Assessing the vulnerability of native vertebrate fauna under climate change, to inform wetland and floodplain management of the River Murray in South Australia.

FINAL REPORT

June 2011

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Executive Summary

Under climate change, the most significant impact to the South Australian Murray-Darling Basin is a forecast reduction in the frequency, duration and extent of flooding of the River Murray. Through a risk assessment process, 37 species of aquatic-ecosystem dependent vertebrate fauna were identified as most vulnerable to the impacts of climate change along the River Murray in South Australia from Wellington to the state border. This risk assessment process addressed the influence of each species ecology, physiology, genetics and resilience to its vulnerability under climate change. Summaries produced for each of the 37 most 'at risk' species identify the major factors influencing their vulnerability. Species reliant on seasonal flooding and flow regimes, with narrow habitat requirements, a low tolerance to salinity, limited dispersal ability, small population size and low reproductive capacity and recruitment rates are most at risk under climate change. Spatial distribution and proximity analyses were performed to determine the distribution of these most vulnerable species with respect to wetlands and Key Environmental Assets (KEAs) comprising wetland complexes, to develop a priority list of areas for management. Seventeen KEAs (with records of 10 or more 'most vulnerable' species) have been identified for priority management.

Major recommendations for management include: the provision of environmental flows through creeks and anabranches to support species reliant on flowing water habitat for foraging, reproduction and dispersal; environmental watering of temporary wetlands and floodplains, and maintenance of natural wetting and drying regimes to support species reliant on fluctuating water levels for foraging, reproduction and other life history requirements; the retention of long lived vegetation, such as river red gums identified as critical to the existence of a number of vulnerable species, and maintenance of aquatic and terrestrial habitat diversity and structure in still, flowing and floodplain habitats. The application of project results for management may be limited by the availability and accuracy of data for analysis, limited and/or inconsistent survey effort across the study region during the data capture period, lack of applicable species research and uncertainties over the scale of impact of climate change on the SA MDB.

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1.0 Introduction & Background

Climate change is forecast to have significant and wide ranging effects on regional weather patterns. In Australia, the outlook is for higher temperatures, more rainfall in the north and less in the south, and more short-term variability (CSIRO 2007). Effects on dry regions are expected to be greatest, and the annual discharge of the Murray-Darling Basin in particular could fall by 30 percent, with greater variations between years (CSIRO 2008).

This project will identify aquatic-ecosystem dependent fauna species along the River Murray in South Australia that are vulnerable to the impacts of climate change. Information gathered about each species' vulnerability and distribution will be used to inform floodplain and wetland management. The following impacts on aquatic systems of the River Murray are expected as a result of these changes to climate and basin discharge (CSIRO 2008).

Less frequent floods, resulting in reduced frequency of inundation of temporary wetlands and floodplains, and longer dry periods between floods:

- Reduced habitat for fauna species reliant on temporary wetlands for breeding, foraging, shelter etc.
- Decline in populations and breeding events, most evident for species reliant on flooding cues to trigger reproduction.
- Decline in vegetation health and change in vegetation structure and composition to a more drought-tolerant species assemblage and loss of aquatic species with short propagule longevity.
- Increased frequency and duration of faunal migration and dispersal events reducing fitness and increasing risk of predation.
- Accumulation of salt in wetlands and floodplains altering species diversity and population structures favouring species with higher salt tolerance.

Increased evaporation rates:

- Decreased periods of wetland inundation e.g. temporary wetlands will dry out more rapidly following floods.
- Reduced recruitment of species unable to complete breeding cycles prior to drying of wetlands, with greatest impact on species requiring long inundation periods for reproductive success.
- Permanent and semi-permanent wetlands will completely dry more frequently affecting species reliant on permanent systems and with limited dispersal ability

Reduced flow in the river channel and associated anabranches:

- Impacts on fauna species reliant on flow, e.g. for migration and breeding cues, and feeding.
- Alteration of in-channel vegetation composition and structure

Low rainfall coming into summer and less soil moisture storage:

- Stress on floodplain vegetation affecting health, structure and vegetation composition.
- Greater influence of saline groundwater resulting in increased salinisation of floodplain soils and surface waters.
- Impacts on reproductive success for species that rely on a certain soil moisture &/or temperature range for egg incubation, e.g. turtles.

The effects on species and ecosystems are expected to be wide ranging and include changes in species distributions and abundances, ecosystem processes, interactions between species, and various threats to biodiversity (CSIRO 2008).

However, the nature and extent of impacts on individual species are largely unknown. Determining which species of fauna within the region are most vulnerable to the forecasted effects of climate change and their distribution will ensure that management of the Lower River Murray corridor and its wetlands and floodplains in South Australia incorporates the requirements to protect vulnerable populations and their habitats.

The allocation of environmental water for wetlands and floodplains needs to be scientifically based, and applied to ensure the maximum ecological benefits at local and regional scales. A process that identifies species within the management region most vulnerable to climate change and its impacts, and the distribution of these species at the local landscape scale, makes an important contribution to the informed management of aquatic ecosystems.

1.1 Project objectives

- Identify native aquatic-ecosystem-dependent vertebrate species along the River Murray in South Australia (excluding the Lower Lakes and Coorong) that are vulnerable to climate change.
- Develop a method and assess the 'vulnerability' of native vertebrate species to climate change by collating and evaluating available information regarding the ecology, physiology, genetics and resilience of each species.
- Identify regional 'hotspots' that support high diversity of species that are 'at risk' to climate change as determined through vulnerability assessments.
- Identify wetland and Key Environmental Asset (KEA) areas associated with the distribution of 'at risk' species.
- Develop management recommendations relating to wetland and KEA areas and 'at-risk species'.

1.2 Study area and region extents

A method to assess the vulnerability to climate change of regional flora and fauna was developed (Walker 2010) and is described in later sections. To identify native aquatic-ecosystem dependent species at greatest risk from climate change within the study region initially involved identifying *all* species in the study region to ensure that none were overlooked. The identification of vulnerable flora species was beyond the scope of this project but flora was included in the initial collation of distribution data (sections 2.1 & 2.2).

Recent biological distribution records from a number of sources were collated for uploading to the DENR Biological Database of South Australia (BDBSA) for analysis. Species data from the River Murray Wetland Baseline survey study 2003-07 was collated and reformatted for input to the BDBSA, and fish survey data was sourced from the SA Freshwater Fish database, incorporating data from a number of government agencies, museums and universities (Miles & Gonzalez 2011).

The project focussed on a study area of the 1956 floodplain from the Victorian border down to Wellington (see Figure 1). Spatial analyses focused on generating species-specific distribution data at 6 different spatial scales; State-wide (~98 million ha), South Australian Murray Darling Basin (SA MDB) region (~5.3 million ha), 1956 floodplain (~230,000 ha), study area (~110,030 ha), geomorphic reach (~55,000 ha) and lock reach (~15,000 ha). The geographic extents of these boundaries are shown below in Figures 2 and 3. This analysis provided species distribution information within the study region, but also the extent of a species' range outside the study region, and consequently an indication of the status of the population within the study region at a broader scale.

The set of polygon layers containing regional boundaries was extracted from the DENR SDE database and a geodatabase containing geomorphic and lock reach boundaries. These datasets were processed through spatial models to generate polygon feature classes for each boundary. Details of the processes applied to generate these layers are given in the supporting methodology report, Miles and Gonzalez (2011). Table 1 summarises the spatial extents of the regions within the study area, Figures 1, 2 and 3 show the geographic extents of the study area and lock and geomorphic reaches, respectively.

Boundary	Area (ha)	Area (km^2)
South Australia	98228873	982289
SA MDB region	5670283	56703
1956 floodplain	228111	2281
Study Area (Border to Wellington)	110030	1100
Mannum - Wellington	10184	102
Overland Corner - Mannum	29041	290
Border - Overland Corner	70804	708
Lower Lakes	118080	1181
Border - Lock 6	12129	121

Lock 6 - Lock 5	18788	188
Lock 5 - Lock 4	16552	166
Lock 4 - Lock 3	19936	199
Lock 3 - Lock 2	7911	79
Lock 2 - Lock 1	9427	94
Lock 1 - Wellington	21971	220

Table 1 Summary of regional boundary areas used in this project.

Figure 1 Project study area defined as the 1956 floodplain of the River Murray corridor in South Australia, excluding the Lower Lakes and Coorong.

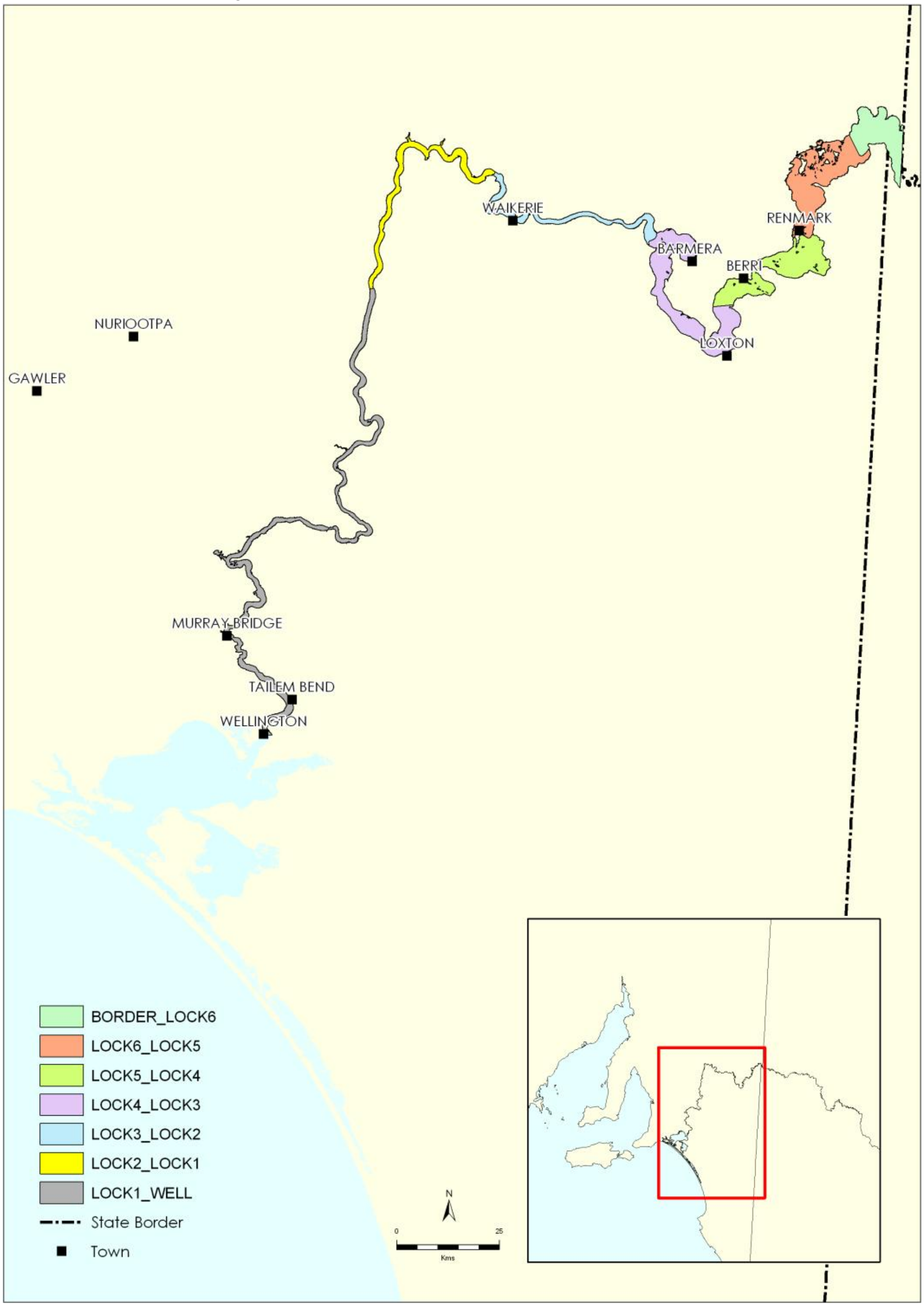

Figure 2 Lock reach regions within the study area.

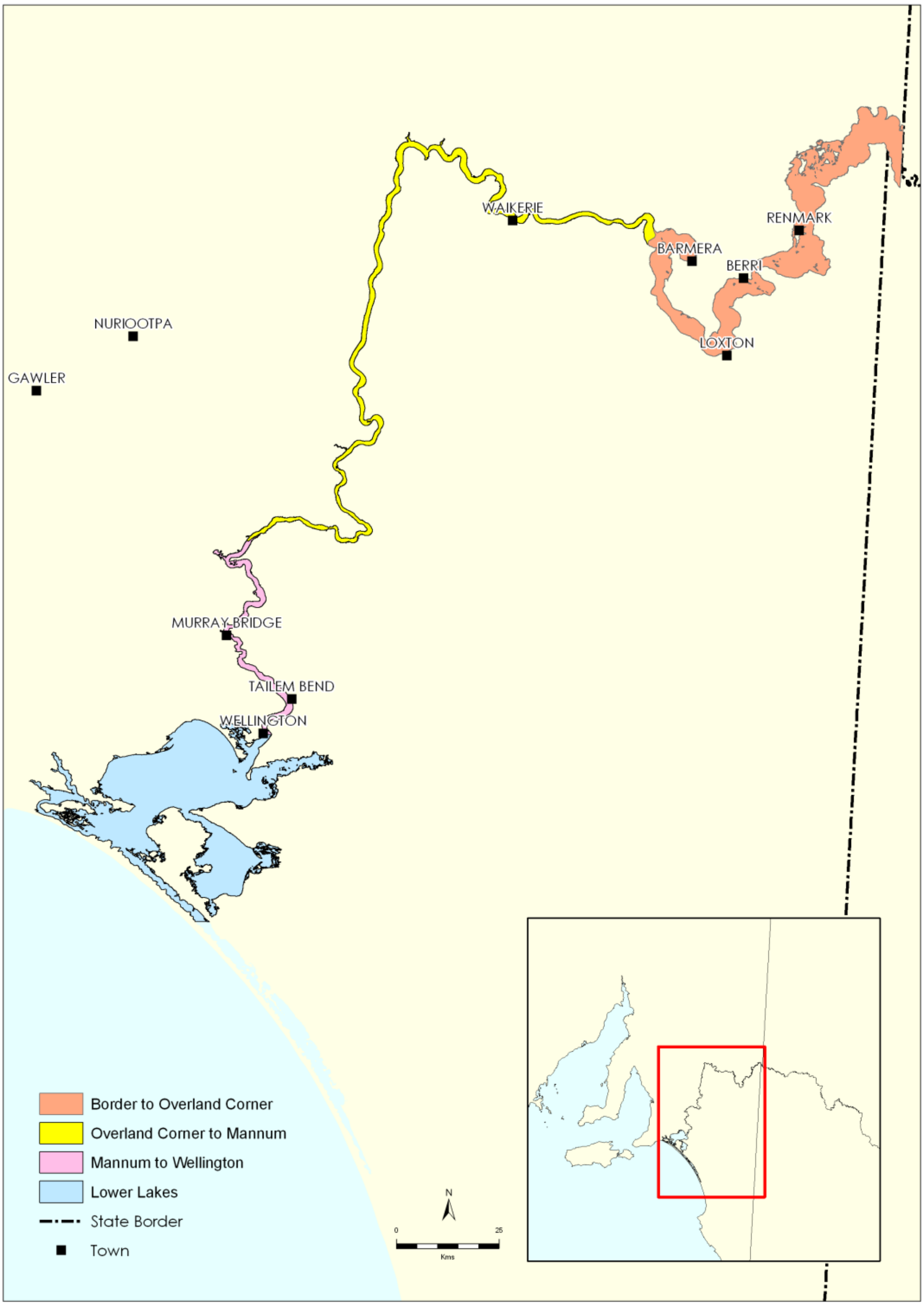

Figure 3 Geomorphic reach regions used in the project (Lower Lakes was not part of final analyses).

1.3 Species selection process

A cut-off date of January 1st, 1990, was used as the first filter to separate more recent data from historical records and exclude species that have not been recorded within the region in the last 2 decades. The preliminary list contained 465 vertebrate species – encompassing all species recorded within the 1956 floodplain of the South Australian River Murray Corridor since 1990 (Table 1). Many of these species are either introduced species, or terrestrial species that utilise the river corridor but are not considered dependent on aquatic-ecosystems and hence not within the context of this project. A process to refine the list of species for further assessment was undertaken and is outlined below. Table 2 documents the 5 stages in this process as 'number of species' remaining after each stage. Following this process, 75 aquatic-ecosystem (includes floodplain) dependent native vertebrates were identified for further assessment to determine their *level* of vulnerability to climate change. This species list is presented in Appendix 1.

Category of inclusion for next stage	Fish	Frogs	Reptiles	Birds	Mammals	TOTAL
Stage 1. All vertebrate fauna species occurring within SA 1956 flood level from 'Post 1990 Master' tables.	33	13	58	312	49	465
Stage 2. All vertebrate fauna species occurring within study region (SA Border to Wellington (1956 flood level).	27	12	46	239	42	366
Stage3: Native vertebrate fauna species occurring within study region.	21	12	46	234	30	343
Stage 4: Aquatic ecosystem dependent native vertebrate fauna species *occurring* within the study region.	21	12	9	85	4	131
	Number of species to undertake 'Vulnerability to Climate Change' assessment.					
	Fish	**Frogs**	**Reptiles**	**Birds**	**Mammals**	**TOTAL**
Stage 5: *Aquatic ecosystem dependent native* fauna species *reliant* on habitat within the study region expected to be impacted by climate change	18	12	9	32	4	75

Table 2 Process to determine the number of fauna species to undergo assessment for vulnerability to climate change.

Stage 1. All vertebrate fauna species recorded within 1956 flood level (Fauna 'Master' table).

A list of 465 fauna (312 bird; 13 frog; 49 mammal; 33 fish & 58 reptile species) recorded as occurring within the 1956 floodplain level (post-1990) from the SA-Vic border to the Lower Lakes, including both native and introduced species.

Stage 2. All vertebrate fauna species recorded within study region, SA-Vic Border to Wellington (excluding Coorong & Lower lakes)

The study region excludes the Coorong and Lower lakes. In addition, species with 100% of distribution records below Wellington (56 bird, 5 reptile, 6 fish and 2 mammal species) were removed from the list.

Stage 3. Native vertebrate fauna species recorded within study region.

In order to recognise *only* native species for further assessment within the study region 24 introduced species were identified and excluded:

- 5 fish species (brown trout excluded in stage 2);
- 12 mammal species
- 7 bird species

Stage 4. Aquatic ecosystem dependent native vertebrate fauna species recorded within the study region.

The next stage in refining the list was to exclude all non-aquatic-ecosystem dependent species in the study region. This step was undertaken by seeking advice from 'experts' with knowledge on the ecology of each vertebrate class within the region. Following exclusion of non-aquatic-ecosystem dependent native species from each vertebrate class, 85 bird, 21 fish, 9 reptile, 12 frog & 4 mammal species remained that have distribution records within the study region.

Stage 5. Aquatic ecosystem dependent native vertebrate fauna reliant on habitat within the study region expected to be impacted by climate change (and consequently most vulnerable to the effects of climate change within the study region).

Fish, amphibians, reptiles & mammals

A decision was made to *include* for vulnerability assessment all aquatic-ecosystem dependent fish, frog, reptile and mammal species recorded within the study region due to their limited capacity for long ranging movements within short time scales (compared with birds) and consequently greater reliance on local habitats:

- However, of the 21 native fish species recorded within the study region, 3 species were excluded from further assessment as expert opinion and biological records indicated their distribution to be largely outside the study area.

Birds

Birds make up the vast majority of aquatic ecosystem dependent vertebrate species recorded within the study region and many are highly mobile, rapidly dispersing, wide ranging and/or transient visitors at a particular location. These factors, to varying degrees and between species, reduce their reliance on individual, or clusters of, aquatic ecosystems compared with other vertebrates that generally use a much smaller 'patch' size at a landscape scale. As a result it was not considered appropriate to include all aquatic-ecosystem dependent bird species for vulnerability assessment.

Each of the 85 bird species was assessed via expert consultation, and decisions were made to exclude a species from assessment if it met 2 or more of the following criteria:

- Habitat within the study region expected to be impacted by climate change is not considered important to the species
- The study region is on the edge of the species' range
- The species has an extensive range of which the study area only forms a small component.
- The species is a vagrant to the region
- The species does not breed within the study region

Thirty-two aquatic- ecosystem dependent bird species recorded within the study region were identified for assessment from this process.

2.0 Methodology

2.1 Baseline survey & biological data sources

Recent baseline survey data collected by various agencies and private consultants were collated and prepared for upload to the Biological Database of South Australia (BDBSA). These surveys were conducted as part of the River Murray Wetland Baseline RMCWMB 2004 study (Survey 165) and contained bird, reptile, mammal and amphibian species (summarised in Table 1 in Miles and Gonzalez 2011)

Fish survey data were sourced from the SA Freshwater Fish database collated by Michael Hammer for the 'Action Plan for South Australian Freshwater Fishes: 2007-2012'. The dataset includes data from the following sources: (NFA (SA)), Aquasave, SARDI, SA Water Quality Centre, AMLR & SAMDB NRM Boards, DENR (SE region), DWLBC, University of Adelaide, SA Museum, Victorian Museum, and the Australian Museum. Freshwater fish and BSBSA data are summarised for taxonomic groups in Table 3 and limited to records found only within the 1956 floodplain, and split into two epochs, namely pre- and post-1990.

Source	Taxa	No. Records Pre-1990	No. Species Pre-1990	No. Records Post-1990	No. Species Post-1990
BDBSA	Amphibian	133	10	2366	13
BDBSA	Avian	8509	287	87507	312
BDBSA	Mammal	356	35	2974	49
BDBSA	Reptile	407	57	1490	58
BDBSA	Fish	0	0	3256	22
BDBSA	**Total Fauna**	**9405**	**389**	**97593**	**454**
BDBSA	Flora	6310	1118	13213	874
SDE SA Freshwater Fish	Fish	487	35	2747	33

Table 3 Summary of data contained in the BDBSA and Freshwater Fish databases within the 1956 flood plain (data as at 1, Oct 2010).

A number of records collected within the last 20 years from three additional sources were not included in the distribution and spatial accuracy analyses detailed in Sections 2.1, 2.2 and 2.3. These included DENR Upper Murray wetland monitoring data collected by Mike Harper (DENR) and SA MDB NRM Board and DFW wetland monitoring data. Mike Harper's data were available and included in the distribution mapping and proximity analyses used to determine spatial associations with wetland and key environmental assets (KEAs) and determination of species richness 'hot spots' at wetland and KEA scales (see methods in Section 2.3 and results in Section 3.2).

2.2 Distribution of biological records

The distribution of aquatic ecosystem-dependent species at 6 different spatial scales: state-wide, within the SA MDB region, within the 1956 floodplain, within geomorphic reaches, within lock reaches and within the study area. This was initially produced to aid determination of 'vulnerable species' to be assessed according to their presence (or absence) within the study area relative to wider records.

Table 4 summarises the distribution of post-1990 biological point records from the BDBSA flora and fauna records and the SA Freshwater Fish SDE layer. Species abundance and richness are shown for State, SA MDB, floodplain, geomorphic and lock reach regions and the study area (above Wellington). No filters were applied for this analysis; it serves to describe the volume and variety of records (species richness) at these 6 spatial scales.

