwater marsh, shrub carr, alder thicket on inorganic soil
- Freshwater swamp forest, seasonally flooded forest, wooded swamps, on inorganic soils
- Peatlands, forest, shrubs or open bogs
- Alpine and tundra wetlands: includes alpine meadows, tundra pools, temporary waters from snow melt
- Freshwater springs, oasis and rock pools
- Geothermal wetlands
- Inland, subterranean karst wetlands

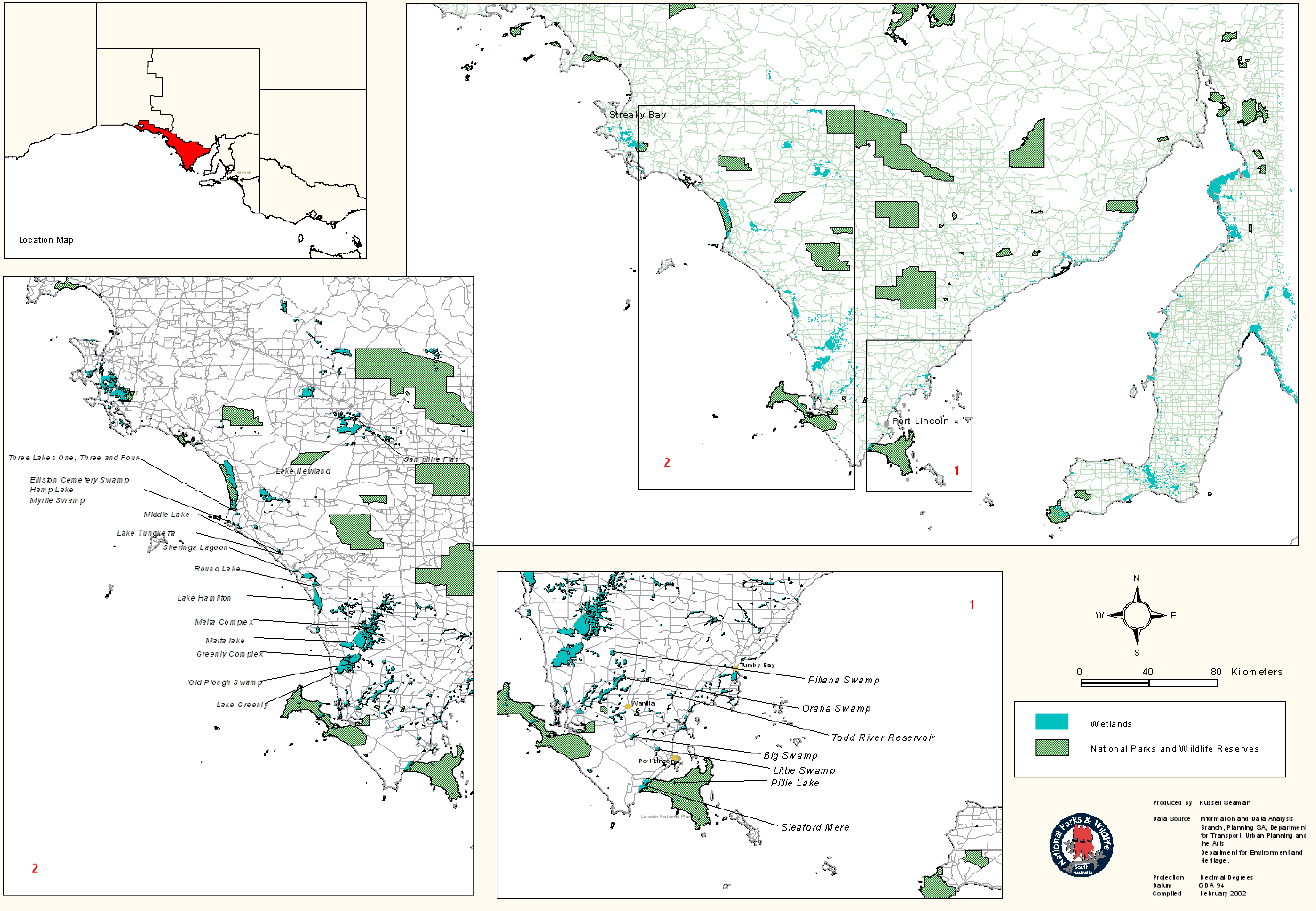
C- Human-made wetlands

- Water storage areas; reservoirs, barrages, hydro-electric dams, impoundment’s (generally over 8 ha).
- Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
- Aquaculture ponds; fish ponds shrimp ponds
- Salt exploitation, salt pans, salines
- Excavations; gravel pits; borrow pits, mining pools.
- Wastewater treatment areas; sewage farms, settling ponds, oxidation basins.
- Irrigated land; includes irrigation channels and rice fields, canals, ditches
- Seasonally flooded arable land, farm land
- Canals