DATASET	NUMBER OF RECORDS (NUMBER OF SPECIES) POST 1990							
	State-wide	SA MDB	Flood 56	Study Area (Border to Wellington)	Border - Overland Corner	Overland Corner - Mannum	Mannum - Wellington	Lower Lakes
BDBSA Flora	629677 (6549)	90066 (3031)	13213 (874)	10907 (715)	5421 (448)	4212 (498)	1274 (254)	2306 (381)
BDBSA Fauna	1261062 (1139)	369830 (645)	97593 (454)	45179 (381)	18922 (321)	18004 (301)	8141 (236)	52523 (299)
SA Freshwater Fish	6231 (56)	3816 (38)	2747 (33)	1521 (27)	571 (18)	553 (24)	397 (22)	1226 (29)
DATASET	LOCK 1-WELL	LOCK 2-1	LOCK 3-2	LOCK 4-3	LOCK 5-4	LOCK 6-5	BORDER-LOCK 6	
BDBSA Flora	2930 (431)	1238 (307)	1319 (257)	1830 (279)	903 (194)	1761 (278)	926 (185)	
BDBSA Fauna	13926 (283)	5367 (244)	6847 (241)	6609(242)	5992 (241)	4733 (266)	1585 (184)	
SA Freshwater Fish	745 (26)	144 (16)	74 (15)	131 (15)	150 (17)	150 (16)	127 (15)	

Table 4 Distribution of post-1990 biological records and species richness across State and regional boundaries (data as at 1, Oct 2010).

The list of potential aquatic ecosystem-dependent species was initially compiled by extracting the flora and fauna records within the 1956 floodplain above Wellington . A 20 year cut-off date was then applied to remove older historical records. Post-1990 frequency tables were provided to the SA MDB NRM Board where consultants and experts in wetland and riverine ecology applied additional filters (see section 1.3). This process compiled a manageable species list for further assessment of climate change risk.

The spatial accuracy of the biological point data sources was important to recognise as it would have implications on the application of methods and interpretation of results. Table 5 summarises the spatial accuracy of post-1990 records of species within the study area (see Figure 1). Shaded values in Table 5 show where the spatial accuracy of the largest proportion of the data lies. More than half of all records were accurate to within 250m; flora was the most spatially accurate with 89% of data within 50m of its true location. SA Freshwater Fish records showed the most error with 39% of data accurate to 100m and 79% accurate to 250m. 75% of BDBSA fauna records were accurate to within 100m.

Spatial Accuracy	SA Freshwater Fish			BDBSA Fauna			BDBSA Flora		
	Frequency	% Records	Cum. %	Frequency	% Records	Cum. %	Frequency	% Records	Cum. %
0-5m	0	0	0	20	0	0	11	0	0
5-50m	344	23	23	14858	33	33	9724	89	89
51-100m	245	16	39	19164	42	75	22	0	89
101-250m	609	40	79	516	1	77	105	1	90
251-500m	157	10	89	6275	14	90	0	0	90
501-1000m	3	0	89	1103	2	93	227	2	92
1-10km	1	0	89	1911	4	97	64	1	93
11-30km	5	0	90	16	0	97	0	0	93
31-125km	0	0	90	0	0	97	1	0	93
>25km	142	9	99	0	0	97	3	0	93
>625km	0	0	99	0	0	97	0	0	93
Entered	14	1	100	1308	3	100	763	7	100
No. Records	**1520**			**45171**			**10920**		

Table 5 Spatial accuracy of post-1990 biological records *within the study area* from BDBSA and SA Freshwater Fish. Highlighted values correspond to 1st half of data (>50 Cumulative %) (data as at Oct 1, 2010).

A comparison of spatial accuracies of the pre-1990 records is given in Appendix 2. This further supports the filtering out of old and less reliable data. The spatial accuracy of the pre-1990 data was much more variable compared to later records. Eighty five percent of the fauna data had a spatial accuracy of up to 10km and 51% within 1km and 69% within 10km. The SA Freshwater Fish data was slightly more accurate with 65% with 500m (Appendix 2).

2.3 Proximity analyses of 'at-risk' species

A critical question this project set out to answer was what key areas are most important in the distribution of 'at-risk' species. Following completion of the vulnerability assessment process (outlined in section 2.4) on the 75 species identified for assessment, a list of 'at-risk' species for each taxonomic group was generated (see Section 3.0).

Proximity spatial models were used to estimate distances of species records to the nearest wetlands or key environmental asset (KEA) area within a given search radius. In order to perform the proximity analyses, the spatial accuracy of the data was an important consideration. The search radii for these relationships were determined from examining the spatial accuracy of the records for each taxonomic group. Following species vulnerability assessments, the spatial error of state-wide, post-1990 records of the 'at-risk' species was examined. For example, as shown in Table 6, over half of the fish data was accurate to within 50m and 81% was accurate to within 250m. After this, the increase in cumulative percentage of records is reduced with decreasing spatial reliability. For this reason, analyses of wetland relationships with fish were restricted to records accurate to within 250m. Similarly, around 80% of mammal records were accurate to within 500m beyond which the cumulative percentage of records was reduced with increased spatial error.

The search radius in the proximity model was determined by doubling the spatial error of the records to account for this lack of precision. For example, a point with accuracy of +/-500m that is plotted 500m away from a wetland may in reality be located on the edge of the wetland or up to 1000m away (see Figure 4). The spatial models were set to return only one 'search' result for each record, i.e. only the closest wetland (or KEA) within the set search radius was recorded for any one point record. This avoided issues with multiple or overlapping counts experienced with buffered intersect modelling methods while accounting for the spatial error of records. Spatial models and filtering processes are described in detail in Section 3 of Miles and Gonzalez (2011).

	Fish			Mammals			Birds			Reptiles			Frogs		
Spatial Accuracy	Freq	% Records	Cum. %	Freq	% Records	Cum. %	Freq	% Records	Cum. %	Freq	% Records	Cum. %	Freq	% Records	Cum. %
0-5m	129	7.4	7.4	74	4.4	4.4	427	3.8	3.8	137	16.9	16.9	1044	4.1	4.1
5-50m	1103	63.5	70.9	696	41.1	45.4	403	3.5	7.3	188	23.2	40.0	1470	5.8	9.9
51-100m	162	9.3	80.3	256	15.1	60.5	4807	42.3	49.6	115	14.2	54.2	1070	4.2	14.1
101-250m	196	11.3	91.5	300	17.7	78.2	116	1.0	50.6	69	8.5	62.7	388	1.5	15.7
251-500m	44	2.5	94.1	122	7.2	85.4	1773	15.6	66.2	88	10.8	73.5	20302	80.1	95.8
501-1000m	7	0.4	94.5	30	1.8	87.2	2901	25.5	91.7	25	3.1	76.6	42	0.2	95.9
1-10km	5	0.3	94.8	154	9.1	96.3	611	5.4	97.1	114	14.0	90.6	915	3.6	99.5
11-25km	0	0.0	94.8	7	0.4	96.7	1	0.0	97.1	0	0.0	90.6	0	0.0	99.5
>25km	70	4.0	98.8	0	0.0	96.7	11	0.1	97.2	1	0.1	90.8	0	0.0	99.5
11-30km	3	0.2	99.0	0	0.0	96.7	0	0.0	97.2	24	3.0	93.7	0	0.0	99.5
31-125km	0	0.0	99.0	0	0.0	96.7	0	0.0	97.2	0	0.0	93.7	0	0.0	99.5
<625km	0	0.0	99.0	0	0.0	96.7	0	0.0	97.2	0	0.0	93.7	0	0.0	99.5
Not entered	18	1.0	100.0	56	3.3	100.0	321	2.8	100.0	51	6.3	100.0	119	0.5	100.0
No. Selected Records	1590			1448			10427			736			25231		
Total No. Records	1737			1695			11371			812			25350		
Search Radius Applied		500m			1000m			2000m			1000m			1000m	

Table 6 Spatial accuracy of post-1990 state-wide records of 'at-risk' species and search radii used in proximity models.

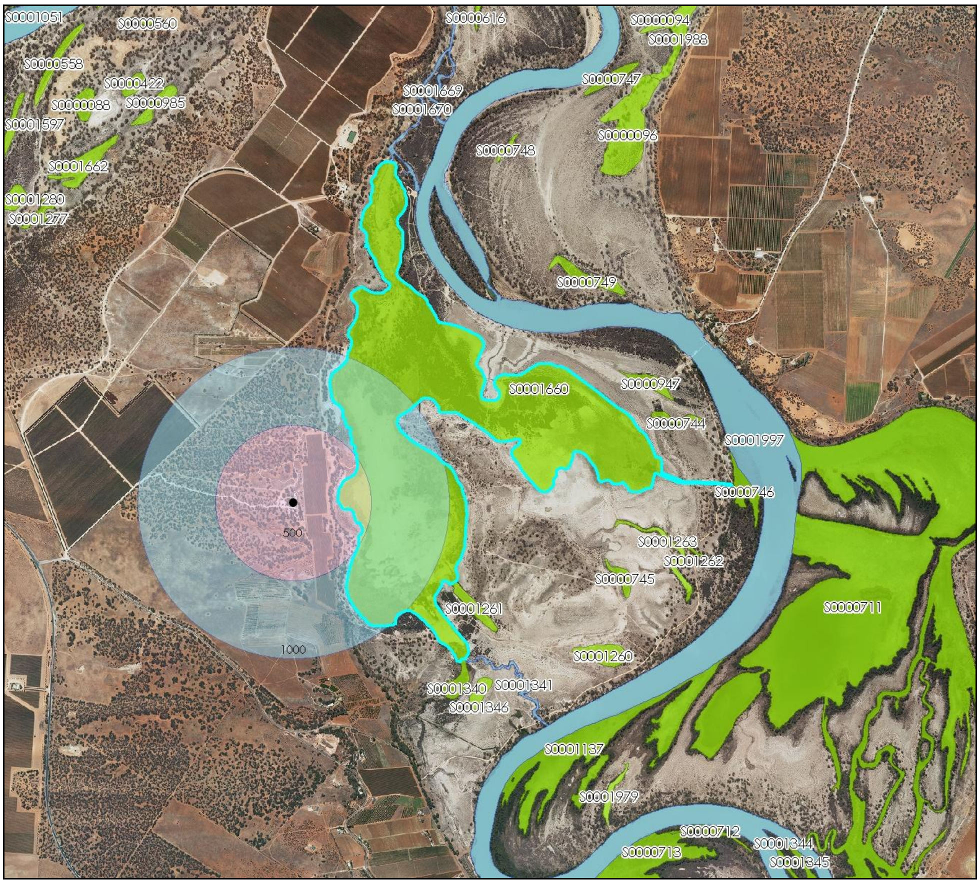

Figure 4. An example to demonstrate fauna point record proximity to nearest wetland. A 1000m search radius is represented by the blue shaded circle and the spatial accuracy of the point record is shown as the pink circle. The highlighted wetland (AUSWETNR S0001660) is nearest to this point record and would be the wetland associated with this record.

Main outputs from the proximity models included a table giving the frequency of records of a given species within the search radius of wetlands or KEAs, to highlight the areas most frequently associated with each 'at-risk' species. 'Species richness hotspots' were generated through a table listing the number of 'at-risk' species within the search radius of each wetland or KEA. These 'hot spots' were grouped into taxonomic groups (birds, fish, reptiles etc.) and also combined as overall species richness of all 'at-risk' species. Outputs were designed to inform wetland management by highlighting key areas of species richness of 'at-risk' species.

The coarser scale proximity analyses using KEA areas were conducted in an identical fashion to the wetland scale models, substituting the wetland boundaries for the KEA boundaries as described for the above wetland models. This served as a comparison with results from wetland scale proximity models and served also to inform management recommendations at a larger spatial scale. KEA boundaries represent individual floodplains that are wetted at certain flow rates and typically comprise a wetland complex containing one or more wetland and/or tributaries. Figure 5 shows the Nigra/Schillers KEA with the wetlands Schillers Lagoon, Nigra Lagoon and Nigra Creek contained within.

A caveat with the KEA-scale analytical model is that the main channel of the River Murray is not delineated as a 'KEA'. As the main channel was not of interest in terms of determining management outcomes, the main channel polygon from the DENR wetlands layer (AUSWETNR S0001997), was used to clip out records located within the river prior to running the proximity analysis. This has the effect of under-representing some KEAs where records plotting in the main channel, due to spatial error, actually corresponded to the adjacent, connected wetland or wetland complex (see Figure 5). The occurrence of this situation is much less frequent than the over-representation generated by assigning all records in the main channel with the nearest KEA, regardless of their connectivity with wetlands within the complex.

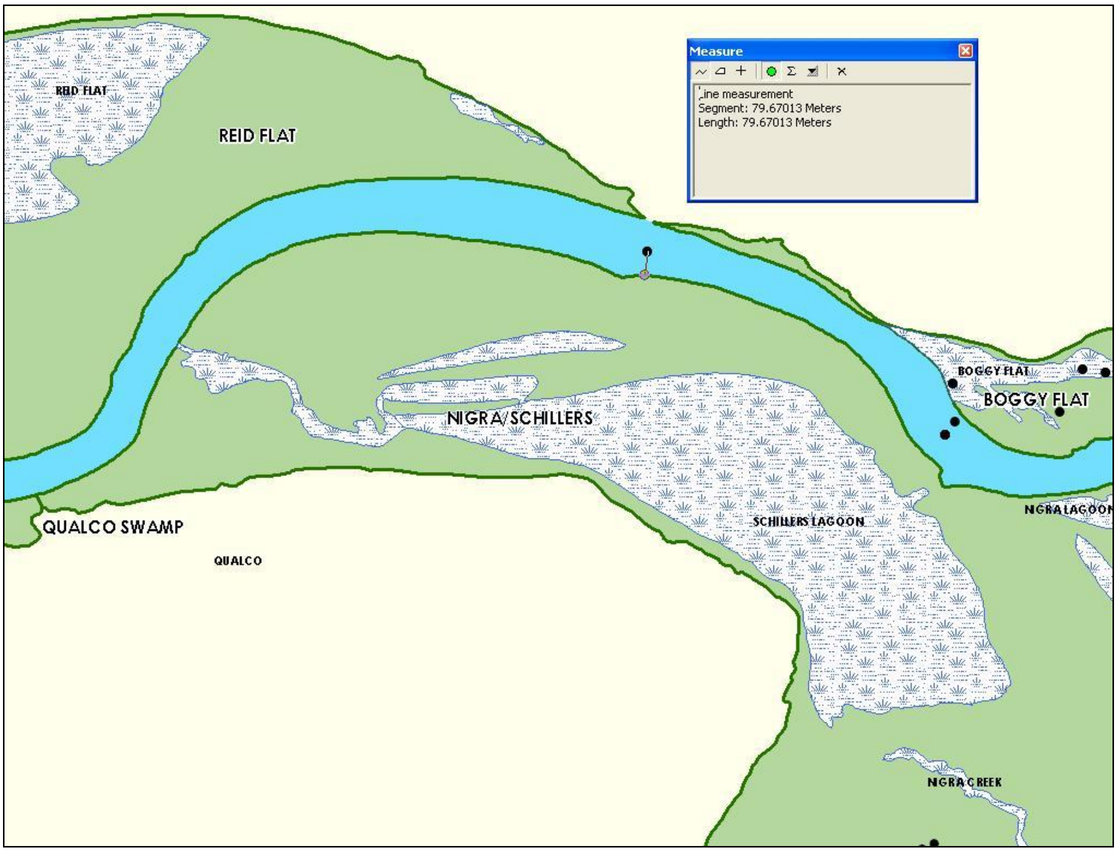

Figure 5. A species record in River Murray main channel would be associated with the nearest KEA (Nigra/Schillers) without realistic connectivity with the underlying wetland (Schillers Lagoon) regardless of spatial error. Records occurring in the main channel were removed for the KEA-scale proximity analyses.

Species richness of 'at-risk' species were also summarised for all taxonomic groups combined at both wetland and KEA scales. Separate species richness layers for each group (bird, frog, mammal etc.) were merged and statistics generated to give the number of taxonomic groups and number of 'at-risk' species associated with wetlands and KEAs through the proximity models to give an 'overall' species richness at the 2 spatial scales.

2.4 Vulnerability assessment methods

A method was developed to assess the vulnerability to climate change of regional flora and fauna (Walker 2010), based on the model developed by Williams et al (2008) It is in the form of a 'risk assessment' process assessing the vulnerability (defined as exposure and sensitivity) of individual species to climate change. The purpose of the assessments is to rank species in terms of their exposure and sensitivity, hence vulnerability to climate change (Walker 2010). To undertake a species vulnerability assessment, the following question was addressed for each of 12 life history traits/ factors listed below in Table 7.

"To what extent does this trait (or factor) limit the ability of the regional population of the species to tolerate climate change?"

		Life History Trait/ factor	Description of how trait/attribute may influence individual species vulnerability
ADAPTIVE CAPACITY	Ecology	Habitat	Species in diverse habitats are at less risk than those with narrower requirements.
		Mobility & Dispersal	Species capable of free movement are at less risk than those whose movements are constrained by habit, or by artificial or natural barriers.
		Competition	Species with a strong capacity to compete for resources (e.g. food, light, space) are less at risk than "weak" competitors.
	Physiology	Survival	Species with broad tolerances (e.g. salinity, temperature and water regime) are at less risk than those with narrow tolerances. This refers to adults rather than juveniles or propagules.
		Growth	Species able to maintain growth across a range of conditions (e.g. salinity, temperature and water regime) are at less risk than those with narrow tolerances. This refers to adults or juveniles.
		Reproduction	Species able to maintain reproduction across a range of conditions (e.g. salinity, temperature and water regime) are at less risk than those with narrow tolerances. This refers to adults, juveniles or propagules, although juveniles often are the least tolerant life stage.
	Genetics	Gene Pool	Species with a large, diverse gene pool are less at risk than species with a small, homogeneous gene pool.
		Gene Flow	Species with few or no barriers to gene flow between individuals and sub-populations are less at risk than species where gene flow is limited.
		Phenotypic plasticity	Species whose genotype allows for significant phenotypic plasticity in response to changing conditions are less at risk than those who have no capacity for phenotypic variations
Resilience		Population Size	Large regional populations are less prone to extirpation than small ones.
		Reproductive capacity	Species with a capacity to produce large numbers of propagules are less at risk than those with low reproductive capacity.
		Recruitment	Species with a relatively short generation time and a short time to maturity are less at risk than those with a longer life cycle.

Table 7 Life history traits/attributes to determine a species sensitivity rating for vulnerability to climate change.

A 3-category system of rating the vulnerability of each species for each trait was applied, following Walker (2010). Literature reviews were conducted for the 75 vertebrate species, and vulnerability ratings of high, moderate and low were assigned to each trait or factor based on this research. These ratings are supported by explanatory notes for each trait (detailing documentary or other evidence), and linking statements according to the climate change process that influences the perceived risk. Importantly, if the question invites a comparison, this was made within the same broad group (e.g. birds, frogs, fish etc.) as the species under consideration. For example, the vagility of a fish species should be compared with those of other fish in the Lower Murray region, and not birds as they are generally much more mobile and not reliant on connectivity per se. Detailed descriptions of the thought processes applied to arrive at ratings for each trait or factor are given within the separate assessment sheets for each species that are contained in Attachments 1 (Fish), 2 (Birds), and 3 (Amphibians, reptiles, mammals) to this report. Notes on the more common factors and variables that were considered when addressing each of the assessment questions and applying the vulnerability ratings for fish, frog and bird groups are summarised in Appendix 4, 11 & 17 respectively. Vulnerability ratings were not assigned for the 9 reptile and 4 mammal species due to the variability in reptile and mammal life histories and the comparatively small number of species to compare. Assessments were restricted to commentary on the major variables and factors affecting vulnerability under climate change and the geographic areas of potential concern and recommendations for wetland management made with respect to these factors. All mammals and reptiles were included as 'at-risk' species in the proximity analyses.

Vulnerability rating methods described in Walker (2010) were refined in order to account for uncertainty over species assessments through the inclusion of a 'confidence' estimate based on the amount and quality of available information relating to each life history trait. These confidence ratings were based on a 5 category system developed by Muller (2010) for an Ecological Risk Assessment undertaken of the Barrages in the Lower Murray. This model is simplified to a 3 category system for the purposes and scope of the current study and is described below in Table 8 in context with the rating system in Muller (2010).

Confidence Rating (Muller 2010)	Description	Confidence Rating (Current Study)	Description
5	local info available, documented process, experts agree	High	local or regional info available, documented process, experts confirm high certainty
4	regional info available, documented process, experts differ	Medium	local or regional info available, some conflicting/inconclusive conclusions, experts confirm some certainty
3	regional info limited, documented process, experts differ	Medium	local or regional info available, some conflicting/inconclusive conclusions, experts confirm some certainty
2	perception based on some info (not local or regional)	Low	perception based on some info (not local or regional), inconclusive/conflicting or no documented process, experts confirm uncertainty
1	perception only, no supporting info	Low	perception based on some info (not local or regional), inconclusive/conflicting or no documented process, experts confirm uncertainty

Table 8. Confidence rating system adapted from Muller (2010) to fit with requirements and scope of the current study. These ratings relate to the degree of confidence behind the research and vulnerability rating for each trait.

An expert consultation phase was applied as a quality assurance measure to ensure the research and ratings were aligned to the current knowledge of the species and its ecological relationships under the generalised climate change scenario described in Section 1.0. The expert panel consisted of experienced wetland ecologists, and bird, fish, frog and reptile biologists from DENR, SA MDB NRM Board, South Australian Research and Development Institute (SARDI) Aquatic Sciences, Adelaide University, South Australian Museum, Charles Sturt University, Australian National University and private consultants. Appendix 3 contains an example of a vulnerability assessment for the great egret *Ardea alba*, and shows the expert comments underlined as personal communications.

For the purposes of ranking the species according to vulnerability, a numerical rating system was applied. The number of each vulnerability (and confidence) ratings were summed for each species. Summed 'Low' vulnerability ratings were assigned a multiplier of 1, summed 'moderate' vulnerability ratings were assigned a multiplier of 2, 'high' vulnerability ratings were assigned a multiplier of 3, therefore, the highest vulnerability and confidence score for any given species is 36. Numerical ratings were then summed and divided by 36 to give a vulnerability and confidence coefficient (on a scale of 0-1.0). An example of this method is given below in Table 9. Confidence ratings did not influence the final vulnerability ranking of a species, their purpose being to indicate the level of certainty of each species overall vulnerability coefficient.

CRITERIA	Confidence Rating	Vulnerability Rating	
Habitat	H	**H**	
Mobility	H	**M**	
Competition	H	**L**	
Survival	H	**H**	
Growth	H	**H**	
Reproduction	H	**H**	
Gene Pool	H	**H**	
Gene Flow	H	**H**	
Phenotypic Plasticity	H	**H**	
Population Size	H	**H**	
Reproductive Capacity	L	**M**	
Recruitment	L	**M**	
Rating	**Summed Confidence**	**Weighted Confidence**	**Confidence Coefficient**
H	10	**30**	0.89
M	0	**0**	
L	2	**2**	
	Summed Vulnerability	**Weighted Vulnerability**	**Vulnerability Coefficient**
H	**8**	**24**	**0.86**
M	**3**	**6**	
L	**1**	**1**	

Table 9 An example to demonstrate the methods for vulnerability and confidence scoring for an unnamed species (H = high, M = moderate, L = low risk).

3.0 Results & Discussion

3.1 Species vulnerability assessments and 'at risk' species

3.1.1 Native Fish

The vulnerability assessment process identified 11 out of the total 18 fish that formed a group of most 'at-risk' species. These species are highlighted in Table 10 below and consist of some iconic Murray species e.g. Murray cod and golden perch (callop), endangered purple-spotted gudgeon and rare and the slow-growing freshwater specialist the freshwater catfish. These 11 'at-risk' species were determined observing the class break shown in Figure 6. The vulnerability and confidence ratings assigned to all criteria for each of the 18 fish assessed are presented in Appendix 4.

Rank	Species	Vulnerability Coefficient	Confidence
1	FRESHWATER CATFISH *(Tandanus tandanus*)	0.94	94%
2	MURRAY COD (*Maccullochella peelii peelii*)	0.94	89%
3	SOUTHERN PURPLE-SPOTTED GUDGEON (*Mogurnda adspersa*)	0.92	94%
5	MURRAY HARDYHEAD (*Craterocephalus fluviatilis*)	0.89	86%
4	SHORT-HEADED LAMPREY (*Mordacia mordax*)	0.89	69%
6	ESTUARY PERCH (*Maquaria colonorum*)	0.86	89%
7	GOLDEN PERCH (CALLOP) (*Macquaria ambigua ambigua*)	0.83	94%
8	SILVER PERCH (*Bidyanus bidyanus*)	0.83	86%
9	COMMON GALAXIAS (*Galaxias maculatus*)	0.81	97%
10	DWARF FLATHEADED GUDGEON (*Philypnodon macrostomus*)	0.81	72%
11	CRIMSON-SPOTTED RAINBOW FISH (*Melanotaenia fluviatilis*)	0.78	92%
12	LAGOON GOBY (*Tasmanogobius lasti*)	0.69	72%
13	CARP GUDGEON (*Hypseleotris* spp. complex)	0.67	97%
14	FLYSPECKED HARDYHEAD (*Craterocephalus stercusmuscarum fulvus*)	0.64	81%
15	FLAT-HEADED GUDGEON (*Philypnodon grandiceps*)	0.61	92%
16	SHORT-FINNED EEL (*Anguilla australis*)	0.61	81%
17	AUSTRALIAN SMELT (*Retropinna semoni*)	0.58	94%
18	BONY HERRING (*Nematalosa erebi*)	0.58	89%

Table 10 Native fish species ranked from 'most' to 'least' vulnerable. Top 11 'at-risk' species are highlighted in yellow corresponding to a vulnerability coefficient class break >0.8 (more than double the difference between any other species in the list order).

Confidence was generally high for the 11 'at-risk' fish species. The short-headed lamprey had the least confidence of the 18 species assessed and was driven mainly by a lack of knowledge about the species' genetic status within the study area and the size of its effective population. The size of the effective population, including the extent of sharing with distant populations e.g. eastern coast of Australia, is difficult to determine without targeted investigations. This in turn affected assessment of genetic diversity and extent of gene flow throughout the regional population based on abundance and distribution data, as few specific studies on population genetic structuring within the region currently exist. The dwarf flat-headed gudgeon had the second least confidence of the 'at-risk' species and this was driven mainly by a lack of knowledge of its mobility which affected estimations of effective population sizes, gene pool diversity and gene flow. The species' reproductive capacity is also unknown and was inferred from a similar species (flat-headed gudgeon) as was its longevity which in turn affected confidence in the recruitment assessment. This study revealed a range of key knowledge gaps in the biology and ecological requirements of a number of native fish including some rare and iconic species. Further research is required to fill these gaps.

Freshwater catfish (Tandanus tandanus)

Freshwater catfish populations have declined significantly since the late 1970s/early 1980s, and the species is no longer common in many areas where it was formerly abundant (Lintermans 2007). It is listed as 'endangered' under IUCN criteria and in 'probable decline' in the DENR Murraylands region and in the Murray Mallee and Murray Scroll Belt IBRA sub-regions (Gillam and Urban 2010). It prefers slow-flowing habitat such as rivers and wetlands with structure including snags, undercut banks and aquatic plants (Hammer *et al.* 2009) and tends to primarily be associated with benthic areas within its habitat. It is a relatively sedentary species and adults show very limited movement; most individuals move less than 5 km (Lintermans 2007) and tend to remain in the same river section for most of their life (Reynolds 1983). Long periods of low flow and subsequent settlement and build up of silt are likely to interfere with their bottom-feeding behaviour (smothering productive surfaces), nesting requirements (coarse particles being covered with fine silt), and general habitat requirements (loss of structure and aquatic vegetation). Hence, significant river regulation and loss of flow volume and flushing flows and floods in the River Murray are a threat (Hammer *et al.* 2009), and are likely to be exacerbated by climate change.

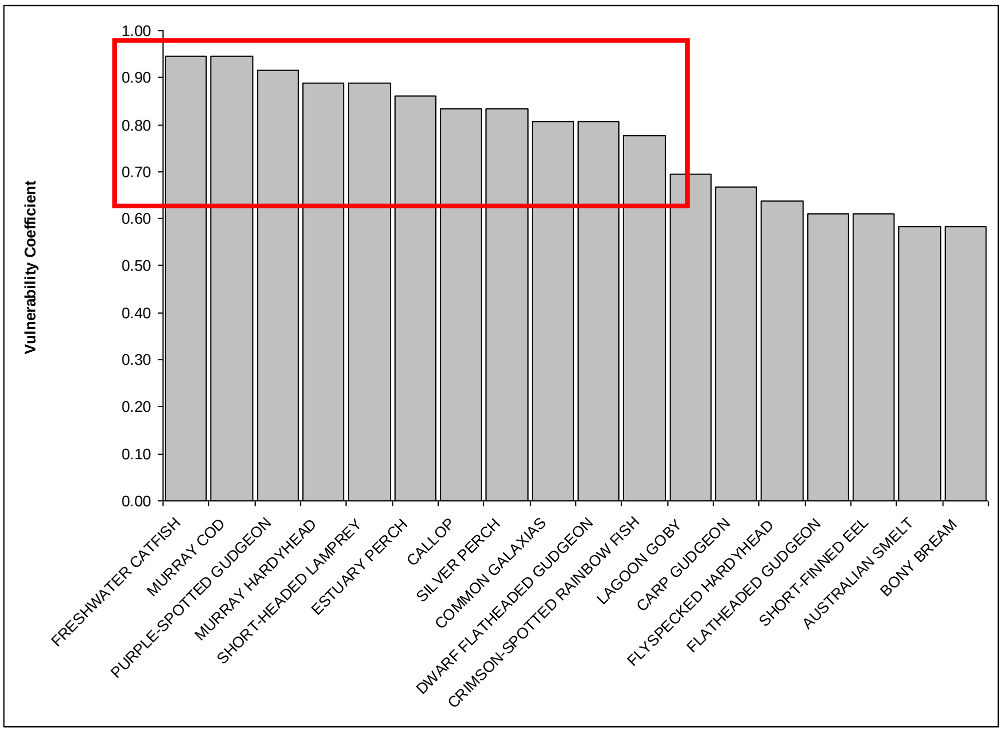

Figure 6 Distribution of fish species vulnerability coefficients determined through assessment process. Top 11 'at-risk' species are highlighted within the red outline corresponding to a vulnerability coefficient class break >0.8 (more than double the difference between any other species in the list order).

Murray cod (Maccullochella peelii)

The Murray cod is an iconic species that is under serious threat in the study area. Wild populations have patchy distribution and abundance (Lintermans 2007) and the species is nationally listed under the EPBC Act as 'vulnerable' (Gillam and Urban 2010). It is listed as 'endangered' under IUCN criteria and in 'definite decline' in the DENR Murraylands region and Murray Scroll Belt IBRA sub-region, and 'critically endangered' in the Murray Mallee sub-region (Gillam and Urban 2010). It is generally associated with deep holes in rivers and prefers habitats with in-stream cover such as rocks, snags or undercut banks (Lintermans 2007). An overarching and continuing threat, is reduced and altered flow patterns from intensive flow regulation and abstraction which directly affect Murray cod and impact ecological processes (e.g. food resources and appropriate habitat for juveniles). Reduced flows and related poor water quality may also lead to fish kills (e.g. Hammer 2009). These effects may intensify under climate change.

Southern purple-spotted gudgeon (Mogurnda adspersa)

The southern purple-spotted gudgeon has very low abundance restricted to localised populations near Murray Bridge (Hammer *et al.* 2009). The species is listed as 'critically endangered' under IUCN criteria and in 'definite decline' in the DENR Murraylands region and Murray Mallee IBRA sub-region and is regionally extinct in the Murray Scroll belt sub-region (Gillam and Urban 2010). The BDBSA contains very few recent (post-1990) records, mainly restricted to the Jury Swamp and Toora Levee area around Mypolonga. The restricted distribution and unique habitat occupied by this species suggest a limited dispersal capability (SAAB 2001). The decline is probably due to a the combined effects of reduced flows, increased turbidity along the River Murray, decreased water quality, and loss of submerged and emergent macrophytes (Faulks *et al.* 2008; Hammer *et al.* 2009). These factors are likely to be exacerbated under climate change. Interactions with introduced fishes, especially predation by Redfin perch and aggressive interactions, competition and predation of fry by eastern gambusia are likely to be significant. There is also a causal link between the arrival of common carp in the River Murray and the disappearance of *M. adspersa* through potential habitat modification, loss of aquatic vegetation and transmission of disease (Hammer *et al.* 2009).

Murray hardyhead (Craterocephalus fluviatilis)

The Murray hardyhead is nationally listed as vulnerable (EPBC Act 1999), endangered in South Australia (NPW Act 1972) and critically endangered in NSW under the Fisheries Management Act 1994 (DEHWA 2010). It is listed as 'critically endangered' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions (Gillam and Urban 2010). Known South Australian populations occur, in two salt evaporation basins near Berri, in the Rocky Gully wetland near Murray Bridge and in the Lower Lakes (Bice et al 2008). The species tolerates highly saline environments (Hammer et al 2009), the extent of which may expand with increased aridity and reduced flood frequency, but ephemeral deflation basin lakes where it appears to thrive (Hammer et al 2009) are expected to decrease with reduced flood frequency. Littoral aquatic vegetation habitats that are relied on for feeding and breeding may become exposed with a decline in water levels, and while water conditions may continue to be suitable for the species, breeding and feeding habitat and protective cover from predators may be lost (M. Hammer 2002, pers. comm. as cited in DEHWA 2010). Data suggests the species' distribution is severely fragmented. The disconnection of floodplain lakes and drying of wetlands was attributed to population extinctions in Victoria (Hammer et al 2009) and increased frequency of these events is expected with further river regulation and reduced flooding under climate change.

Short-headed lamprey (Mordacia mordax)

Short-headed lamprey could formerly be seen in large numbers in the Lower Murray on their spawning run at migration barriers such as weirs (Lintermans 2007) but opportunistic records have diminished since the 1970s despite increased sampling. There have been a few records near the Murray Mouth with recent intensive and temporally repeated sampling, and two single individuals were recorded along the River Murray channel (Hammer et al 2009). Current distribution and abundance are difficult to ascertain without targeted investigations as this species is cryptic in both adult and juvenile form. It is listed as 'critically endangered' under IUCN criteria in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions (Gillam and Urban 2010). A diadromous species, switching between fresh and marine habitat, migrating up-river in spring for spawning and down in high-flow winter conditions (Hammer et al 2009). Downstream migrants need conditions associated with winter flows (e.g. increase in flow and decrease in water temperature) to trigger downstream migration and upstream migrants require conditions associated with summer flows, (e.g. decrease in flow and increase in water temperature). This species has a clear reliance on connectivity and seasonal flow patterns in the system. Increasingly managed flows, such as altered seasonality and reduced water levels, affect breeding and migration. As a filter feeder with long larval and juvenile life stages, the species is reliant on fresh water and consistent flows (Hammer et al 2009).

Estuary perch (Maquaria colonorum)

Estuary perch is rare in the Murray Darling Basin and listed as 'endangered' in South Australia. It is only recorded from the Lower Murray, Lower Lakes and Coorong (Lintermans 2007). It is listed as 'critically endangered' in the DENR Murraylands region and Murray Mallee IBRA sub-regions under IUCN criteria (Gillam and Urban 2010). Estuary perch was common before construction of the barrages, but is now absent from the River Murray, Lower Lakes and Coorong (Bice 2010). It typically occurs in tidally-influenced estuaries but will penetrate into fresh waters. Juvenile growth to adulthood may take place in estuaries but upstream migrations also occur. Downstream access to estuaries is required for spawning migrations (Bice 2010). The main reason for its decline in the SA MDB relates to a continuing decline in the area and quality of suitable habitat, the physical barrier of the barrages, combined with a two-thirds reduction in River Murray flow (Hammer et al 2009). Specimens have been recorded in recent years from as far up the Murray as Swan Reach (Lintermans 2007), and although dispersal capacity is unknown, tagged fish have been found to travel 14 to 29 km on spawning migrations (McCarraher1979). Threats to habitat, reproduction and dispersal, as a result of reduced flows and barriers to movement, are expected to be exacerbated under predicted climate change scenarios.

Golden perch (Macquaria ambigua ambigua)

Golden perch (or callop) has a patchy abundance and distribution in the River Murray in South Australia (Smith et al 2009). It is listed as 'vulnerable' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions under IUCN criteria (Gillam and Urban 2010). It is a migratory species, and extensive upstream movements of more than 1000 km have been recorded for some adult fish (Lintermans 2007). Upstream movements by both immature and adult fish are stimulated by small rises in flow and most movement in the Murray occurs between October and April. Recent research suggests that some fish may also move downstream to spawn (Lintermans 2007). The ability to move unrestricted along the river is critical to the reproductive life stage of the species undertaking spawning migrations and post breeding dispersion. Alteration of natural seasonal flow and water temperature regimes as a consequence of river regulation and construction of dams and weirs threaten reproduction in this species. Reduced frequency and magnitude of flows, lower water levels and decreasing system connectivity is expected under climate change.

Silver perch (Bidyanus bidyanus)

Silver perch was formerly widespread over much of the Murray-Darling Basin, but has declined over most of its range. Numbers moving through a fish way at Euston Weir on the River Murray declined by 93% from 1940-1990 (Lintermans 2007). There are only 12 records of the species since 1990 within the SA MDB floodplain but they are widely distributed from the Lower Lakes up to Paringa near the Victorian border (BDBSA 2010). It is listed as 'endangered' in the DENR Murraylands region and Murray Scroll Belt IBRA sub-region and 'critically endangered' in the Murray Mallee IBRA sub-region under IUCN criteria (Gillam and Urban 2010). It undergoes significant upstream spawning migrations (up to 600 km) (Merrick 1996 as cited in SAAB 2001) that are linked to increased flow and flooding. Immature fish are also known to move upstream during the day after small rises in water level. Little or no spawning occurs in drought years and this species therefore appears particularly sensitive to flow regulation (Hammer et al 2007). The timing of flooding is important, with spring/ summer flooding required because spawning only occurs at water temperatures above 23^{o}C (Lake 1967; Llewellyn 1983 in SAAB 2001) and adults migrate up past the flood peak and spawn in flooded backwaters (Cadwallader 1977 as cited in SAAB 2001). Current major identified threats to this species include a loss of access to upstream spawning areas caused by high-level dams, coupled with altered thermal and flow regimes (Merrick and Schmida 1984 as cited in SAAB 2001). Silver perch clearly rely on connectivity and natural flow regimes in order to complete critical breeding migrations, and will be threatened with increased flow regulation and a reduction in flow volumes and frequencies predicted under climate change.

Interactions with alien fish species are a suspected threat for silver perch (Lintermans 2007), including competition with common carp for similar food resources (Hammer et al 2007) and predation on fry by redfin perch. This is coupled with a high susceptibility to foreign disease transmitted by exotic species particularly Epizootic Haematopoietic Necrosis Virus (EHNV), unique to Australia and carried by redfin perch (ACT Government 2003). Climate change may increase competition with alien species as these often possess competitive advantages and may increase in abundance with increasingly regulated flows. Stocking of hatchery-reared silver perch is a threat to patchily distributed wild populations through 'genetic swamping', reduced genetic diversity and disease (Hammer et al 2009).

Common galaxis (Galaxias maculatus)

The common galaxis (or jollytail) was historically common in the lower reaches of the River Murray, and although still often seen, massed spawning migrations no longer occur (SAAB 2001). Recent surveys indicate a population of moderate abundance, (Smith et al 2009) but one that is largely concentrated in the Lower Lakes extending to Mannum, with few records above Wellington (BDBSA 2010). It typically occurs amongst aquatic vegetation in standing to slow-flowing waters in smaller water bodies or the margins of streams, lagoons and lakes, commonly in lower reaches and in estuaries and coastal habitats (SAAB 2001; Lintermans 2007). The species is reliant on migration to downstream tributaries or lakes to spawn in riparian vegetation above the water line, in flooded shallow margins of streams or above the normal tide line in estuaries. Eggs survive up to 8 weeks non-immersed and hatching is stimulated by high tide or flooding. Reduced flows reduce spawning opportunities for landlocked populations as well as recruitment and migration (Lintermans 2007). Newly hatched larvae are transported to the sea where they remain during winter before migrating back up into estuaries and rivers in spring where they move into adult habitats and mature over summer (SAAB 2001). The species has a clear reliance on spawning migrations and movement between wetlands and the main channel for breeding (Lintermans 2007) and lowered water levels, reduced flows and barriers threaten reproductive success and passage for all life stages.

Dwarf flathead gudgeon (Philypnodon macrostomus)

The dwarf flathead gudgeon has a very restricted distribution within the MDB, occurring in a few localities in the River Murray in SA and NSW, the upper reaches of the Macquarie River and in the lower Condamine River (Hutchinson et al 2008). Within the SA MDB, floodplain records are patchily distributed from the Lower Lakes to the state border (BDBSA 2010). It is listed as 'near threatened' in the Murray Scroll Belt and Murray Mallee IBRA sub regions (Gillam & Urban 2010). It can occupy fresh to brackish habitats but is most commonly associated with structure and aquatic vegetation. Loss of vegetated habitat through lowered water levels and flows may force fish into shallow or open water areas where they are more vulnerable (Bice 2010). Larvae and eggs have a low tolerance for salinity (< 6.9ppt) and vegetation is required for egg attachment, refuge and feeding. Juveniles and adults have a higher tolerance to salinity (< 33ppt) but require pH > 5 (Bice 2010). Optimal breeding and refuge habitat is expected to decrease with a loss of accessible vegetative cover and diversity, waters moving from brackish to saline and increased acidification in some areas, with a reduction in water levels, flow and flood frequency.

Crimson-spotted rainbow fish (Melanotaenia fluviatilis)

The Crimson-spotted rainbow fish formerly widespread across the Basin, has declined in the Murray region. It is still considered common but localised in wetlands and vegetated edges of the main channel, and is patchily distributed in the middle and lower sections, but appears to have disappeared from the Lower Lakes (Lintermans 2007). Records within the BDBSA confirm a patchy but wide distribution within the study region from Wellington to the state border (BDBSA 2010). It is listed as 'least concern' in the DENR Murraylands Region and Murray Scroll Belt IBRA sub-region and 'near threatened' in the Murray Mallee IBRA sub region (Gillam & Urban 2010). It appears to have relatively narrow habitat preferences, favouring still clear water near dense aquatic or riparian vegetation. Aquatic plants are also required as attachment sites for eggs (SAAB 2001). Major threats are loss of suitable vegetated habitats through clearing and ecological degradation and predation on adults by redfin perch and larvae by eastern gambusia (Lintermans 2007). Male spawning is triggered at water temperatures above 20°C (Bice 2010) and warming shallow floodwaters are spawning sites (SAAB 2001). Juveniles and eggs are tolerant of only mildly brackish conditions (<12ppt) and neutral pH (Bice 2010). Fecundity is very low compared to other sympatric fish species (Lintermans 2007). Reduced recruitment under climate change is expected with reduced flood frequency and extent, decreased flow volumes, and increased salinisation (and acidification) exacerbated by low fecundity.

3.1.2 Native birds

The species vulnerability assessment process on 32 bird species identified 11 most 'at-risk' species (Table 11), although the natural break in vulnerability coefficients was not as pronounced as with the fish (Figure 7). Among the top11 'at-risk' birds a number of threatened species were highlighted, including the white-bellied sea eagle ('endangered' NPW Act 1972), Australasian bittern ('vulnerable' NPW Act 1972; IUCN 'endangered Red List'), musk duck, blue-billed duck and spotless crake ('rare' NPW Act 1972) and regent parrot ('vulnerable' NPW Act 1972 and EPBC Act). Other species identified as being highly at risk were deemed vulnerable through the assessment process due to limiting life history strategies according to the criteria detailed in Section 2.4. Of more relevance to this study was the recent species threat assessment work conducted by Gillam and Urban (2010), considering a large range of species against IUCN criteria for the DENR SA Murraylands region and IBRA sub-regions. Ratings in that study were based on BDBSA records of abundance and distribution, population trend analyses and extensive expert consultation. These regional and sub-regional ratings for the top 11 'at-risk' bird species determined in this study are presented in Table 12. The vulnerability and confidence ratings assigned to all criteria for each of the 32 birds assessed are presented in Appendix 16.

Confidence in assessments was generally high for the 'at-risk' species with the exception of the ducks *B. lobata* and *O. australis*. The lowered confidence for these species was driven mainly by gaps in knowledge of growth limitations, reproductive capacity and recruitment and potential for phenotypic plasticity to mitigate vulnerability to climate variation. The equal first most 'at-risk' species *P. flavipes* also had limited confidence in the assessment, due mainly to little conclusive information on the species' mobility that in turn affected determination of the effective population size, diversity of the available gene pool and extent of gene flow within or between regional populations. The reproductive capacity of *P. flavipes* is another area of uncertainty and affected confidence in rating the capacity for recruitment. The assessment for the Australian spotted crake (*P. fluminea*) also has confidence limitations arising from a lack of information on reproductive capacity and recruitment.

As shown in Figure 7, the distribution of vulnerability coefficients for the bird species did not contain an obvious break as for fish species (see Figure 6). The top 3 birds were scored more highly than the others, but the differences then are much less pronounced. A panel of experts consisting of DENR and SA MDB NRM Board staff was brought in to decide where the list should be divided to give a useful list of species most likely to suffer pressure under a generalised climate change model. It was decided that this list should include both ducks assessed and exclude the swamp harrier, Australian reed warbler and red-kneed dotterel, due to their abundance and wide distribution in various habitats across the study area. They were deemed either 'generalist' species with healthy populations unlikely to suffer marked declines, or did not represent species that frequently used habitat within the study area and that historically had never been very abundant in the SA MDB.

Rank	Species	Vulnerability Coefficient	Confidence
1	WHITE-BELLIED SEA EAGLE *(Haliaeetus leucogaster)*	0.89	86%
2	YELLOW-BILLED SPOONBILL *(Platalea flavipes)*	0.89	72%
3	AUSTRALASIAN BITTERN *(Botaurus poiciloptilus)*	0.86	89%
4	BAILLON'S CRAKE *(Porzana pusilla)*	0.78	78%
5	SPOTLESS CRAKE *(Porzana tabuensis)*	0.75	94%
6	MUSK DUCK *(Biziura lobata)*	0.75	67%
7	REGENT PARROT *(Polytelis anthopeplus)*	0.72	81%
8	AUSTRALIAN SPOTTED CRAKE *(Porzana fluminea)*	0.72	72%
9	BLACK-FRONTED DOTTEREL *(Elseyornis melanops)*	0.69	100%
10	NANKEEN NIGHT HERON *(Nycticorax caledonicus)*	0.69	72%
11	BLUE-BILLED DUCK *(Oxyura australis)*	0.69	64%
12	YELLOW ROSELLA *(Platycercus elegans flaveolus)*	0.67	94%
13	BUFF-BANDED RAIL *(Gallirallus philippensis)*	0.67	92%
14	SWAMP HARRIER *(Circus approximans)*	0.67	86%
15	DARTER *(Anhinga melanogaster novaehollandiae)*	0.64	89%
16	RED-KNEED DOTTEREL *(Erythrogonys cinctus)*	0.64	86%
17	AUSTRALIAN REED WARBLER *(Acrocephalus stentoreus)*	0.64	86%
18	AUSTRALIAN SHELDUCK *(Tadorna tadornoides)*	0.64	81%
19	GREAT CORMORANT *(Phalacrocorax carbo)*	0.58	86%
20	GREAT EGRET *(Ardea alba)*	0.56	94%
21	FRECKLED DUCK *(Stictonetta naevosa)*	0.56	69%
22	BLACK-WINGED STILT *(Himantopus himantopus)*	0.53	94%
23	PURPLE SWAMPHEN *(Porphyrio porphyrio)*	0.53	94%
24	BLACK SWAN *(Cygnus atratus)*	0.53	86%
25	LITTLE PIED CORMORANT *(Microcarbo melanoleucos)*	0.53	78%
26	AUSTRALASIAN SHOVELER *(Anas rhynchotis)*	0.53	58%
27	AUSTRALIAN WHITE IBIS *(Threskiornis molucca)*	0.50	92%
28	CHESTNUT TEAL *(Anas castanea)*	0.50	72%
29	STRAW-NECKED IBIS *(Threskiornis spinicollis)*	0.47	83%
30	LITTLE BLACK CORMORANT *(Phalacrocorax sulcirostris)*	0.47	78%
31	RED-CAPPED PLOVER *(Charadrius ruficapillus)*	0.44	83%
32	HOARY-HEADED GREBE *(Poliocephalus poliocephalus)*	0.42	72%

Table 11 Native bird species ranked from most to least vulnerable. Top 11 'at-risk' species are highlighted in yellow corresponding to a vulnerability coefficient class break and expert consultation.