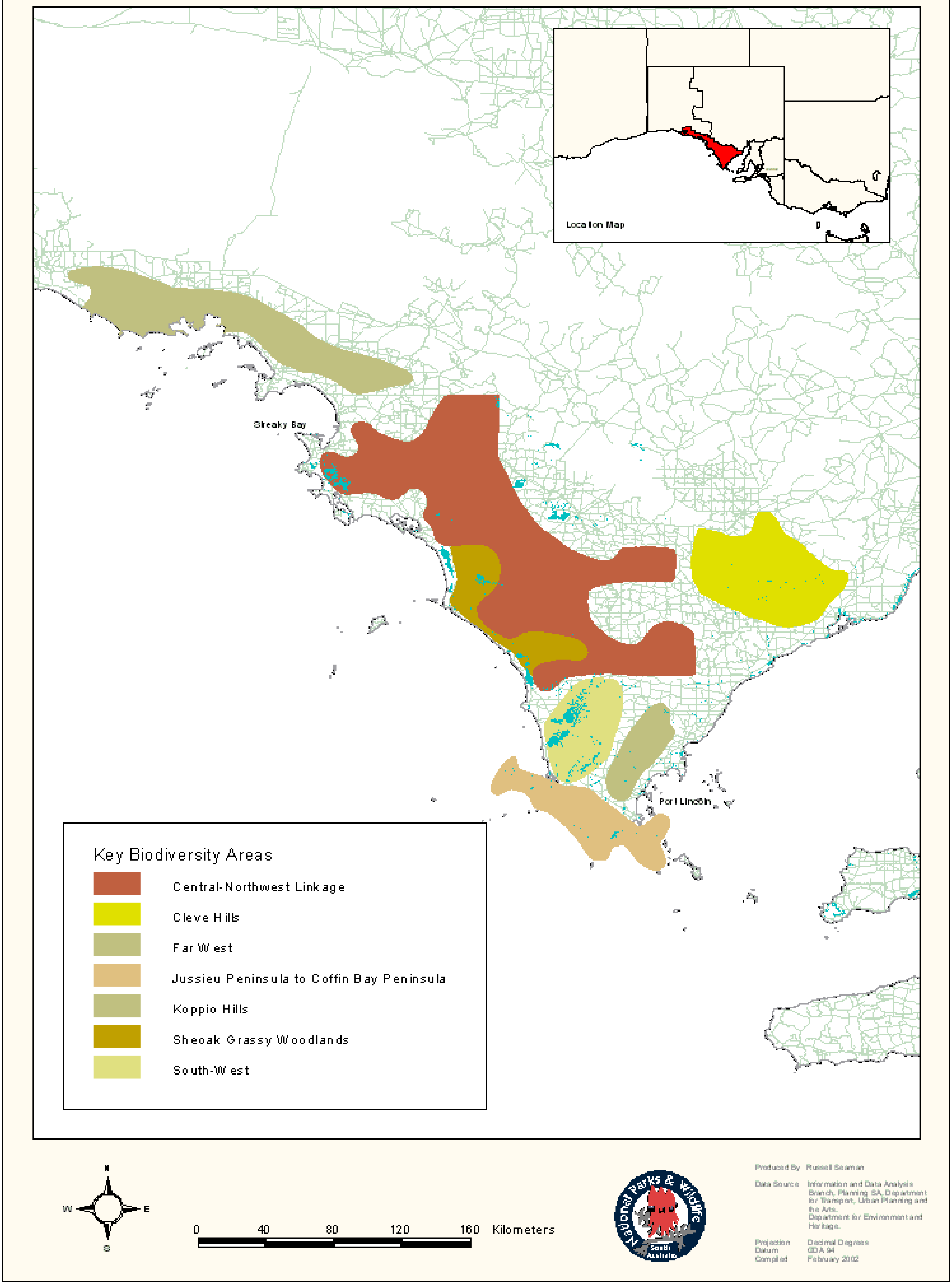
Map 1 Natural Heritage Trust Boundary for Eyre Peninsula



Map 2 Wetland Survey Localities



Map 3 Key Biodiversity Areas



Map 4 Geology underlying wetlands on Eyre Peninsula