Species	Murraylands	South Olary Plain	Murray Scroll Belt	Murray Mallee
WHITE-BELLIED SEA EAGLE	CR (--)		CR (--)	
YELLOW-BILLED SPOONBILL	VU (-)	RA (-)	EN (-)	EN (-)
AUSTRALASIAN BITTERN	CR (-)			CR (-)
BAILLON'S CRAKE	CR (-)		CR (-)	CR (-)
SPOTLESS CRAKE	VU (-)		VU (DD)	EN (-)
MUSK DUCK	VU (0)		VU (0)	VU (0)
REGENT PARROT	EN (--)	EN (--)	EN (--)	EN (--)
AUSTRALIAN SPOTTED CRAKE	RA (-)	RA (DD)	RA (-)	RA (-)
BLACK-FRONTED DOTTEREL	RA (-)	RA (DD)	NT (-)	RA (-)
NANKEEN NIGHT HERON	VU (-)	RA (DD)	EN (-)	EN (-)
BLUE-BILLED DUCK	EN (-)		EN (-)	EN (-)

Status Category	Abbreviation
Regionally Extinct	RE
Critically Endangered	CR
Endangered	EN
Vulnerable	VU
Rare	RA
Near Threatened	NT
Least Concern	LC
Data Deficient	DD
Not Evaluated	NE

Trend Category	Symbol
Definite Decline	--
Probable Decline	-
Stable/No Change	0
Probable Increase	+
Definite Increase	++
Data Deficient	DD

Table 12 Regional and sub-regional status' of 'at-risk' bird species listed under IUCN/IMCRA criteria. Trends are shown in parentheses. Adapted from Gillam and Urban (2010).

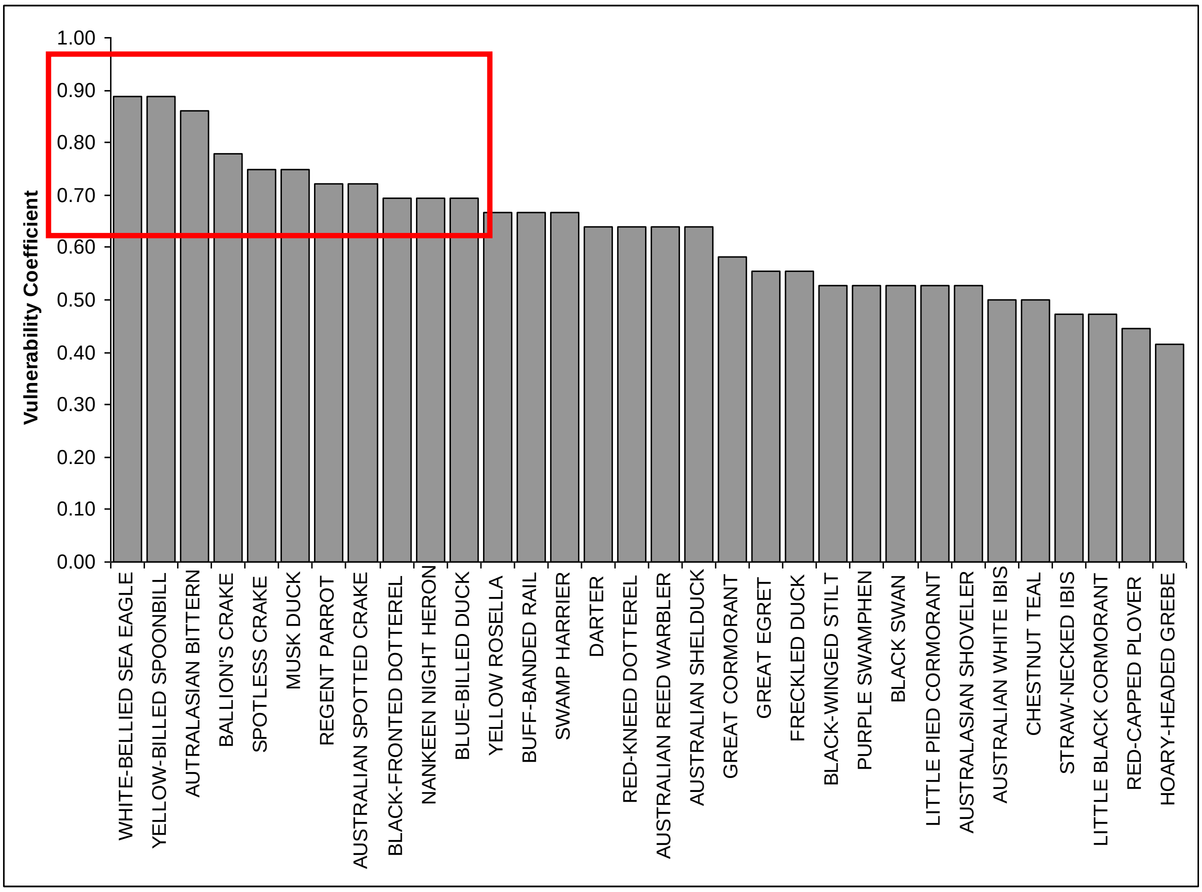

Figure 7 Distribution of bird species vulnerability coefficients determined through assessment process. Top 11 ‘at-risk’ species are highlighted within the red outline corresponding to a vulnerability coefficient class break and expert consultation.

White-bellied sea eagle (Haliaeetus leucogaster)

The white-bellied sea eagle is widely recognized as a very rare species and is threat listed at national, state and regional levels in high risk categories. It inhabits large open coastal and terrestrial wetlands, particularly deep freshwater swamps, lakes, reservoirs and billabongs (Marchant and Higgins 1993). Open water tracts with tall riparian trees or other perching structures are critical habitat requirements (T. Dennis pers. comm. 2010). There is a high dependence on the quality and size of undisturbed sites particularly when breeding but also foraging (Dennis and Baxter 2006). River red gums are used as nest sites and all occupied, recently abandoned and long abandoned nest sites along the Murray were found to be constructed over water (T. Dennis pers. comm. 2010). Clearing or loss of structural vegetation near water bodies is associated with localised extinctions, and the decline in red gum forests with reduced flood frequency and increasing salinisation expected under climate change poses a significant threat for the species within the study region.

Competition is a major factor affecting the breeding cycle of this species, nest site and territorial disputes are common with conspecifics and other birds, and parental nest defence is not strong (Marchant & Higgins 1993). Pairs can be very sensitive, abandoning nest preparation or eggs if disturbed (T. Dennis pers. comm. 2010). Violent interactions with more common and larger wedge-tailed eagles over hunting and breeding territory (Marchant & Higgins 1993) are another significant competitive pressure. It has low reproductive capacity and recruitment success; usually 1-2 eggs are laid with 1 hatchling fledging. Long-lived eagles at the top of their food chain don't necessarily breed every year (T. Dennis pers. comm. 2010) and sexual maturity is not reached until 6-7 years of age (Marchant and Higgins 1993). Genetic diversity and gene flow are likely to be highly restricted given current abundance and declining trend and the fact that SA populations are geographically isolated from other populations in Australia. The River Murray is considered an important corridor for genetic exchange between SA's isolated population and the eastern states (T. Dennis pers. comm. 2010).

Yellow-Billed Spoonbill (Platalea flavipes)

The Yellow-Billed Spoonbill is not conservation listed at the state or national level but a population of low abundance and patchy distribution occurs within the study region (BDBSA 2010). It is listed as ‘vulnerable’ in the DENR Murrylands region and is sub-regionally listed as ‘endangered’ in the Murray Mallee and Murray Scroll Belt and ‘rare’ in the South

Olary Plain (Gillam and Urban 2010). It occurs mainly inland at fresh or brackish wetlands with low vegetation. It prefers shallow swamps with abundant aquatic flora, also flooded pastures, and shallow zones of lakes either in open water or among emergent vegetation. The bill structure limits feeding to depths of <0.4m over soft substrates of mud, sand or clay (Marchant and Higgins 1990) and it avoids saline environments (P. Wainwright 2010, pers. comm.). A reduction in flood frequency and increased extent of saline wetlands are expected to significantly reduce the area of preferred foraging habitat and diversity of invertebrate prey species. Spoonbills are particularly responsive to large floods, and only breed when certain thresholds of overbank flows are exceeded (Olsen and Weston 2004). To initiate and complete breeding, and for young to fledge, water needs to remain under nest trees for at least 5 and up to 10 months following flooding (Briggs and Thornton 1999). Reliance on significant flood events and duration of flood water for successful fledging of young raises the vulnerability risk considerably with a decrease in frequency and magnitude of such events expected. The species has a low reproductive capacity, with average clutch size of 3 eggs and low recruitment rates with less than 50% fledging success (Marchant and Higgins 1990). Losses are attributed mainly to starvation, but nest falls and attacks from crows and Whistling Kites are also blamed (Marchant and Higgins 1990).

Australasian bittern (Botaurus poiciloptilus)

The Australasian bittern has a small regional population in South Australia concentrated in the Lower Lakes and is sub-regionally listed as 'critically endangered' in the Murray Mallee and in 'probable decline' (Gillam and Urban 2010). It is state, nationally and internationally listed as 'vulnerable'. It has narrow habitat preferences, preferring shallow, vegetated freshwater or brackish swamps. It is seen most frequently in exceptionally wet years, possibly because the population size increases and isolated ephemeral wetlands are occupied. Pairs occupy territories containing a mixture of tall and short sedges for breeding (Garnett and Crowley 2000). They build nests in deep cover over shallow water, but in 'rushland' they avoid densest areas (Ecological Associates 2010). Dense beds of cumbungi (*Typha* spp.), which are increasing with reduced flow and flood frequency in pool level wetlands of the study region (SA MDB NRM unpublished data), are not likely to provide suitable breeding habitat. As a 'habitat specialist' tolerant of only minor increases in salinity (Ecological Associates 2010) and quite specific water depth and vegetation requirements, increased wetland salinisation, decreased vegetation diversity and reduced flood frequency are expected to put this species at high risk . The extent to which all aspects of the species' physiology and resilience influence the level of vulnerability to climate change is closely linked to the narrow habitat preferences of this species. Gene pool and gene flow are likely to be highly restricted for this species. There is no indication of large-scale movement and with sedentary tendencies and narrow habitat preferences limiting dispersal options, coupled with low population size and declining numbers.

Baillon's Crake (Porzana pusilla), Australian spotted crake (Porzana fluminea) and the *Spotless crake (Porzana tabuensis)*

All three species of crake are thought to be more common than records suggest due to their cryptic habits (Marchant & Higgins 1993). Baillon's Crake has the smallest population of the three species in the study region and is listed as 'critically endangered' and in 'probable decline' in Murray Mallee and Murray Scroll Belt IBRA sub-regions (Gillam and Urban 2010). The spotless crake is listed as 'rare' under NPW Act 1972, 'vulnerable' in DENR Murraylands region and Murray Scroll Belt IBRA sub-region and 'endangered' and in 'probable decline' in Murray Mallee (Gillam and Urban 2010). The Spotted Crake is common throughout eastern South Australia (Marchant and Higgins 1993), though post 1990 records within the SA MDB floodplain and study area above Wellington suggest low numbers and patchy distribution compared to other birds assessed in this study (BDBSA 2010). It is listed as 'rare' and in probable decline in the Murray Scroll Belt and Murray Mallee IBRA sub-regions (Gillam and Urban 2010).

All species utilise a range of permanent and ephemeral terrestrial and coastal wetlands (Marchant and Higgins 1993) and appear to have a preference for fresh to brackish waters (Halse et al. 1993, Blakers et al. 1984 as cited in SAAB 2001), with Baillon's crake rarely using saline waters and the spotless crake appearing least restricted by salinity (Marchant and Higgins 1993). Wetland habitats are usually well vegetated, with emergent vegetation though the Spotted Crake is thought less dependent on dense vegetation (Marchant and Higgins 1993). Baillon's Crake also appears to favour sites with abundant floating vegetation and is thought to prefer wetlands subject to fluctuating water-levels (Bryant 1942; Moore 1983 as cited in Marchant and Higgins 1993), while the spotless crake prefers habitats with flowing water (Bryant and Amos 1949 as cited in Marchant and Higgins 1993). Changed hydrology and salinity are identified as major threats to populations in the Murray-Darling Basin (ANRA 2010a), coupled with a subsequent decline in diversity and quality of aquatic and riparian vegetation.

These are small birds (up to 30-65g), and predation is a high risk. Predators include foxes, rats, snakes, raptors and feral and domestic cats and dogs (Marchant and Higgins 1993; SAAB 2001). The birds are generally not aggressive and will normally flee rather than defend areas or nest sites, though may put up more defence if eggs are present (Marchant and Higgins 1993). The spotless crake has been observed to destroy its own eggs after human disturbance (Bryant and Amos 1949 as cited in SAAB 2001). All species appear to be seasonal breeders with relatively short breeding seasons of 3 to 4 months, between late Winter/Spring to Early Summer. A short extension of the breeding season for Baillon's Crake into February may occur in exceptionally wet summers (Marchant and Higgins 1993).

Breeding success would be threatened by a decline in, and change in seasonality of, flooding if species have a limited capacity to capitalise on good conditions outside the breeding season. Dense vegetation required for nesting (Marchant and Higgins 1993) may also suffer degradation through salinity and changes to hydrological regimes. Nest abandonment can occur when parents are forced to forage widely for food due to habitat fragmentation (P. Wainwright pers. comm. 2011) or if water levels drop or fluctuate significantly during the breeding season (Marchant and Higgins 1993; Bryant and Amos 1949 as cited in Marchant and Higgins 1993).

Musk duck (Biziura lobata)

The musk duck is listed as 'rare' in South Australia (NPW 1992) and regionally, is listed as 'vulnerable' in the Murray Mallee and Murray Scroll Belt IBRA sub-regions (Gillam and Urban 2010). It is an almost entirely aquatic, diving duck, reliant on deep water habitats of large wetlands, lakes and estuaries with a preference for sites with abundant aquatic flora (Fjledsa 1985; Frith 1982 as cited in SAAB 2001). When breeding, it disperses on deep fresh swamps, lakes, billabongs and rivers where dense vegetation is important to provide nesting cover (Marchant and Higgins 1990), though requires clear open pools among reeds for feeding and display (Fjledsa 1985). Highest numbers of ducks have been correlated with high water levels in wetlands with fluctuating water levels (Harper 1990). Many freshwater wetlands suitable for breeding have been destroyed or modified by drainage, clearing, grazing, burning, increased salinity and increased inundation (Marchant and Higgins 1990). Declining water levels in deep wetlands, a decrease in diversity of aquatic vegetation and increasing salinity levels are expected to continue the loss of habitat under climate change.

Though reported to require permanent freshwater wetlands (Marchant and Higgins 1990), the musk duck has been observed more often in the study region on large deep fresh to brackish temporary wetlands with an extended hydro-period (SA MDB NRM unpublished data). These wetlands have much higher productivity than permanent pool level wetlands with stable water levels. Abundance and diversity of aquatic invertebrates are linked to natural flooding cycles, and a reduced flood frequency decreases the available food resource (Law & Anderson 1999). Musk ducks prey on a range of aquatic invertebrates (Marchant & Higgins 1990) and although they can access more of the water column with their diving behaviour, increased competition expected from introduced fish such as common carp coupled with high water turbidity would limit primary productivity and reduce the diversity and abundance of prey available in deeper water for diving species. It has low reproductive capacity with only1-3 eggs per clutch, and the little information available suggests low recruitment rates. Purple swamp hens have been observed to destroy nests and eat eggs (Marchant & Higgins 1990).

Regent parrot (Polytelis anthopeplus)

The regent parrot has a very limited national distribution and is EPBC listed as 'vulnerable'. Its total population is estimated to be from 1500 (Gannet and Crowley 2000) to around 2300 individuals (DEHWA 2010b). Its area of occupancy has decreased to the extent that the population is now fragmented and a continuing decrease in population size is likely (Gannet and Crowley 2000). Its conservation status is 'endangered' in NSW and 'vulnerable' in South Australia and Victoria (Higgins 1999). One of its main populations occurs in the Murray Mallee region, South Australia. It is listed as 'endangered' and in 'definite decline' in Murray Mallee, Murray Scroll Belt and South Olary Plain IBRA sub-regions (Gillam and Urban 2010). It is reliant on habitat of riverine and Mallee eucalypt woodlands and forests. Within the study region they breed from Renmark to Morgan nesting mainly in river red gums, using hollows in large dead or living trees (Gannet and Crowley 2000). In South Australia they nest mostly in dead trees (up to 94% of nests) that have been drowned due to lock and weir construction, but it is likely that birds simply continue to nest in trees that have since died due to high nest fidelity, because the trend does not follow in other areas. High site fidelity is of concern because these dead trees eventually will fall. The requirement for large trees means that breeding sites must be within 60m of either permanent or temporary water (Higgins 1999). The future health of river red gums within the study region is threatened by several factors, but largely salinisation (Gannet and Crowley 2000) and reduced flood frequency.

The regent parrot forages mainly for seeds, berries and flowers of grasses and herbaceous plants in Mallee woodland within 20 km of the nesting site, particularly where Christmas Mallee or Yellow Mallee dominate. But the use also of agricultural and horticultural crops by the regent parrots has exposed a proportion of the population to poison, shooting, and, when feeding on spilt grain, vehicles (Gannet and Crowley 2000). Foraging sites are required to be in proximity to nests during the breeding season, but species may travel long distances for food outside the breeding season (Higgins 1999). Much remaining foraging habitat has been separated from breeding habitat and continues to be grazed (Gannet and Crowley 2000). The main competitive forces for this species are around competition for space and nesting hollows with other species. Suitable nesting hollows must have a minimum girth of 25 cm. Feral honey bees are known to have excluded regent parrots from hollows in Victorian populations (Gannet and Crowley 2000). Interspecies interactions with other parrot species, such as rosellas and galahs, can be aggressive (Higgins 1999).

Black-fronted dotterel (Elseyornis melanops)

The black-fronted dotterel is widespread throughout Australia; Watkins (1993) estimated the Australian population at approximately 17000. It is not state or nationally conservation listed but is listed as 'near-threatened' or 'rare' and in 'probable decline' in the DENR Murraylands region and IBRA sub-regions throughout the study area (Gillam and Urban 2010). Primary habitat is the margins of terrestrial wetlands, particularly fresh shallow wetlands with muddy bottoms and sparse vegetation. It generally forages on soft fine wet sediments of silt or mud at water edges and occasionally in shallow water (Ecological Associates 2010). It prefers freshwater wetlands and tends to avoid brackish and saline environments (P. Wainwright 2010, pers. comm.). Its diet is omnivorous, taking molluscs, annelids, crustaceans, arachnids and a diverse range of aquatic and terrestrial insects, and occasionally seeds (Marchant and Higgins 1993). A decline in freshwater wetlands with fluctuating water levels that provide productive shorelines and shallow water for foraging are expected to decline with reduced flood frequency and increased salinisation. This species is largely sedentary around the natal site, with most birds remaining within 1-2km and only foraging short distances away (Marchant and Higgins 1993). This limited mobility and dispersal capacity has implications for gene flow. Increased habitat fragmentation expected under climate change may force birds to travel farther for food or strand some populations.

Nankeen night heron (Nycticorax caledonicus)

The nankeen night heron is widespread in northern, eastern and south-western Australia (SAAB 2001) but within the SA MDB study region its population, though widespread, is of low abundance (BDBSA 2010). It is listed as 'vulnerable' in DENR Murraylands and 'endangered' in Murray Mallee and Murray Scroll Belt and 'rare' in the South Olary Plain (Gillam and Urban 2010). It is mainly nocturnal and is usually seen perching in trees over water (Slater et al 2001). Prey includes a diverse range of aquatic and terrestrial animals, principally fish but also frogs, freshwater crayfish and various other invertebrates and some small vertebrates (Ecological Associates 2010). It forages in deep or shallow water and on inland systems, prefers floodplain wetlands especially those with woody edges and swamps with tall emergent vegetation. It prefers lower salinity waters (Halse et al 1993), with saline habitats used less often, but birds are still regularly found in coastal and estuarine habitats and salt marshes (Ecological Associates 2010). Recently in the study region it has been observed (during the day and night) foraging in newly flooded temporary wetlands and flowing waters filling wetlands (SA MDB NRM unpublished data). It breeds colonially, usually in central parts of swamps and flooded areas, broadly in spring and summer, but reproduction is probably influenced by rainfall, flooding and water conditions (Marchant and Higgins 1990). Nesting habitat in natural freshwater wetlands and floodwaters has been destroyed or modified by drainage, clearing, grazing, burning, increased salinity, groundwater extraction and flood mitigation schemes (Marchant and Higgins 1990). Preferred freshwater floodplain wetlands with dense cover and tall woody vegetation over water are limited and declining within the study region and a reduction in flood frequency, flow and increasing salinisation are considered the greatest threats to foraging and breeding habitat.

3.1.3 Native Reptiles

All 'vulnerable' reptile species were included as 'at-risk' species, as there were only 9 species (3 snakes, 3 lizards and 3 turtles) included for assessment that were considered dependent on the SA MDB floodplain. Assessments were conducted but not scored or ranked (due to few species and highly variable life histories), and spatial associations were performed for all 9 species.

Turtles are the most water-dependent group of reptiles and it is likely all three turtle species occurring within the study region-the broad-shelled turtle (*Chelodina expansa)*, common long-necked turtle (*Chelodina longicollis)* and Murray short-necked Turtle (*Emydura macquarii*)will be negatively impacted by climate change through declining water quality; reduced productivity of wetlands and the river channel; loss of habitat, as a result of reduced river flows, and, reduced flood frequency, extent and duration.

For all three species development time of embryos is influenced by temperature of the nest (Booth 2002; Goode & Russell 1968). Higher nest temperatures (due to location of nest in open areas with more sun exposure or time of year) increase the development rate of embryos (Goode & Russell 1968). Shorter time in the nest may be advantageous in some circumstances where it decreases exposure time of the egg to detrimental environmental conditions and/or predators, but indications are that higher temperatures produce smaller hatchlings which may reduce overall fitness and decrease survival ability, e.g. phenotypic influence of incubation temperature can affect post hatch behaviour and growth for all species and may be an important determinant of hatchling survival and therefore reproductive fitness (Booth 2002).

While similarities exist between the three sympatric turtle species, and all are expected to be vulnerable to climate change, their otherwise variable ecology, physiology and resilience indicate that the reasons for their vulnerability differ, and the major influential factors for each species are discussed below.

Broad-shelled turtle (Chelodina expansa)

The broad shelled turtle has a relatively broad distribution throughout the Murray Darling Basin but occurs in low numbers and is less common than the two sympatric species (Thompson 1993; Spencer & Thompson 2005). Low population densities may increase vulnerability to threatening processes (Cann 1998). It is listed as 'vulnerable' in South Australia (NPW 1972) and 'Rare' in the Murray Scroll Belt and Murray Mallee IBRA sub-regions (Gillam and Urban 2010). However, it is thought these listings 'may reflect their secretive nature and difficulty of capture rather than their population vulnerability (Spencer and Thompson 2005)'. It is most often represented in deep permanent lakes and billabongs and prefers habitats with structural complexity (D. Bower unpublished review) such as diverse aquatic vegetation, submerged logs, dead trees and root systems. It is a selective and specialised predator feeding primarily on prey such as decapod crustaceans, aquatic bugs and small fish (Chessman 1983) but it may consume vegetation at times of low resource availability (Meathrel et al 2002). A decrease in flood frequency, increased stability of water levels particularly in permanent pool level wetlands, coupled with an overall reduction in water depth of wetlands, could potentially reduce the diversity and complexity of vegetation structure and decrease the abundance of specialised food resources. Increased abundance of alien fish may provide some foraging benefits but these are likely to be outweighed by the negative impact these fish have on the aquatic ecosystem (Ralph et al 2011). It is a highly aquatic species with very limited terrestrial mobility (Chessman 1988; Spencer & Thompson 2005), and barriers such as weirs probably restrict its movement within the River Murray. This low terrestrial mobility and restriction to aquatic movement within the study region indicate it would have very limited ability to escape deteriorating habitat conditions.

Chelodina expansa is able to tolerate short periods of high salinity (Scheltinga 1991) though its ability to occupy saline environments would be limited by the salt tolerance of vegetation and prey species. Nesting occurs in autumn-winter and is triggered by rainfall and air-temperature changes associated with rain (Bowen et al 2005). A decline in rainfall frequency and intensity during the nesting period is likely to restrict reproduction. Increased evaporation rates, receding waters, reduced rainfall and increasing salinity may result in preferred vegetated nesting sites (Ercolano unpublished report) and drying soils close to the water becoming increasingly unsuitable for nesting and nests more conspicuous to predators. Mortality rates of females may increase as they can move up to 1km to nest (Cann 1998 as cited in SAAB 2001) and may have to travel increasing distances to suitable sites. Eggs are tolerant of a wide temperature range (4.9-29.6°C) (Goode & Russell 1968; Georges 1984 in Greer 2003) but apparently not of temperatures ≥30°C (Legler 1985 in Greer 2003) which may occur more commonly under climate change and with a reduction in vegetative cover. Long but variable incubation times (192 to 522 days) (Good and Russell, 1968; Georges, 1984) can benefit hatchlings, allowing them to emerge under favourable conditions but extended time may increase chance of exposure of eggs to potential extremes of climate and predation.

Common long-necked turtle (Chelodina longicollis)

The common long-necked turtle is widely distributed and abundant (Georges 1993), and the most widespread of Australian chelid turtles (Parmenter 1985 as cited in Greer 2003). The species does not have any state or national conservation listing but is listed as 'near threatened' in the Murray Scroll Belt and Murray Mallee IBRA sub-regions and in 'probable decline' (Gillam and Urban 2010). Although described as a habitat generalist occurring in a range of water bodies (Chessman 1988), it has a strong preference for ephemeral and shallow wetlands often remote from the River Murray and is scarce in large, stable water bodies (Chessman 1988). It is an opportunistic carnivore (Kennet & Georges 1990) feeding on a range of aquatic invertebrates (Chessman 1988). Fish are a significant competitor for invertebrates and occupation of ephemeral waters is probably of ecological advantage to *C. longicollis* because it permits feeding on dense populations of aquatic invertebrates which develop in the absence of predatory fish (Chessman 1988). However a decline in extent of ephemeral wetlands with reduced flood frequency and duration are expected to significantly reduce habitat and food resources for *C. longicollis* and increase competition with introduced fish. Reduced reproductive output is also likely with a decline in extent of productive ephemeral wetlands (Kennett and Georges 1990). Compared to other freshwater turtles, *C. longicollis* is highly mobile undertaking overland migrations and dispersing considerable distances between ephemeral water bodies (Kennett and Georges 1990; Chessman 1988; Thompson 1993; Goode 1967). Increasing distance between suitable water bodies and the need to move more often may reduce fitness and increase the risk of mortality during migrations. Of the Murray turtle species *C. longicollis* is considered the least prone to desiccation with a low rate of evaporative water loss, ability to rehydrate well and aestivate (Chessman 1984a). High predation on nests by foxes significantly impacts recruitment (Thompson 1993).

Murray short-necked turtle (Emydura macquarii)

The Murray short-necked turtle is a common and abundant species in parts of its range though caution is suggested by some authors that indicate abundance and population robustness may be overestimated (Spencer & Thompson 2005; Chessman 1988). It is listed as 'vulnerable' in South Australia (NPW 1972) and 'near threatened' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions and in 'probable decline'(Gillam and Urban 2010), indicating that abundance within the study region may be lower than in other parts of its range. It is the species most often found in the river channel itself and river backwaters, e.g. permanent waters connected to the river channel. Abundance of *E. macquarii* is positively correlated with water body depth, transparency, persistence during dry conditions and flow velocity (Chessman 1988). Although river regulation and the creation of permanent stable water bodies (such as weir pools and pool level wetlands) are thought to have advantaged *E. macquarii* (Chessman 1988), declines in water level and loss of permanent wetlands, increased turbidity and reduced flow is expected to reduce habitat quality for this highly aquatic species. It is an opportunistic omnivore eating a range of plant and animal material. 'Plant' material' constitutes the majority of the diet and includes algae, macrophytes, microorganisms and fungi. Animal material includes mostly carrion (fish) and invertebrates (Chessman 1986). It is described as 'the most versatile of the three' species occurring in the River Murray (Legler 1978). Though a decline in aquatic productivity would reduce food resources for this species, its broad omnivorous diet is expected to decrease the impact compared to other turtle species, and introduced fish may provide an increasing source of carrion.

Being highly aquatic (Chessman 1984a), confined to, and rarely found far from, permanent water, it only comes on to dry land to nest, bask and occasionally move between water bodies (Thompson 1993; Chessman 1978 as cited in SAAB 2001). It has strong home range attachment (Goode & Russell 1968) and dispersal would be highly restricted in the event of drying (or decline in water level/ quality) of permanent water bodies. It has the lowest resistance to desiccation of the three turtles (Chessman 1984a), with a relatively high rate of evaporative water loss and aestivation unlikely (Chessman 1978 [in SAAB 2001]). However, although high mortality would likely occur if a permanent wetland dried it displays moderate survival tolerances because its main habitats within the study region are less likely to dry (river and regulated water bodies).

Nesting is triggered by rain associated with warm weather (Bowen et al 2005; Green 1996 as cited in Greer 2003) and hatchlings often remain in the nest until rain softens the soil (Goode and Russell 1968). Increased aridity may affect nesting success. Eggs are deposited from mid spring to early summer and hatchlings emerge late summer. A short incubation period of 66-85 days (Goode and Russell 1968) may decrease exposure time to extreme climatic conditions and predators compared with other species. During drought, nesting occurs opportunistically whenever rain does fall, even during the day (Green 1996 as cited in Greer 2003]) suggesting flexibility under changing climatic conditions. A change in rainfall seasonality to increasing summer rains could lead to delayed nesting but may also provide increased nesting opportunities. Nest sites are usually close to water and adults have high nest site fidelity (Goode and Russell 1968; Green 1996 as cited in Greer 2003]). Nesting success may be affected if sites become unsuitable due to salinisation &/or declining water levels. *E. macquarii* usually produces only one clutch of eggs annually but has high fecundity. Thompson (1993) reported an average of 23 eggs/ clutch and Spencer (2002) reports large female *E. macquarii* in the River Murray producing over 36 eggs. Predation on nests by foxes is very high (Thompson 1993).

Tiger snake (Notechis scutatus) & red-bellied black snake (Pseudechis porphyriacus)

The previously defined 2 tiger snake species *Notechis ater* and *N. scutatus* are now considered a single species in SA as no clear justification exists for their separation, similarly, the subspecies have even less justification. They are now classified under the single binomial name *Notechis scutatus* (M. Hutchinson, SA Museum, pers. comm. 2010). Population estimates and species threat listings for the tiger snake are complicated by the recent reclassification, but it is generally considered that the former subspecies *N. ater ater* (Krefft's tiger snake) is restricted to the Flinders Ranges (Cogger et al. 1993). The black tiger snake (*N. ater*) is distributed throughout south-western Western Australia, Tasmania, coastal South Australia (including islands) and Bass Strait (Cogger 2000 as cited in SAAB 2001). The eastern tiger snake (*N. scutatus*) is found in eastern Australia, usually south of Brisbane and also along the River Murray in all states (Worrell 1966 as cited in SAAB 2001). Its distribution extends far inland along banks of major river systems and south-eastern South Australia (Gow 1976 as cited in SAAB 2001). While all these species are considered now under the single binomial, the BDBSA and recent sub-regional threat listing work used the previous taxonomic groupings. For the purposes of this study, all tiger snake species in the BDBSA were consolidated although only one species (*N. scutatus*) was actually recorded within the study area so this had no effect on results.

Both elapid species (*N. scutatus* and *P. porphyriacus*) are heavily reliant on the health of the system as they are highly water-dependent and feed primarily on frogs in the study area (D. Armstrong pers. comm. 2011). Frogs represent a highly vulnerable group of animals within the study area and are likely to suffer reductions in range and abundance in the onset of climate variation under general conceptual models. 'In a prolonged drought, extensive mortality of metamorphosed terrestrial and aquatic amphibians could occur if their behavioural abilities to find moist microclimates for the duration of the drought are exceeded. Even if lethal limits are not reached in a severe drought, survivorship may be reduced because the lack of environmental moisture may limit periods of activity, mobility, ability to evade predators and food supply (Carey & Alexander 2003)'. Vulnerability under climate change, even of common amphibians, has already been identified (Hazell 2003; Piha et al . 2007 as cited in Mac Nally 2009)) and severe droughts have led to significant declines of at least 2 native frog species in southern NSW (Hazel et al. 2003 as cited in McNally 2009). Projected increases in the severity and frequency of drought in south-eastern Australia (Nicholls 2004), climate change has already been attributed as a major factor to anuran and reptile declines (Whitfield et al. 2007 as cited in Mac Nally 2009). Both elapids require wet, swampy areas and populations in the study area (and in SA generally) are isolated by their need for cooler and wetter environments in an otherwise semi-arid to arid environment (D. Armstrong pers. comm. 2011). Both species are known to enter fresh water, sometimes staying submerged for several minutes, to forage and hunt for prey items including tadpoles, frogs and fish (Greer 1997; Michael & Lindenmayer 2010). *P. porphyriacus* has a localised distribution mainly along the River Murray system and its creeks and tributaries in the upper Murray region (Michael & Lindenmayer 2010), and is listed as 'vulnerable' and in 'probable decline' in the DENR Murraylands region and Murray Mallee IBRA sub-region (Gillam & Urban 2010). Management recommendations for these species include preservation and distribution of fallen timber and dead standing trees (better thermal properties for basking than live trees). Wetland protection is also important to prevent over-grazing and soil erosion and allowing natural flow/flooding regimes to prevent wetland disconnection, preservation and planting/distribution of native vegetation to improve water quality and snags and fallen trees in waterways. Changes to flooding regimes have significantly reduced its range and abundance but some areas have seen recoveries where irrigated farming has provided additional habitat. Environmental water delivery is critical to the provision of suitable habitat and prey (Michael & Lindenmayer 2010).

Carpet python (Morelia spilota)

The carpet python is an arboreal, saxicolous (lives amongst rocks) and terrestrial python that inhabits dry forest, grassy box, sandhill, black box and Mallee woodland and river red gum forests. In some areas it is restricted to granite outcrops where suitable food and shelter exists. In the western MDB it is restricted to river red gum forests and well vegetated creeks (Michael & Lindenmayer 2010). At least 2 forms of *M. spilota* are known to use buildings (commonly in attics and rafters) (Greer 1997). A such, it has more general habitat requirements compared to the elapids described above and uses cliff lines, rocky outcrops and burrows for shelter and foraging. It has a less critical dependence on narrow habitat requirements (i.e. large trees, hollows etc.) that are only found in close proximity to water within the study area (D. Armstrong pers. comm. 2011). Management recommendations include the retention and provision of surface rocks and dead trees (good thermal properties) for basking but also nesting and sheltering, conservation of large mature trees used for foraging, basking, sheltering, preservation and distribution of fallen timber and dead standing trees (better thermal properties for basking than live trees). Provision of leaf litter and fine woody debris e.g. beneath trees is important for food availability and nest chamber construction. Fire management needs to be applied carefully to avoid 'blackout burns' and preserve some areas of native vegetation (Michael & Lindenmayer 2010).

Lace monitor (Varanus varius)

The lace monitor shows critical reliance on the river and wetland systems throughout the study area. An arboreal and terrestrial lizard, it inhabits a range of habitats ranging from dry forests, grassy box woodland, sandhill woodland, black box woodland, river red gum forest and Mallee woodland. Management recommendations include preservation and distribution of fallen timber and dead standing trees, conservation of large mature trees used for foraging, basking, sheltering and nesting and control of exotic animals that prey on eggs, young and sometimes adults. Introduced herbivores, e.g. feral goats and sheep, that degrade soil and land through grazing should be controlled (Michael & Lindenmayer 2010). *V. varius* is dependent on relatively narrow habitat requirements within the study area (e.g. large trees near water, hollows etc). It will use terrestrial movement to relocate but forages for nestling birds almost exclusively in trees. It is probably not as dependent on water as the carpet python but requires large trees found almost only near water especially in arid areas (D. Armstrong pers. comm. 2011).

Eastern water skink (Eulamprus quoyii) & Southern water skink (Eulamprus tympanum)

Both scincid lizards assessed, the eastern water skink (*Eulamprus quoyii*) and the southern water skink (*Eulamprus tympanum*), are water-dependent especially in the semi-arid to arid study area. Both species must have access to water, adequate cover and a cool, moist environment to avoid dehydration (D. Armstrong pers. comm. 2011). They are usually found along tributaries and floodplains in river red gum and eucalypt woodlands and grasslands and often bask in moist areas of riverine habitat along the River Murray (Swan and Watharow 2005). A study found that moist, open rocky habitats support higher densities than cool, closed forests with few rocks. Apart from water, rocks were the most useful predictor of presence. The availability of suitable basking conditions (e.g. rocky, open areas) in a particular habitat may be a main factor influencing the population density in a location (Law and Bradley 1990 as cited in SAAB 2001). Management recommendations include preservation of wetlands and waterways used for foraging and sheltering through fencing to prevent grazing and soil erosion. Allowing flooding of wetlands to prevent system disconnection from main channels and retaining snags and fallen trees in waterways that provide basking sites is also considered important as is the retention and provision of surface rocks and dead trees for basking, nesting and sheltering (Michael & Lindenmayer 2010).

3.1.4 Native frogs

The vulnerability assessment process identified 2 frog species, *Litoria raniformis* and *Limnodynastes fletcheri*, as being most 'at-risk' or highly vulnerable under climate change, from 10 species assessed. A second group of 4 species was identified at 'moderate' risk and the last 4 species at 'Moderate to Low' or 'Low' Risk. These species are highlighted in Table 13 below. The vulnerability ratings assigned to each criterion for all frog species assessed is presented in Appendix 10.

While some frog species within the study region are considered *more* vulnerable to the effects of climate change, a reduction in the extent, duration and frequency of wetlands flooded by the River Murray and increased incidence of drought is expected to negatively impact all species (Carey & Alexander 2003; Hazell 2003; Piha *et al*. 2007 as cited in Mac Nally 2009). An increase in summer and autumn rains are forecast for the area to the north of the study region under climate change (Dunlop & Brown 2008)and the study region may experience these climatic conditions in some years providing a localised increase in 'rain fed' breeding sites and increased terrestrial moisture. Any increase in moisture or humidity under climate change would benefit frogs (Tyler 1994). However, the inundation extent and length of hydro-period of rain fed wetlands is much less than wetlands inundated by a high river or flood event, and consequently, a significant loss of habitat.

It is re-iterated that the vulnerability coefficients calculated should only be compared amongst other frog species and not species from other taxonomic groups. Spatial associations were conducted for the 2 most 'at-risk' species and presented in section 3.2.

Knowledge gained from research and expert consultation indicated that it was more applicable to categorise frog species by 'level of Vulnerability' to climate change rather than ranking species per se (as performed for birds and fish) because of a perceived increased probability of error in the vulnerability ratings applied to frogs. This was due to a number of factors but specifically, differences in life history between species being minor and difficult to quantify, significant influence of micro-habitat and high intra specific variability across range and under different environmental conditions. Additionally there is a general scarcity of information for many frog species that address the questions of the assessment method particularly in regards to water regime, flooding and micro habitat requirements (though see Wassens & Maher 2010, Wassens 2010, Healey et al 1997, Lane et al 2007) and sometimes, difficulty inferring vulnerability from laboratory or limited field studies, e.g. salinity tolerance. For frog assessments, confidence ratings were not considered to provide additional robustness to the assessment process and have not been applied. Due to the complications with assessment outlined above, the factors/ traits that most influence the vulnerability risk for each species assessed is discussed.

Species	Vulnerability Coefficient	Vulnerability to climate change
Limnodynastes fletcheri	0.75	High
Litoria raniformis	0.72	High
Limnodynastes dumerili	0.61	Moderate
Litoria peronii	0.61	Moderate
Neobatrachus pictus/ N. sudelli	0.61	Moderate
Crinia parinsignifera	0.56	Moderate-Low
Crinia signifera	0.56	Moderate-Low
Litoria ewingi	0.50	Moderate-Low
Limnodynastes tasmaniensis	0.42	Low

Table 13 Native frog species ranked from 'High' to 'Low' Risk of Vulnerability. Top 2 'high-risk' species are highlighted in red.

Three criteria—Competition, Phenotypic plasticity and Recruitment—were entirely excluded from analysis due to lack of information and confidence across most or all species.

A few records exist in the BSBSA for *Pseudophryne bibroni* and *Limnodynastes peronii* and vulnerability assessments for these species were initially undertaken, but later excluded, because it was decided via expert consultation that the study region is at the edge of their range and the River Murray has little influence on populations of these species

(M. Tyler, University of Adelaide, pers. comm. 2011). Two *Neobatrachus* species, *N. pictus* and *N. sudelli* are recorded to occur within the study region, but due to confusing taxonomy and limited research (M. Tyler pers. comm. 2011) a combined assessment was made for the two species.

Following research and expert consultation, the following factors were identified as most likely to influence the vulnerability of frogs to climate change: Level of reliance on seasonally 'flood fed' riverine temporary wetlands, habitat specificity and vegetation requirements, triggers for breeding, water quality tolerances (e.g. salinity), length of tadpole development phase (and therefore wetland hydro-period required), mobility and dispersal (triggers, limitations and extent), adult survival mechanisms, breeding seasonality and level of predation/competition. Notes on the specific factors and life history traits that were considered in order to address each of the assessment questions are listed in Appendix 11 and were limited to those where information was available for most frog species.

Southern bell frog (Litoria raniformis)

The southern bell frog is a vulnerable (EPBC Act 1999) wetland species that has undergone significant range declines over the past 30 years (Wassens et al 2008). It is listed as 'vulnerable' in South Australia (NPW 1972) and 'near threatened' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions and 'rare' in the South Olary Plain and Lowan Mallee IBRA sub-regions and in 'probable decline' under IUCN criteria (Gillam and Urban 2010). It is locally common in parts of the study region but is largely only observed after natural or artificial flood events (SA MDB NRM unpublished data). Populations of *L. raniformis* within more arid areas such as the study region are highly reliant on seasonal flooding of temporary floodplain wetlands for breeding (Clemann & Gillespie 2010; Schultz 2007; Wassens et al 2008a). Research in the Lowbidgee Floodplain, NSW (a similar semi-arid regulated river floodplain) demonstrated a high sensitivity to reduced flood frequency, and annual flooding of key sites is considered essential for *L. raniformis* to persist (Wassens et al 2010). The probability of occurrence of *L. raniformis* has been shown to increase with increasing complexity of aquatic vegetation (Wassens et al 2010).Tangled Lignum *(Muehlenbeckia florulenta) and River Red Gum (Eucalyptus camaldulensis)/Spike Rush (Eleocharis sp.) wetlands are* known preferred habitats (Schultz 2006; S. Wassens, Charles Sturt University, pers. com. 2011) and both have declined with reduced flood frequency of the River Murray. It is highly mobile, known to travel long distances between wetlands but these movements are strongly linked to flooding (S. Wassens, Charles Sturt University, pers. comm. 2011). Without flooding frogs are thought relatively sedentary at permanent refuge sites. It is highly sensitive to drying and drought (particularly in semi-arid areas) with mass mortality of adults common when core permanent water bodies dry 'and this should be taken into account when considering climate change impacts as most climate models predict and increase in the frequency and severity of severe droughts (S. Wassens pers. comm. 2011)'.

Tadpoles appear to have a moderate length development phase in semi-arid regions: from 3 months (Schultz 2007; S. Wassens pers. comm. 2011) under ideal conditions and high water temperatures, but more often 5-6 months (S. Wassens pers. comm. 2011). It is thought less flexible in its development than other wetland species with significant tadpole mortality recorded in the Lowbidgee floodplain when wetlands are flooded from October to January (S. Wassens pers. comm. 2011). Decreased recruitment rates are expected with reduced flood duration and extent and altered flood timing. The long-term persistence of this species depends on regular flooding events to promote recruitment. After a period of reduced flood frequency, annual flooding over a number of years may be required in order to re-establish population numbers (Wassens et al 2008a; Schultz 2007)'. Intensive predation on *L. raniformis* tadpoles by alien fish, common carp and eastern gambusia has been observed (S. Wassens pers. comm. 2011).

Long-thumbed frog (Limnodynastes fletcheri)

The long-thumbed frog has a widespread distribution within the study region but records from call surveys indicate low abundance (SA MDB NRM unpublished data). It is restricted to the Murray corridor in South Australia (Cogger 2000). It is listed as 'near threatened' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions and 'rare' in the South Olary Plain IBRA sub-region and in 'probable decline (Gillam and Urban 2010)'. It is known to occupy a range of habitats including dams, rice bays, creeks and wetlands but is most common in seasonally-flooded wetlands with long hydro-periods of approximately 6 months (Wassens 2011). Breeding sites are usually temporary, shallow and containing abundant aquatic vegetation (Wassens & Maher 2010; Wassens 2011; Healey et al (1997). Highly dependent on wetlands, and with similar flooding requirements to *L. raniformis*, it is likely to be sensitive to declines in flood frequency (S. Wassens pers. comm. 2011). *L. fletcheri* can be highly mobile and dispersive in the event of a large flood and is able to recolonise wetlands during these events, but dispersal is linked to flooding, and reduced opportunities are expected with reduced flood frequency (S. Wassens pers. comm. 2011). It is described as an aquatic, non-burrowing species always found in water or sheltering in moist places (Amey & Grigg 1995). Dense aquatic vegetation at the water's edge is important refuge along the River Murray (Tyler 1994). It has limited tolerance for wetland drying, and is excluded if there are no permanent refuge sites nearby (Wassens 2011). Maintaining good refuges during droughts can probably increase resilience (S. Wassens pers. comm. 2011).

Eastern banjo frog (Limnodynastes dumerili)

The eastern banjo frog is widespread along the River Murray into South Australia (Wassens 2011). It was the 'fourth' most common species recorded during the 1998 SA "Frog Census" (Walker et al. 1999) and recent surveys indicate it remains common and widespread within the study region, though with high variability between sites (SA MDB NRM unpublished data). It is listed as 'near threatened' in the DENR Murraylands region and Murray Scroll Belt, 'least concern' in Murray Mallee and Lowan Mallee IBRA sub-regions and 'rare' in the South Olary Plain IBRA sub-region (Gillam and Urban 2010). It occupies most habitats throughout its range except those in alpine areas, rainforest and extremely arid zones (Barker et al. 1995) although no studies on specific habitat requirements are known (Wassens 2011). It breeds in a range of water bodies including swamps, slow moving streams, farm dams, lakes, urban and garden ponds and seasonally flooded wetlands (Barker et al. 1995; Cogger 2000, Wassens 2011, Tyler 1977), and although it does respond well to flooding it will also breed in permanent water bodies (S. Wassens pers. comm. 2011). Males are known to migrate considerable distance to breeding sites (Barker et al. 1995) though emergence, dispersal and breeding is thought rainfall dependant and linked to rain events (Wassens 2011, S. Wassens pers. comm. 2011).

The tadpole development phase is medium to long and successful recruitment may require wetlands to be flooded for around 6 months (Wassens 2011). Altered seasonality, frequency or intensity of rain fall (S. Wassens pers. comm. 2011) coupled with reduced flooding, particularly duration, is expected to influence reproductive success in *L. dumerili*. It can burrow to escape desiccating conditions (Tyler 1977) but is not known to significantly slow metabolism during these periods. Instead it is likely to burrow further down through the soil profile as water tables decline in order to maintain its moisture balance. Emergence to forage during heavy rains may extend the length of time individuals can persist between floods (Wassens 2011) but it is thought sensitive to desiccation and distribution may be restricted by soil type; 'It is possible that dispersal capability and use of refuges might be more important than burrowing ability in terms of recovery following extended dry periods (S. Wassens pers. comm. 2011)'. In a salinity field study in the Victorian Wimmera tadpoles of *L. dumerili* had a greater probability of occupancy at higher salinities compared to other species but tadpoles were not present above 6000uS/cm (Smith et al 2007). Breeding is usually seasonal but breeding can occur at any time and species has a high reproductive capacity increasing its resilience to changing seasonality of rainfall and flooding and chance of successful recruitment.

Peron's tree frog (Litoria peronii)

Peron's tree frog is widespread throughout the Murray-Darling Basin (Barker et al. 1995) and although is common, widespread within the study region abundance is highly variably between sites is listed as 'near threatened' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions and 'rare' in the South Olary Plain and Lowan Mallee IBRA sub-regions (Gillam and Urban 2010). It utilises a wide range of permanent, semi-permanent and temporary water bodies, including dams, creeks, ponds and seasonally flooded wetlands. It prefers deeper open ponds and rarely breeds in very shallow well vegetated water bodies. During the day it shelters in tree hollows and under loose bark most abundant in River Red Gum forests. It appears relatively unaffected by moderate reductions in flood frequency and is able to breed successfully in permanent water bodies and small residual pools (Wassens 2011), though temporary floodplain reaches are more likely to support breeding than permanent reaches (Wassens & Maher 2010). It has a medium to long tadpole development phase requiring an extended wetland hydro-period (S. Wassens pers. comm. 2011)and tadpoles have a low salinity tolerance (Smith et al 2007). Reduction in flood frequency and duration and increasing salinisation are expected to reduce breeding and refuge habitat for *L. peronii* within the study region. It is expected to have good dispersal and survival ability, known to exist in terrestrial habitats a considerable distance from water (Cogger 2000) and appears to be, together with *Limnodynastes tasmaniensis*, the most resilient species following extended drying, being present at isolated re-wetted wetlands dry for extended periods (S. Wassens pers. comm. 2011). Its peak calling period is later than most other species (late spring/summer) and a change in rainfall seasonality to increasing summer rains may benefit this species in some years.

Burrowing frog (Neobatrachus pictus) & Sudell's frog (N. Sudelli)

The *Neobatrachus* frogs are listed as 'least concern' in the DENR Murraylands region and associated IBRA sub-regions (*N. sudelli* is listed as 'rare' just in Lowan Mallee). Non-dependence on the river is cited as the reason for this listing (Gillam and Urban 2010). However, records within the BDBSA (2010) and recent call surveys (SA MDB NRM unpublished data) indicate *Neobatrachus* spp. is uncommon within the study region. *Neobatrachus* spp. occur in a wide range of arid and semi-arid areas including Mallee, shrubland, grassland, woodlands and heathland (Barker et al. 1995). Breeding occurs in temporarily inundated sites including flooded grassy marshes, roadside ditches, clay pans, and wetlands (Cogger 2000). Along the Murray in NSW *N. sudelli* breeds in flooded wetlands and in rain fed wetlands but is less widely distributed through rain fed wetlands and is sensitive to reduced flood frequency and duration of river flooding (S. Wassens pers. com). Breeding in *Neobatrachus* spp. is adversely affected by drought and a lack of free standing water (SAAB 2001). They do not appear to be highly dispersive (S. Wassens pers. comm. 2011) and although individuals can be found far from permanent water, dispersal is rainfall dependent (Cogger 2000; Tyler 1977). Increasing aridity is expected to decrease dispersal opportunities. *Neobatrachus* spp. will aestiviate and form a cocoon in response to a lack of free water that significantly reduces evaporative water loss enabling it to survive extended dry periods (Withers 1995). Distribution may be limited to areas with specific soil types suitable for burrowing (S. Wassens pers. com). Tyler (1997) advocates research into the conservation of this and other poorly known genera which inhabit arid areas in Australia.

Common froglet (Crinia signifera) & Murray Valley froglet (C. parinsignifera)

Crinia species are common and widespread within the study region but *C. parinsignifera* dominates in the north and *C. signifera* in the south. *C. parinsignifera* is restricted to the River Murray Corridor in South Australia. Both species are listed as 'near threatened' in the DENR Murraylands region and Murray Scroll Belt and Murray Mallee IBRA sub-regions and 'rare' in the South Olary Plain. *C. signifera* is also listed as 'rare' in the Lowan Mallee IBRA sub-region (Gillam and Urban 2010). They are habitat generalists, highly adaptable with a broad habitat range (Williamson & Bull 1996, Wassens 2011, Anstis 2002). They have a preference for sites with abundant aquatic or submerged terrestrial vegetation (Wassens 2011) but with a short tadpole development stage they are able to exploit highly ephemeral water bodies (Lane & Mahoney 2002) and have good breeding success in both rain and flood fed sites (S. Wassens pers. comm. 2011). Dispersal ability is thought more restricted and there is limited information on the capacity of these species to aestivate during dry conditions and it's not clear whether they burrow or move into newly flooded wetlands from the associated river systems during flooding (Wassens 2011). Limited dispersal ability may also restrict gene flow. *C. parinsignifera* was found to be common, but not as widespread as some other species, through re-wetted flooded or rain fed wetlands that had been subject to extended drying in the Lowbidgee floodplain (S. Wassens pers. comm. 2011). *C. signifera* is less common in the more arid parts of the study region (SA MDB NRM unpublished data) and laboratory studies have shown *C. signifera* to have reduced water conserving mechanisms and temperature tolerance (Warburg 1965). However, Crinia species are widely described as highly adaptable and resilient (Wassens 2011; McNally et al 2009) and may display some unknown survival mechanisms. Tadpoles are cryptic, well camouflaged & fast swimmers (Anstis 2002; Peterson et al 1992) and while rapid metamorphosis allows them to utilise ephemeral sites with less exposure to predators such as fish (Lane & Mahoney 2002), common carp have been observed to limit tadpole recruitment in riverine/flood fed systems (S. Wassens pers. comm. 2011). *C. signifera* tadpoles appear to have a moderate salinity tolerance detected at salinity levels up to ~4000uS/cm in a field study in the Victoria Wimmera (Smith et al 2007). They can breed opportunistically and are less likely to be affected by changing seasonality of flooding and rainfall.

Southern brown tree frog (Litoria ewingi)

The Southern brown tree frog is a common and widespread species found in the lower south-east and lower River Murray in South Australia (Walker et al 1999; Tyler 1977). It is listed as 'near threatened' in the DENR Murraylands region and Murray Mallee IBRA sub-region, and 'rare' in the Lowan Mallee IBRA sub-region (Gillam & Urban 2010). It is a habitat generalist recorded in a range of temporary and permanent water bodies including flooded grassland, marshes, ponds, dams, lakes, wetlands, flooded roadside ditches coastal swamps and lagoons, and documented from a range of habitat types such as wet and dry sclerophyll forest, farmland, heathland, semi-arid areas, alpine regions and suburban gardens (Cogger 2000; Barker et al 1995; Anstis 2002; Mallee CMA 2009). It is able to exploit highly ephemeral rain fed sites due to a short larval phase (Martin and Littlejohn 1982 in Lauck et al 2005) and can be found far from water when not breeding (Mallee CMA 2009; SAAB 2001) indicating good mobility, and the ability to disperse and escape deteriorating habitat conditions. Described as an agile climber and jumper and voracious insectivore capable of leaping and catching prey in mid-air (Mallee CMA 2009; SAAB 2001), it is expected to be a good competitor for terrestrial prey.

Results of laboratory research on its water conserving ability and temperature tolerance appear non-conclusive in determining its survival abilities. Warburg (1965) reports it to have a low temperature tolerance but Cree (1985) reports good water conservation and rapid re-hydration abilities. The salinity tolerance of tadpoles is also unclear with some conflicting results between field and laboratory studies. In a field study in the Victorian Wimmera *L. ewingi* appeared to have a low-moderate salinity tolerance with tadpoles detected at salinity levels up to ~3000 µS/cm (~ 6% Sea water (SW)) (Smith et al 2007) but laboratory studies show it surviving in higher salinities of 12% SW without apparent negative effects (Chinathamby et al 2006; A. Scott unpublished data). Squires et al (2008) found at 15% SW tadpoles were less active and prone to increased predation. The short tadpole development phase would allow individuals to escape more quickly from increasing saline conditions as temporary water bodies evaporate. It can breed opportunistically at any time of the year and is thus less likely to be affected by changing seasonality of flooding and rainfall.

Spotted grass frog (Limnodynastes tasmaniensis)

The spotted grass frog is one of the most common and widespread frogs in the Murray-Darling Basin (Wassens 2011) and is very common in the study region (SA MDB NRM unpublished data). It is listed as 'least concern' in the DENR Murraylands region and all IBRA sub-regions (Gillam & Urban 2010). It is a habitat generalist, (S. Wassens pers. com) will readily colonise any wet freshwater area and does not have specific requirements in terms of aquatic vegetation, though tadpoles are generally more abundant in aquatic vegetation (Wassens 2011). It is described as a very resilient species (McNally et al 2009) and often the first frog to colonise new habitats (Mokoney 2007). It is highly dispersive, with short tadpole development times, opportunistic breeding (e.g. wide breeding window so less likely impacted by altered seasonally of rainfall) and present in wetlands that have been subject to reduced flooding (S. Wassens pers. comm. 2011). In the South Western Slopes and Riverina, NSW it dominated rain fed wetlands that had been dry for a number of years after drought breaking rains even though some were quite isolated, and in riverine/ flood fed wetlands, it appeared the most resilient species following extended drying (S. Wassens pers. com). Of 6 species in a field study in the Victorian Wimmera, *L. tasmaniensis* were detected at the highest salinities after *L. dumerili* but not above 6000uS/cm (Smith et al 2007). Recruitment success is limited by predation on tadpoles by common carp and eastern gambusia (S. Wassens pers. comm. 2011).

3.1.5 Native mammals

All mammal species initially identified as 'vulnerable to climate change', due to being either aquatic or dependant on floodplain habitat, were included as 'at-risk' species for assessment. Assessments were completed with a discussion of relevant research, but criteria were not rated and species not ranked by their 'level' of vulnerability, due to the small number of species with very different life histories. Major factors affecting each species level of vulnerability to climate change are discussed below. Spatial associations were conducted for all 4 species and spatial relationships are presented in the following section (Section 3.2).

Common brushtail possum (*Trichosurus vulpecula)*

The common brushtail possum is largely confined to River Red Gum (*Eucalyptus camaldulenis*) forests and Black Box (*Eucalyptus largiflorens*) woodlands of the River Murray Corridor in the study region and is conservation listed as 'rare' in South Australia (NPW 1992). It is listed as 'rare' in the DENR Murraylands region and in 'probable decline', 'vulnerable' in the Lowan Mallee and 'near threatened' in the Murray Scroll Belt and Murray Mallee within IBRA sub-regions(Gillam and Urban 2010). It is 'locally common' in some parts of the Murraylands (Gillam and Urban 2010) but populations are confined to the river corridor resulting in a near linear habitat which may increase detectability and possibly exaggerate the appearance of a larger population. Populations are also likely to be patchy depending on local habitat suitability and fluctuate from year to year with climatic changes.

Within floodplain woodlands, hollow bearing mature river red gums provide essential day roost and breeding den sites, and foliage, flowers and fruit from herb, shrub and tree species make up the majority of the generalist diet of this species ((Kerle & How 2008)). The floodplain vegetation within these communities particularly, river red gums require frequent flooding to maintain health and facilitate recruitment of new cohorts. A decrease in flood frequency and increase in soil salinity are attributed to the death of river red gums and loss of diversity and preferred forage species in floodplain vegetation communities. A contraction of available habitat to an increasingly linear strip along the river channel and main anabranches is expected with a decrease in flood frequency, duration and extent. High mobility and extensive dispersal occurs in New Zealand populations (Cowan et al 1997; Cowan 2001; Stratham & Statham 1997) but under very different climatic conditions. The extent of mobility and dispersal within the study region is unknown but likely to be limited by the arid climate and linear nature of the River corridor. Some normal seasonal movements by juvenile males (Cowan et al 1997; Stow *et al* 2006) are expected. Strong attachment to home range (Cowan 2001) may limit movement in response to deteriorating habitat conditions.

It is described as a 'hardy survivor with the ability to adapt to many environments (Statham and Statham 1997 as cited in Le Mar & McArthur 2005]) but it is declining throughout arid and semi-arid areas (Kerle 2001; Kerle et al 1992; Papenfus 1990). This may indicate that survival tolerances/ physiological limitations of this medium sized mammal are already being exceeded in some arid areas (Kerle et al 1992) with a similar climate to that of the study region. Below average rainfall and drought has been implicated in mortality and population decline of brushtail possums (Kerle et al 1992). A varied diet is required for adequate nutrition (Kerle & How 2008), and a reduction in flowers and fruits is implicated in a decline in body condition and reproduction (Ramsey et al 2002). Flowers and fruits are considered 'essential for successful breeding' in arid areas (Kerle & How 2008). Under drought conditions most plants don't reproduce and possums must revert to drought staples (Evans 1992), such as Eucalypt and other foliage, however the gut of the brushtail possum is not designed for a high fibre, entirely foliar diet like some other possums (Kerle & How 2008). A decrease in water availability to trees (e.g. due to salinity, increasing aridity or reduced flooding) is also attributed to reduced palatability of foliage (Munks et al 1996), further reducing its suitability as a sole food source under drought conditions. Body condition and reproduction are expected to be significantly impacted under climatic scenarios due to a decline in adequate food resources.

Most populations have a major autumn and a minor spring breeding season with one young produced per year but in arid areas breeding can be continuous if food resources are available (Kerle & How 2008)and growth of young more rapid (Foulkes 2001). Breeding patterns in the study region are unknown, but continuous breeding may occur under favourable conditions (expected to be less frequent under climate change). In some populations a high percentage of females breed each year (Ramsey et al 2002; Smith et al 1969). However, overall reproductive capacity is low due to a single young born and a long period of parental care. Survival of young to independence is often high, however considerable mortality can occur during juvenile dispersal (Kerle & How 2008).

Eastern water rat (Hydromys chrysogaster)

The eastern water rat has a broad distribution and is common across its range where suitable habitat exists (Scott & Grant 1997). Recent surveys indicate the species is relatively common within the study region (Carthew & Reardon 2009). It is listed as 'near threatened' in the Murray Scroll Belt and Murray Mallee IBRA sub-regions but 'data deficiency' is highlighted (Gillam and Urban 2010). It inhabits permanent waters including man-made water bodies, with high numbers recorded in permanent wetlands and irrigation channels (Olsen 2008). It has a wide habitat range from beaches and estuaries to most inland river systems (Woollard et al 1978). Many permanent water bodies of the study region such as pool level wetlands, backwaters and anabranches will be largely retained (though with reduced levels) due to water supply requirements and the ability to regulate river flow. Water rats are not normally associated with the river channel of large rivers (Olsen 2008) but with reduced flows and subsequent increased reed growth, weir pools of the main Murray channel and large anabranches may become increasingly attractive habitat. A reduction in habitat and food availability for the water rat would occur with decreased flooding, but the impact would be minimised by its adaptability, generalist habits and tolerance of many conditions and it appearing not significantly limited by water regime, temperature or salinity (Scott & Grant 1997; Woollard *et al* 1978). Its occupation of highly saline waters may be limited by the salt tolerance of habitat vegetation and prey species and/or the proximity of freshwater. Their preference for permanent waters ensures that during times of extended drought within the study region pool level water bodies and stable weir pools will provide refuge.

It can move considerable distances overland in search of food, and dams and weirs are not considered a barrier to movement (except where terrestrial barriers also occur) though increased terrestrial movement may increase predation and mortality rates (Scott and Grant 1997). The water rat maintains a home range of up to 3.9 river km for males, and has no migratory patterns (Scott & Grant 1997). Its capacity for dispersal in response to deteriorating local conditions is unknown. Its highly opportunistic diet would reduce competition and reliance on any one particular prey item. Competition may occur from piscivorous birds, diving ducks, large fish, turtles and other reptiles. Introduced fish such as the common carp may provide an increasing food source. Young animals are preyed upon by snakes and large fish and adults and young by raptors, foxes and cats (Olsen 2008). Though fertility is high and *H. chrysogaster* is able to produce several litters a season under good conditions, (McNally 1960) recruitment rates would be reduced by the species short lifespan, low fecundity and predation (Olsen 1982; McNally 1960; Scott & Grant 1997). Drought is implicated in reproduction failures, irregular breeding, smaller litters delayed maturity (Scott & Grant 1997) and reduced life span (Serena in Sullivan 2007).

Southern myotis (Myotis macropus)

The southern myotis (or large-footed myotis) is widely accepted as a rare species across its range (Law & Anderson 1999). It is listed as 'endangered' in South Australia (NPW 1992) but the regional population size is unknown and it is given no conservation listing in the DENR Murrylands region due to 'data deficiency (Gillam & Urban 2010)'. There is only one record of the species within the study region (BDBSA 2010), though more roost sites along the River Murray in South Australia are suspected (Gillam & Urban 2010). It is the most closely linked bat species with aquatic systems, feeding only over water and being Australia's only 'trawling' bat, (Campbell et al 2010), using enlarged hind feet to catch aquatic prey from immediately above, or directly from, the water surface (Campbell 2009). The diet comprises largely aquatic insects, and small fish in varying but usually low quantities, but it is thought fish may make up a greater percentage of the diet in other populations (Law & Urquart 2000). A South Australian study confirmed the presence of fish in the diet but in unknown quantities (Jansen 1987 in Law & Urquart 2000). Law & Anderson (1999) suggest low availability of its aquatic prey is one possible reason for the bat's rarity and that reductions in prey abundance may have resulted from changes to River Murray flow regimes resulting in fewer flood events and an increase in stable water levels (such as in permanent pool level wetlands). Natural wetting and drying of wetlands increases the abundance of invertebrates while those with stable water levels support relatively few invertebrates. Coupled with an overall contraction of large wetlands and reduction in diversity and abundance of aquatic vegetation with reduced flooding, a loss of foraging habitat is expected. Some of its main prey (Chironomidae, Culicidae) are tolerant of poor water quality (Law & Urquart 2000, Law et al 2001)including saline waters, and small bodied introduced fish (e.g. *Gambusia holbrooki*) that prefer non-flowing systems and also tolerate high salinity may provide an increasing component of the diet if other prey sources decline.

The availability of suitable roost sites close to water is essential for the occurrence of the species (Campbell 2009; Law et al 2001; Anderson et al 2006). A variety of man-made and natural structures are roost sites but within the study region, limestone caves (only known colony) and hollow bearing river red gums are expected to be important. Increasing competition for suitable hollows is likely with a decline in abundance of mature river red gums. Colonies are normally small, usually 10-15 individuals (but occasionally up to several hundred (Richards2008)). Fecundity is low, females have one young annually (two in wetter areas) but recruitment rates may be high with extended parental care and harem formation observed (Dwyer 1970). Campbell et al (2010) identifies several potential predators for *M. macropus* in Victoria including owls and the lace monitor *Varanus varius*, which also occur in the study region. An additional predator may be the carpet python that inhabits limestone cliffs in the study region. In a Victorian study, Campbell et al (2009) found significant genetic differentiation between all populations indicating limited interaction between populations. They suggested movement throughout the landscape is constrained by the availability of permanent waterways and associated riparian habitats and the degradation of riparian habitat may severely restrict the movement of individuals along the river.

Giles planigale (Planigale gilesi)

Giles planigale, or the paucident planigale, has a relatively broad distribution through inland areas of eastern Australia and although not uncommon and often encountered during fauna surveys (Read 2008), its distribution is variable and population densities are generally low though fluctuate widely from season to season (Read 1987; Read 2008). Regionally it is listed as 'vulnerable' in the Murray Scroll Belt IBRA sub-region and in 'probable decline' (Gillam and Urban 2010). It is strongly associated with deep cracking clay soil drainage depressions, swamps, dry lakes and creek lines (Strahan 1995 in Briggs et al 2000; Read 1987; Blacket et al 2008; Briggs 1996) and prefers densely vegetated habitats associated with water and will inhabit a number of different communities e.g. tussock grassland, low shrubland, lignum (Read 1987; Blacket et al 2008). Increased drought and reduced flooding may increase the availability of dry wetland beds for *P. gilesi* to colonise in the *short term* but in the long term the interruption of the natural wetting and drying cycle would reduce vegetation cover and prey species. It is the process of drying after floods that induces cracking in clays (Gillam & Urban 2010). Salinisation can also alter soil structure and may contribute to a reduction in extent of deep cracking clay habitat. It is a highly mobile species with naturally shifting home ranges (Read 1984) and some individuals travel more than a kilometre in a few days (Read 2008). Some small inland mammals (species unknown) have been observed leaving flooded lakes on the backs of domestic sheep (Briggs 1997 as cited in Briggs et al 2000]). As a small mammal, limitations are expected where deteriorating habitat conditions and loss of resources are wide ranging. A level of competition with other small mammals and reptiles would occur, but is probably low as P. *gilesi* is a generalist forager , able to forage above and below ground and described as an 'efficient killer(Read 1984)'.

Population declines have been attributed to extended or unusually dry conditions (Denny 1975; Read 1984) but *P. gilesi* is described as 'an accomplished survivor (Read 2008)' and possesses physiological mechanisms to enable survival under increased temperatures, drought conditions and reduced food supply. Activation of torpor can reduce water loss and energy expenditure and a small body size, enhance heat dissipation (Warnecke et al 2010). Together with subterranean living (Read 1986) these are adaptations for living in an arid climate. Torpor can also be activated under conditions of food shortage (Warnecke et al 2010). Several strategies are displayed to adapt breeding to changing climatic conditions, increase chance of successful rearing in an arid and unpredictable climate and capitalize on short periods of optimum conditions. These include large litter size and potential for 2 (or more) litters per season, an extended breeding season, fast growth rate and early independence of young (Read 1987, 2008). Rates of recruitment would be highly variable from season to season.

3.2 Wetland & KEA spatial associations with 'at risk' species

3.2.1 Native fish

No single wetland was in proximity of all 11 'at-risk' fish species but 10 of the species were recorded closest to the River Murray main channel. The distribution of wetland species richness for fish is shown in Figure 8. Four or more species occurred near 19 different wetlands, 3 or more occurred near 47 wetlands and so on. When prioritising environmental water flows, these data can be used to identify critical wetlands for native 'at-risk' fish species.

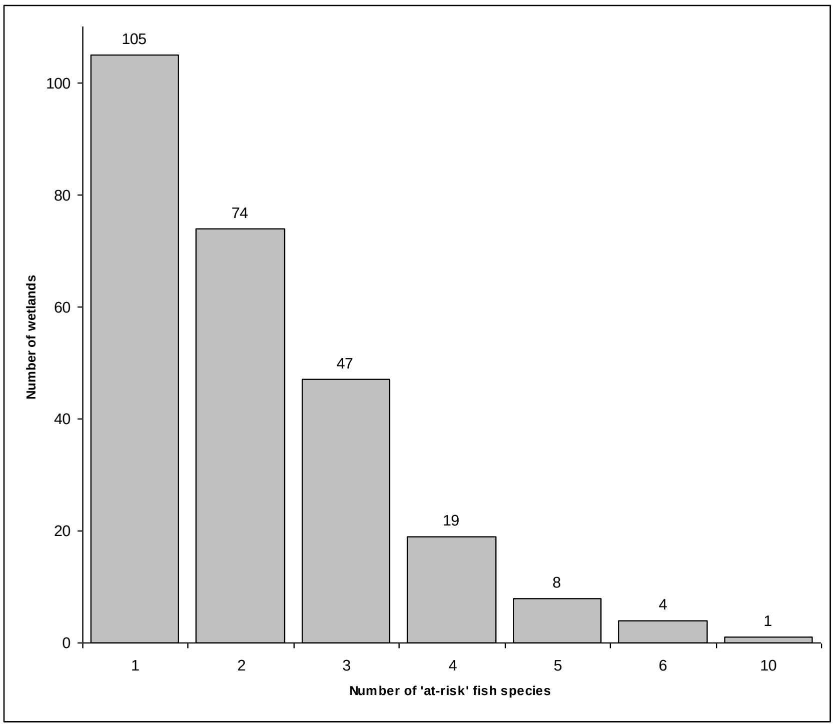

Figure 8 Number of at-risk' fish species within 500m of wetlands.

This list of 19 wetlands (Table 11) identifies those wetlands in close proximity of 4 or more different 'at-risk' fish species; a full list is given in Appendix 6. The main channel hosts the most number of species not surprisingly, but otherwise the area around Mobilong Swamp, Rocky Gully and Tailem Bend and wetlands generally around Mypolonga are important sites.

An additional proximity analysis using the same analytical model as for wetlands was conducted for key environmental assets (KEAs) to identify important species richness areas at a coarser spatial scale. Figure 9 summarises these results for fish species. 46 KEAs were identified with at least 1 species in close proximity, 7 KEAs were associated with at least 5 different species. These 7 KEAs are shown in Table 12 and a full list of associations is given in Appendix 7.

No. 'At-risk' Fish Species	AUS_WETNR	Name	SAAE Classification
10	S0001997	RIVER MURRAY	Permanent Reach
6	S0000047	MOBILONG SWAMP	Permanent Reach
6	S0001486	ROCKY GULLY	Saline Swamp
6	S0001816	JURY SWAMP (JAENSCHS BEACH)	Permanent Swamp - Terminal Branch
5	S0001043	TAILEM BEND	Permanent Lake - Terminal Branch
5	S0001466	MURRUNDI (WELLINGTON NORTH)	Permanent Swamp - Throughflow
5	S0001811	MYPOLONGA LEVEE	Permanent Swamp - Throughflow
5	S0016022	RIVERGLADES	Permanent Swamp - Throughflow
4	S0000113	LAKE CARLET	Permanent Lake - Throughflow

4	S0000174	SWANPORT WETLAND	Permanent Swamp - Throughflow
4	S0000241	MUNDIC CREEK	Permanent Lake - Throughflow
4	S0000609	REEDY CREEK	Permanent Lake - Throughflow
4	S0000938	MUSSEL LAGOON	Permanent Lake - Terminal Branch
4	S0001182	MUNDIC CREEK	Temporary Wetland - Overbank Flow
4	S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch
4	S0001973	PILBY LAGOON	Permanent Swamp - Throughflow
4	S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch
4	S0002460	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
4	S0016023	REEDY CREEK	Permanent Lake - Throughflow

Table 11 Wetlands occurring within 500m of 4 or more 'at-risk' fish species.

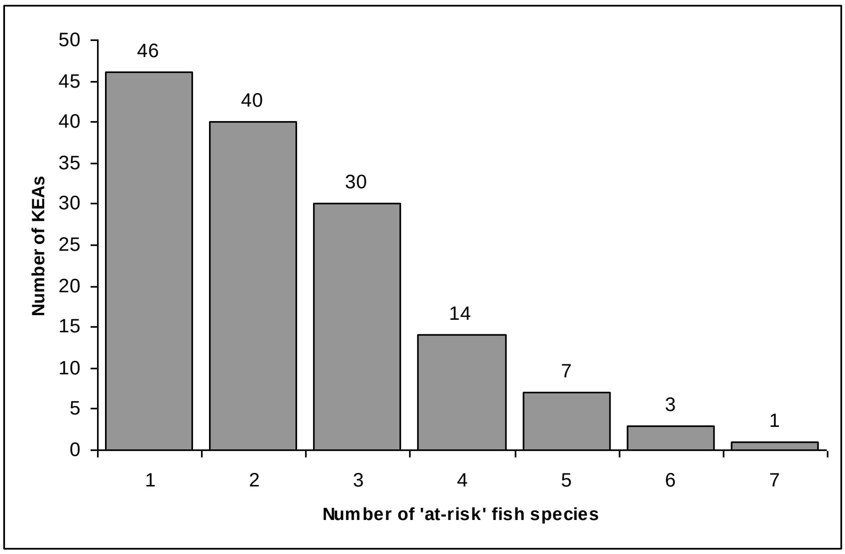

Figure 9 Number of at-risk' fish species within 500m of key environmental assets (KEAs).

No. 'at-risk' fish species	KEA Asset Name	KEA ID
8	Mypolonga/Toora Levee/Jury Swamp	96
7	Mobilong Swamp incl. Rocky Gully	97
6	Riverland Ramsar	1
5	Gurra Floodplain	10
5	Murrundi	106
5	Riverglades	98
5	Tailem Bend	103

Table 12 KEAs occurring within 500m of 5 or more 'at-risk' fish species.

As with the wetland-scale proximity analysis, the areas around Mypolonga and Mobilong Swamp are highlighted as areas of high 'at-risk' fish species richness.

3.2.2 Native reptiles

All 'vulnerable' reptile species were included as 'at-risk' species as there were only 9 species in total. Assessments were conducted but not scored or ranked and spatial associations were conducted for all 9 species. Reptile species richness at the wetland scale showed 78 wetlands with at least 1 species within a search radius of 1km but only 14 wetlands with 2 or more (Figure 10); these are summarised in Table 13 and the full list of associations is given in Appendix 8.

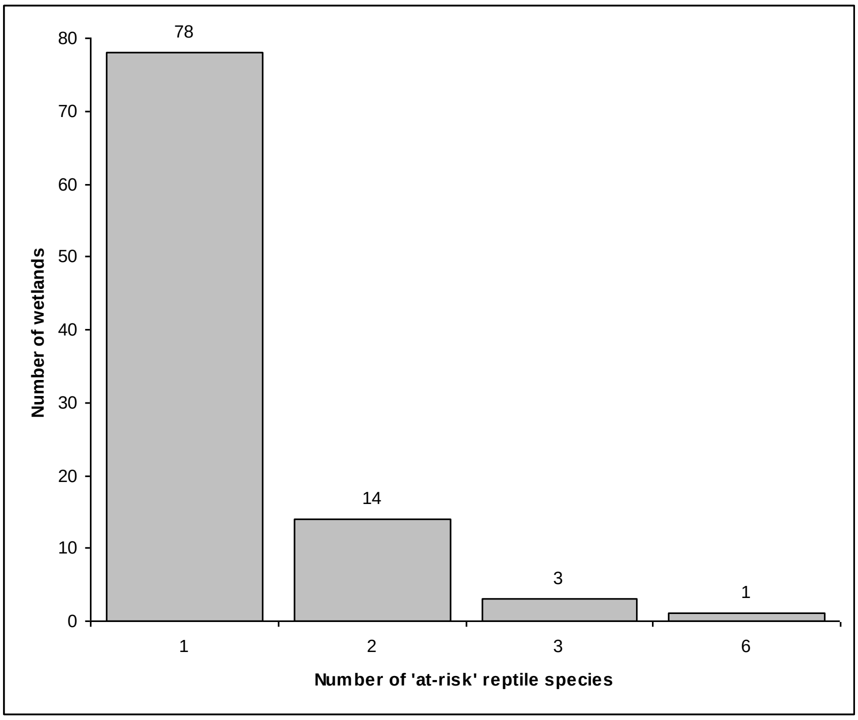

Figure 10 Number of at-risk' reptile species within 1km of wetlands.

No. 'at-risk' reptile species	AUS_WETNR	Name	SAAE Classification
6	S0001997	RIVER MURRAY	Permanent Reach
3	S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow
3	S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
2	S0000347	BERRI CAUSEWAY	Temporary Wetland - Throughflow
2	S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch
2	S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow
2	S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch
2	S0000960	WOOLENOOK BEND COMPLEX	Permanent Swamp - Throughflow
2	S0001100	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
2	S0001283	WOMBAT REST BACKWATER	Permanent Lake - Throughflow
2	S0001309	OVERLAND CORNER COMPLEX	Temporary Wetland - Overbank Flow
2	S0001359	No name	Ephemeral Reach
2	S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch
2	S0001700	NIGRA CREEK	Permanent Reach

Table 13 Wetlands occurring within 1km of 2 or more 'at-risk' reptile species.

Ignoring the main channel, the Gurra Lakes Complex near Berri upstream of Lock 4 and the Morgan Conservation Park are associated with the most number of 'at-risk' reptile species. All wetlands near 2 or more 'at-risk' reptile species are located upstream of Lock 1 at Blanchetown.

An additional proximity analysis using the same analytical model as for wetlands was conducted for key environmental assets (KEAs) to identify important species richness areas at a coarser spatial scale. Figure 11 summarises these results for reptile species. 55 KEAs were identified in proximity to at least 1 species, 18 KEAs were associated with at least 2 different species and so on. 6 KEAs were associated with 3 or more species and are described in Table 14; a full list of associations is given in Appendix 9.

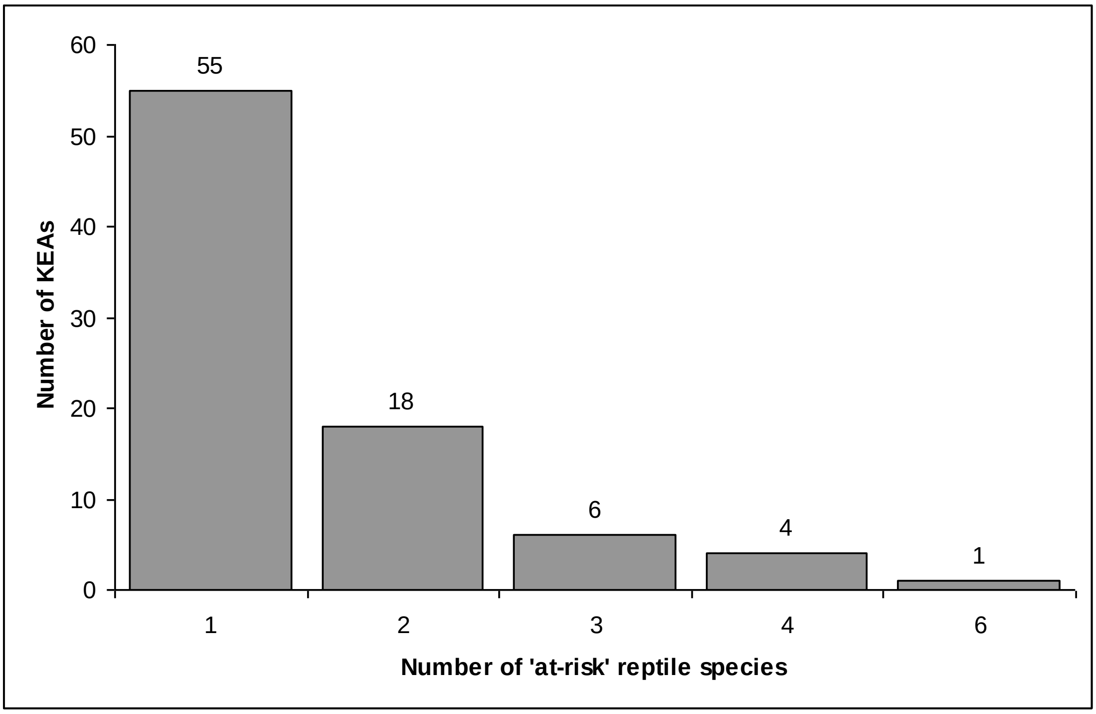

Figure 11 Number of at-risk' reptile species within1km of key environmental assets (KEAs).

No. KEAs	KEA Asset Name	KEA ID
6	Riverland Ramsar	1
4	Gurra Floodplain	10
4	Katarapko Floodplain	17
4	Morgan East & Morgan CP	54
3	Loch Luna and Wachtels Lagoon	23
3	Maize Island Complex	35

Table 14 KEAs occurring within 1km of 3 or more 'at-risk' reptile species.

Similar areas along the floodplain are highlighted as having high species richness as with the wetland scale analysis. The Gurra Floodplain and areas near Morgan are identified and all other areas (Riverland Ramsar, Katarapko Floodplain etc.) lie between the Victorian border and Morgan.

The 3 species of turtles assessed (Broad-shelled Turtle *Chelodina expansa*, Common Long-necked Turtle *Chelodina longicollis* and Murray short-necked turtle *Emydura macquarii*) probably represent the most directly water-dependent group of reptiles and warrants separate consideration. As a group, the turtles were mainly associated with wetlands as opposed to the main channel. The wetland-scale proximity analysis showed only 6 out of a total of 167 records (<4%) most closely associated with the main channel.

The 2 records for *C. expansa* and were associated with the Gurra Lakes and Morgan wetland complexes. Records of *E. macquarii* were also associated with the Gurra Lakes (1 record) and Morgan (1 record) complexes and also the Woolenook Bend Complex (1 record) with 1 record associated with main channel. *C. longicollis* had the highest number of records (160) and were mainly distributed upstream of Lock 4. They were predominantly associated with the Chowilla and Pilby complexes in the north of the study area, the Gurra Lakes complex near Berri and Katarapko Game Reserve Complex near Loxton.

3.2.3 Native frogs

A total of 109 wetlands were found to be spatially associated with at least one 'high-risk' frog species and 31 wetlands with both species (*Litoria raniformis*, *Limnodynastes fletcheri*) and these wetlands are summarised in Table 15. A full list of wetland associations is given in Appendix 12.

No. 'at-risk' frog species	AUS_WETNR	Name	SAAE Classification
2	S0000039	NGAK INDAU OUTLET	Semi-connected
2	S0000098	SLANEY WEIR BILLABONG	Through flow
2	S0000106	PILBY CREEK	Semi-connected
2	S0000271	MARTIN BEND COMPLEX	Overbank flow
2	S0000344	NELWOOD	Terminal branch
2	S0000355	MONOMAN CREEK	Connected
2	S0000366	PIPECLAY BILLABONG	Terminal branch
2	S0000443	RILLI LAGOONS	Terminal branch
2	S0000510	THIELE FLAT	Semi-connected
2	S0000877	CHOWILLA COMPLEX	Terminal branch
2	S0000923	MARTIN BEND COMPLEX	Terminal branch
2	S0000928	BELDORA WETLANDS	Through flow
2	S0000949	OVERLAND CORNER INLET	Connected
2	S0001100	RAL RAL CREEK AND RAL RAL WIDEWATERS	Connected
2	S0001166	MURTHO PARK COMPLEX	Terminal branch
2	S0001179	MURTHO PARK COMPLEX	Terminal branch
2	S0001295	MURTHO PARK COMPLEX	Terminal branch
2	S0001381	WHIRLPOOL CORNER	Through flow
2	S0001446	BERRI CAUSEWAY	Terminal branch
2	S0001477	WALL SWAMP	Through flow
2	S0001478	WALL LEVEE	Overbank flow
2	S0001617	PILBY CREEK	Semi-connected
2	S0001618	WERTA WERT	Terminal branch
2	S0001623	BUNYIP HOLE	Overbank flow
2	S0001626	LAKE LITTRA	Terminal branch
2	S0001775	CAURNAMONT	Terminal branch
2	S0001793	COOLCHA LAGOON	Through flow
2	S0001973	PILBY LAGOON	Through flow
2	S0001974	PILBY CREEK	Terminal branch
2	S0001975	LOCK 6 DEPRESSION	Through flow
2	S0001997	RIVER MURRAY	Connected

Table 15 Wetlands occurring within 1km of 2'high-risk' frog species.

Wetlands associated with both 'high risk' frog species are spread throughout the study region but the greatest concentration is in the northern section above Locks 5 and 6 and to a lesser extent between locks 3 and 5 and below Lock 1.

No. 'at-risk' frog species	KEA Asset Name	KEA ID
2	Caurnamont	81
2	Coolcha Lagoon	85
2	Gurra Floodplain	10
2	Katarapko Floodplain	17
2	Loch Luna and Wachtels Lagoon	23
2	Lyrup East	9
2	Martins Bend	11
2	Mypolonga/Toora Levee/Jury Swamp	96
2	Overland Corner	26
2	Paringa Paddock	4
2	Rilli Lagoons	14
2	Riverland Ramsar	1
2	Spectacle Lakes / Beldora Complex	21
2	Thiele Flat	15
2	Wall Levee/Wood Lane	94
2	Wall Swamp	93
2	Wellington Spit	105
2	Younghusband Complex	87

Table 16 KEAs occurring within 1km of both 'high-risk' frog species.

The majority of the large number of wetlands above Lock 5 and 6 that were associated with both 'high-risk' frog species (Table 15) are incorporated in the Riverland Ramsar KEA, so at the KEA scale, the largest concentration of KEAS associated with both 'high-risk' frog species is below lock 1 and between Locks 3 and 5. A full list of KEA associations is given in Appendix 13.

3.2.4 Native mammals

All 'vulnerable' mammal species were included as 'at-risk' species as there were only 4 species in total. Assessments were conducted but not scored or ranked and spatial associations were conducted for all 4 species.

A total of 61 wetlands were found within 1km of at least 1 'at-risk' mammal species but only 3 near at least 2 species and 1 (River Murray main channel) associated with at least 3 species (Figure 12).

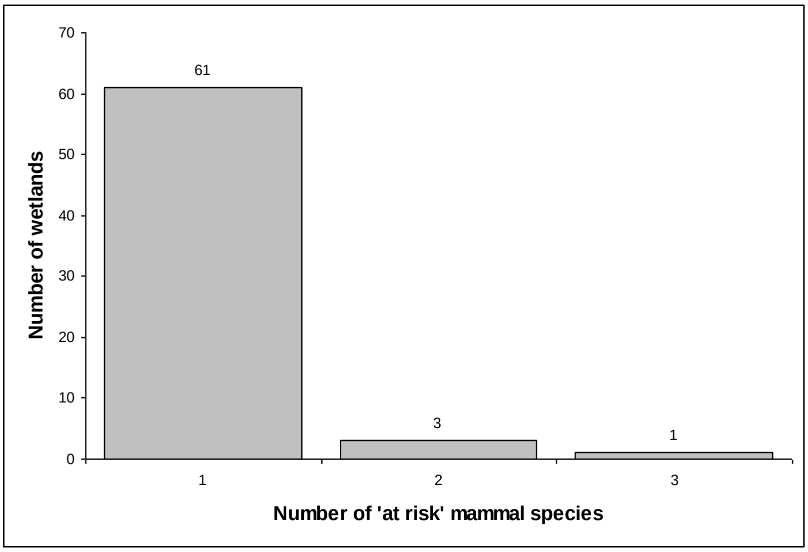

Figure 12 Number of at-risk' mammal species within 1km of wetlands.

The 3 wetlands within 1 km of at least 2 different 'at-risk' mammal species included firstly the main channel (3 species) and then wetlands in the Ral Ral Complex and Murtho Park Complex between Locks 5 and 6 in the northern extent of the study area (Table 17). A full list of wetland associations is given in Appendix 14.

No. 'at-risk' mammal species	AUS_WETNR	NAME	COMPLEX	SAAE Classification
3	S0001997	RIVER MURRAY	RIVER MURRAY	Permanent Reach
2	S0001103	RAL RAL CREEK AND RAL RAL WIDEWATERS	RAL RAL COMPLEX	Permanent Reach
2	S0001104	DOUBLE THOOKLE THOOKLE LAGOONS	RAL RAL COMPLEX	Temporary Wetland - Overbank Flow

Table 17 Wetlands occurring within 1km of 2 or more 'at-risk' mammal species.

At the coarser KEA scale, 45 KEAs were found within 1km of at least 1 'at-risk' mammal species, 5 KEAs near at least 2 species and 2 KEAs near at least 3 species (Figure 13). Two main areas of high 'at-risk' mammal species richness were identified. The Riverland Ramsar area of the floodplain above Lock 5 near Renmark and Kroehns Landing below Lock 1 near Wongulla were both associated with at least 3 species. The Nigra/Schillers KEA near Qualco around the Lock 2 area, and Caurnamont and Neeta Flat Depressions (below Lock 1 near Ponde) were associated with at least 2 species (Table 18). The full list of associations is given in Appendix 15.

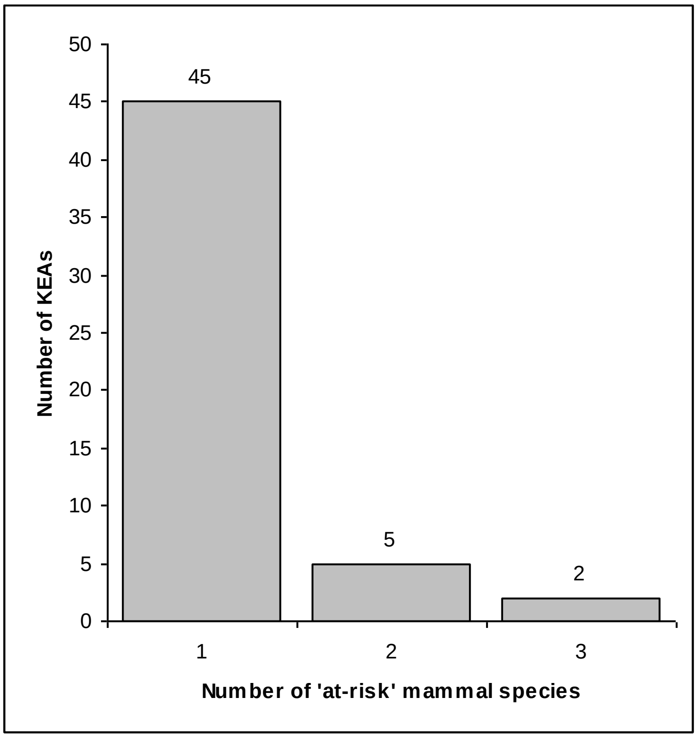

Figure 13 Number of at-risk' mammal species within 1km of key environmental assets (KEAs).

No. 'at-risk' mammal species	KEA Asset Name	KEA ID
3	Kroehns Landing	75
3	Riverland Ramsar	1
2	Caurnamont	81
2	Neeta Flat Depressions	92
2	Nigra/Schillers	41

Table 18 KEAs occurring within 1km of 2 or more 'at-risk' mammal species.

3.2.5 Native birds

Of the 11 'at-risk' birds species identified through the assessment process (see Section 3.1), no single wetland was highlighted as being within the 2km search radius of all 11 species (Figure 14). Table 21 summarises the wetlands with the highest species richness of 'at-risk' birds. Only 1 wetland, Paiwalla Wetland (AUSWETNR S0002461) was identified closest to 10 different 'at-risk' species. This is a temporary, terminal branch wetland located on the eastern side of the River Murray near Mypolonga in the southern part of the study area below Lock 1. The group of wetlands associated with 6 species included another wetland within the Paiwalla Wetland complex along with Banrock Swamp and Watchels Lagoon just above Lock 3 and Morgan Conservation Park a little below Lock 2. A full list of associations is given in Appendix 18.

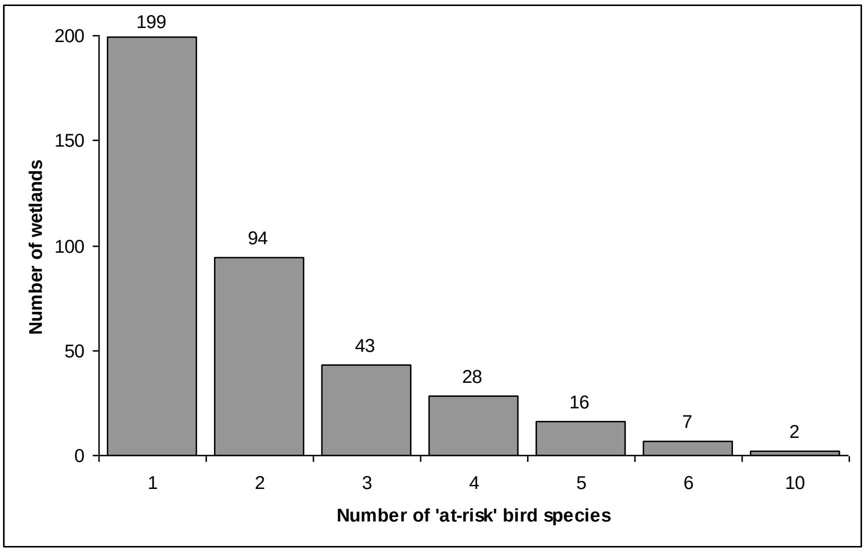

Figure 14 Number of at-risk' bird species within 2km of wetlands.

No. 'At-Risk' Bird Species	AUS_WETNR	NAME	SAAE Classification
10	S0001997	RIVER MURRAY	Permanent Reach
10	S0002461	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
6	S0000266	WACHTELS LAGOON	Permanent Lake - Throughflow
6	S0000970	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
6	S0001481	SUNNYSIDE CONSERVATION PARK AND PAIWALLA SWAMP	Permanent Swamp - Throughflow
6	S0001660	BANROCK SWAMP	Permanent Swamp - Throughflow
6	S0002460	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
5	S0000034	NGAK INDAU INLET	Ephemeral Reach
5	S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch
5	S0000928	BELDORA WETLANDS	Permanent Swamp - Throughflow
5	S0000938	MUSSEL LAGOON	Permanent Lake - Terminal Branch

5	S0001465	EAST WELLINGTON	Temporary Wetland - Terminal Branch
5	S0001486	ROCKY GULLY	Saline Swamp
5	S0001670	BANROCK CREEK	Permanent Reach
5	S0001672	HART LAGOON	Permanent Lake - Terminal Branch
5	S0001721	MORGAN CONSERVATION PARK	Temporary Wetland - Terminal Branch
4	S0000002	NGAK INDAU	Temporary Wetland - Terminal Branch
4	S0000148	KATARAPKO CREEK AND KATARAPKO ISLAND	Permanent Reach
4	S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch
4	S0001058	LAKE BONNEY COMPLEX	Permanent Lake - Terminal Branch
4	S0001263	BANROCK INLETS	Temporary Wetland - Throughflow
4	S0001477	WALL SWAMP	Permanent Lake - Throughflow
4	S0001617	PILBY CREEK	Ephemeral Reach
4	S0001618	WERTA WERT	Temporary Wetland - Terminal Branch
4	S0001705	MARKARANKA SOUTH	Temporary Wetland - Throughflow
4	S0001708	MARKARANKA EAST	Temporary Wetland - Terminal Branch
4	S0001776	SALTBUSH FLAT	Permanent Lake - Throughflow
4	S0001973	PILBY LAGOON	Permanent Swamp - Throughflow

Table 21 Wetlands occurring within 2km of 4 or more 'at-risk' bird species.

At the coarser scale, a total of 85 KEAs were identified within the 2km search radius of at least 1 'at-risk' bird species. 24 KEAs were within closest proximity to at least 4 species (see Figure 15). No single KEA was associated with all 11 species but the Pompoota/Paiwalla/Sunnyside KEA (ID No. 95) located below Lock 1 near on the eastern side of the River Murray near Mypolonga, was in closest proximity to 10 of the 'at-risk' bird species. The Hart Lagoon KEA, between Locks 3 and 2 and the Riverland Ramsar KEA above Lock 5 in the northern part of the study area were associated with 8 species. Generally, the highest richness of 'at-risk' bird species occurred above Lock 3 aside from the Pompoota region below Lock 1. A full list of KEA associations with 'at-risk' bird species is given in Appendix 19.

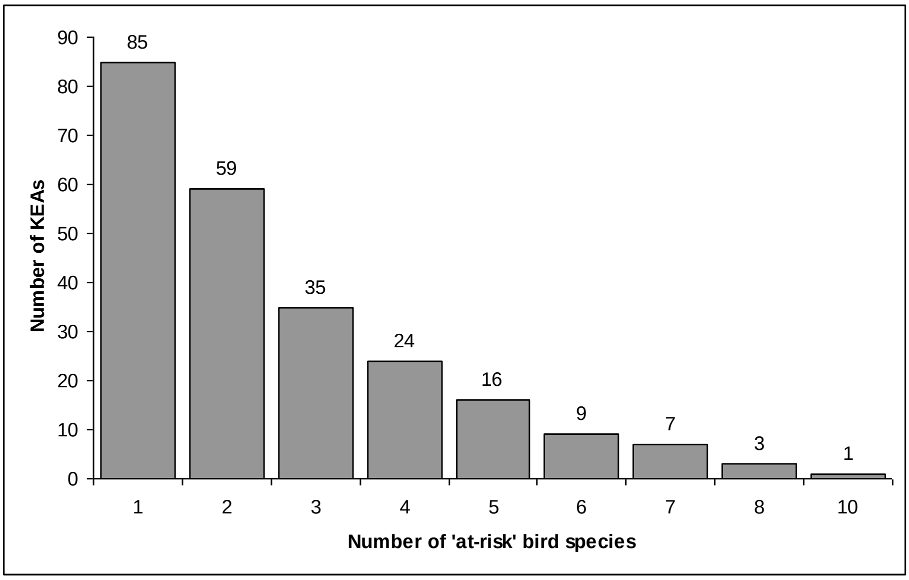

Figure 15 Number of at-risk' bird species within 2km of KEAs.

No. 'At-Risk' Bird Species	KEA Name	KEA ID
10	Pompoota/Paiwalla/Sunnyside	95
8	Hart Lagoon	37
8	Riverland Ramsar	1
7	Banrock Ramsar Complex (inc Wigley Reach)	25
7	Katarapko Floodplain	17
7	Loch Luna and Wachtels Lagoon	23
7	Martins Bend	11
6	Gurra Floodplain	10
6	Morgan East & Morgan CP	54
5	Devon Downs Complex	73
5	Loveday Swamps and Mussel Lagoons	22
5	Mobilong Swamp incl. Rocky Gully	97
5	Moorundie Complex	66
5	Reedy Creek Mannum	91
5	Spectacle Lakes / Beldora Complex	21
5	Wellington Complex	104
4	Boggy Flat	43
4	Donald Flat	61
4	Markaranka Complex	46
4	Ramco Lagoon	38
4	Rilli Lagoons	14
4	Saltbush Flat	82
4	Swanport Wetland	101
4	Wall Swamp	93

Table 22 KEAs occurring within 2km of 4 or more 'at-risk' bird species.

3.2.6 All taxonomic groups combined

When all 'at-risk' species were combined, (i.e. 11 fish, 9 reptiles, 2 frogs, 4 mammals and 11 birds) a total of 320 wetlands across the study area were identified with at least 1 'at-risk' species with the respective search radii for each taxonomic group (see spatial accuracy and search radii presented in Table 6 of Section 2.4). 24 individual wetlands were highlighted as spatially associated with at least 8 'at-risk' species (Figure 16). These wetlands are detailed in Table 23 and a full list of wetland associations is given in Appendix 20. Table 23 also shows the number of taxonomic groups (fish, reptile, frog, mammal, bird) that comprises the species richness for each wetland.

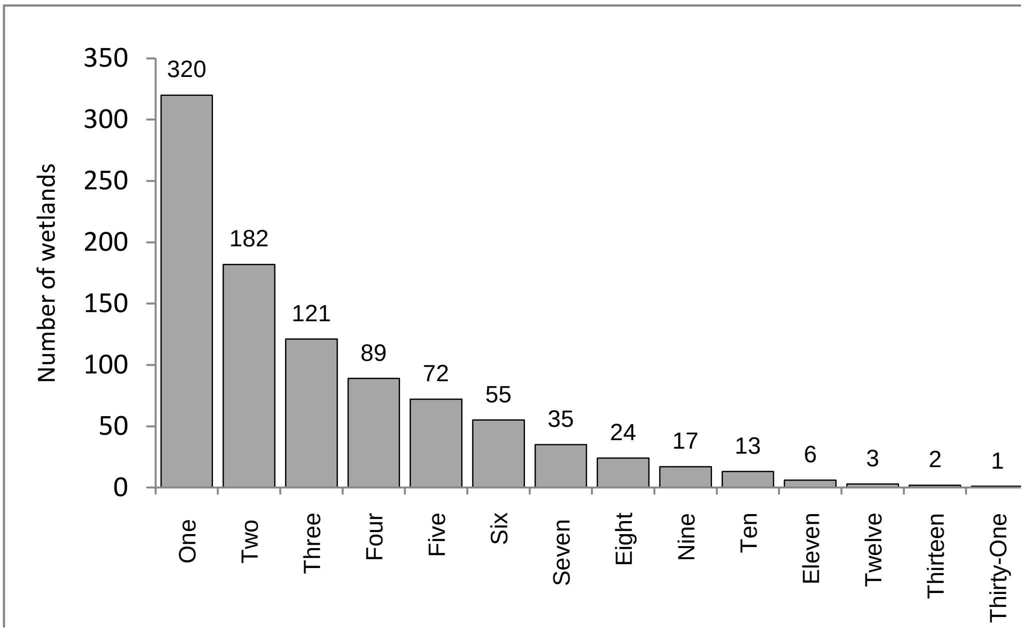

Figure 16 Number of at-risk' species from any taxonomic groups within respective search radii of wetlands.

AUS_WETNR	Name	SAAE Classification	No. Taxa Groups	No. 'At-Risk' Species
S0001997	RIVER MURRAY	Permanent Reach	5	31
S0001486	ROCKY GULLY	Saline Swamp	4	13
S0002461	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch	3	12
S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow	5	11
S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch	4	11
S0001973	PILBY LAGOON	Permanent Swamp - Throughflow	4	11
S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch	4	10
S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow	5	10
S0000938	MUSSEL LAGOON	Permanent Lake - Terminal Branch	3	10
S0001618	WERTA WERT	Temporary Wetland - Terminal Branch	4	10
S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch	4	10
S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow	5	10
S0002460	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch	2	10
S0000928	BELDORA WETLANDS	Permanent Swamp - Throughflow	4	9
S0000970	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow	4	9
S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch	5	9
S0016022	RIVERGLADES	Permanent Swamp - Throughflow	4	9
S0000034	NGAK INDAU INLET	Ephemeral Reach	4	8
S0000047	MOBILONG SWAMP	Permanent Reach	3	8

S0000098	SLANEY WEIR BILLABONG	Temporary Wetland - Throughflow	4	8
S0000174	SWANPORT WETLAND	Permanent Swamp - Throughflow	3	8
S0000933	YATCO LAGOON	Permanent Lake - Throughflow	5	8
S0001617	PILBY CREEK	Ephemeral Reach	4	8
S0001672	HART LAGOON	Permanent Lake - Terminal Branch	4	8

Table 23 Wetlands occurring within respective search radii of 8 or more ‘at-risk’ species from any taxonomic group.

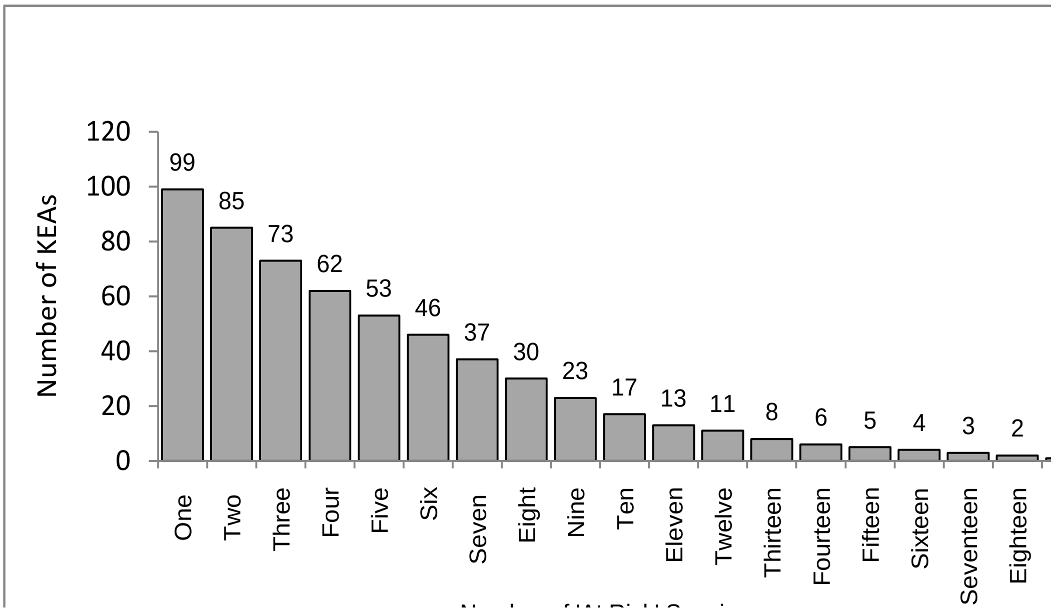

Figure 19 Number of at-risk’ species from any taxonomic groups within respective search radii of KEAs.

At the KEA scale, a total of 99 KEAs were identified as being spatially associated with at least 1 ‘at-risk’ species from any of taxonomic groups and 30 KEAs were associated with at least 8 species (Figure 19). These 30 KEAs are detailed in Table 23 and some were comprised of species from all 5 taxonomic groups. The Riverland Ramsar KEA was by far the most rich in terms of species diversity and was associated with 25 different species from all 5 taxonomic groups. The Gurra and Katarapko Floodplain KEAs were next most species rich and the general pattern of higher species richness in the northern extent of the study area above Lock 3 at the wetland scale is maintained at the KEA scale. The graphic overview schematic of species richness at the KEA scale is presented in Figure 20 highlighting this trend. The full list of KEA associations is presented in Appendix 21.

KEA Asset Name	KEA ID	No. Taxa Groups	No. 'At-Risk' Species
Riverland Ramsar	1	5	25
Gurra Floodplain	10	5	18
Katarapko Floodplain	17	5	17
Loch Luna and Wachtels Lagoon	23	5	16
Pompoota/Paiwalla/Sunnyside	95	3	15
Morgan East & Morgan CP	54	5	14
Martins Bend	11	4	13
Mobilong Swamp incl. Rocky Gully	97	4	13
Hart Lagoon	37	4	12
Reedy Creek Mannum	91	5	12

Spectacle Lakes / Beldora Complex	21	5	12
Loveday Swamps and Mussel Lagoons	22	4	11
Nigra/Schillers	41	5	11
Moorundie Complex	25	5	10
Mypolonga/Toora Levee/Jury Swamp	66	3	10
Paringa Paddock	96	5	10
Riverglades	4	5	10
Boggy Flat	98	4	9
Devon Downs Complex	43	3	9
Murrundi	73	3	9
Paisley Creek/Edsons Flat	106	4	9
Swanport Wetland	65	3	9
Yatco Lagoon	101	5	9
Banrock Ramsar Complex (inc Wigley Reach)	19	3	8
Brenda Park / Morphetts Flat Complex	55	5	8
Coolcha Lagoon	85	4	8
Disher Creek	6	4	8
Overland Corner	26	4	8
Pike-Mundic	8	5	8
Rilli Lagoons	14	4	8

Table 24 KEAs within respective search radii of 8 or more ‘at-risk’ species

4.0 Conclusions, Limitations & Future Work

Thirty-seven vertebrate fauna species (eleven fish, two frogs, nine reptiles, eleven birds and four mammals) were identified through the risk assessment process as most 'at-risk' or most vulnerable under climate change in the South Australian Murray Darling Basin (from Wellington to SA-Vic Border). These are listed in Table 25. Although many aspects of each species' ecology, physiology, genetics and resilience influenced the assessments, the vulnerability of *all* species was driven principally by two main factors. Firstly, the forecast decrease in flood frequency, duration and extent along the River Murray resulting in a significant reduction in area and quality of foraging and breeding habitat (in particular floodplain and flowing habitat). Secondly, an increase in overall salinity levels coupled with a decrease in wetland, floodplain and river productivity and subsequent decline in diversity and abundance of flora and fauna that make up the food resources and habitat structure for all 'at-risk' vertebrate species.

CLASS	Common Name	Scientific name
AMPHIBIA	southern bell frog	*Litoria raniformis*
AMPHIBIA	long-thumbed frog	*Limnodynastes fletcheri*
AVES	white-bellied sea-eagle	*Haliaeetus leucogaster*
AVES	yellow-billed spoonbill	*Platalea flavipes*
AVES	Australasian bittern	*Botaurus poiciloptilus*
AVES	Baillon's crake	*Porzana pusilla*
AVES	spotless crake	*Porzana tabuensis*
AVES	musk duck	*Biziura lobata*
AVES	regent parrot	*Polytelis anthopeplus*
AVES	Australian spotted crake	*Porzana fluminea*
AVES	black-fronted dotterel	*Elseyornis melanops*
AVES	nankeen night-heron	*Nycticorax caledonicus*
AVES	blue-billed duck	*Oxyura australis*
MAMMALIA	common brushtail possum	*Trichosurus vulpecula*
MAMMALIA	Giles' planigale (paucident planigale)	*Planigale gilesi*
MAMMALIA	southern myotis	*Myotis macropus*
MAMMALIA	eastern water rat	*Hydromys chrysogaster*
OSTEICHTHYES	freshwater catfish	*Tandanus tandanus*
OSTEICHTHYES	Murray cod	*Maccullochella peelii*
OSTEICHTHYES	purple-spotted gudgeon	*Mogurnda adspersa*
OSTEICHTHYES	Murray hardyhead	*Craterocephalus fluviatilis*
OSTEICHTHYES	short-headed lamprey	*Mordacia mordax*
OSTEICHTHYES	estuary perch	*Maquaria colonorum*
OSTEICHTHYES	golden perch	*Macquaria ambigua ambigua*
OSTEICHTHYES	silver perch	*Bidyanus bidyanus*
OSTEICHTHYES	common galaxis	*Galaxias maculatus*
OSTEICHTHYES	dwarf flathead gudgeon	*Philypnodon macrostomus*
OSTEICHTHYES	crimson-spotted rainbow fish	*Melanotaenia fluviatilis*
REPTILIA	broad-shelled turtle	*Chelodina expansa*
REPTILIA	common long-necked turtle	*Chelodina longicollis*
REPTILIA	Murray short-necked turtle	*Emydura macquarii*
REPTILIA	carpet python	*Morelia spilota*
REPTILIA	eastern tiger snake	*Notechis scutatus*
REPTILIA	red-bellied black snake	*Pseudechis porphyriacus*
REPTILIA	eastern water skink	*Eulamprus quoyii*
REPTILIA	lace monitor	*Varanus varius*
REPTILIA	southern water skink	*Eulamprus tympanum*

Table 25 Fauna species identified as most 'at-risk' of vulnerability to Climate Change.

From a wetland management perspective, the main goal of this project was to prioritise wetlands for management based on the diversity of these 'at-risk' species present in certain areas. It is presumed that these priority wetlands possess habitat attributes that are required or desirable to these species and should be managed appropriately so they can be maintained through changing climatic conditions.

A species was identified as 'present' at a location if it had a record within the BDBSA and proximity statistics were performed at both the wetland and KEA scale. It is recommended that management decisions are made at the broader KEA scale, allowing for buffering where survey effort misrepresents actual usage of wetlands and to increase data capture such as where a species may regularly move around at a smaller neighbourhood scale. It is recommended that KEA areas are prioritised for management as per the list in Table 24, and those considered highest priority, with records of 10 or more 'at-risk'species, are presented here.

Key Environmental Asset (KEA)
Riverland Ramsar
Gurra Floodplain
Katarapko Floodplain
Loch Luna and Wachtels Lagoon
Pompoota/Paiwalla/Sunnyside
Morgan East & Morgan CP
Martins Bend
Mobilong Swamp incl. Rocky Gully
Hart Lagoon
Reedy Creek Mannum
Spectacle Lakes / Beldora Complex
Loveday Swamps and Mussel Lagoons
Nigra/Schillers
Moorundie Complex
Mypolonga/Toora Levee/Jury Swamp
Paringa Paddock
Riverglades

Funding and resources, in particular access to environmental water, will be the limiting factors that determine how many of the priority KEAs can be managed. Within KEAs where there are several individual wetland units, prioritisation for management should occur as per the individual wetland priority ranking (Table 23) or 'cluster' management e.g. alternate environmental watering as resources become available.

Project limitations and recommendations for future work:

- The risk assessment process used to identify vulnerable species is reliant on the extent, applicability and interpretation of species research and availability of local population information. For many species, research is limited. The expert consultation process for each taxonomic group to review the final assessments improved robustness of the process and confidence in the results. However, to increase robustness of the assessment method, weighting of individual criteria could be considered. Each criterion currently has an equal weighting in its contribution to the final vulnerability rating, but in reality the influence of each criterion on the vulnerability of a species to climate change is likely to be highly variable.

- Due to project time limitations only the presence of vulnerable vertebrate fauna was used to identify priority wetlands for management. This needs to be taken into consideration when using this data to make management decisions, e.g. the presence of potentially vulnerable vegetation species and communities and invertebrate fauna should also be acknowledged.

- Data used to calculate the proximity statistics was restricted to that available within the Biodiversity Database of South Australia (BDBSA) (plus some additional fish data sources). The BDBSA is considered the most comprehensive data source in South Australia but does not include all known fauna survey data (e.g. SA MDB NRM board and DFW data). It is unknown to what extent the addition of this data would change the priority listing of wetlands for management but management decisions should be made with this knowledge, and it is recommended that future work includes the downloading of all known data to the BDBSA and the re-calculation of proximity statistics.

- The importance of a wetland to a particular species may be ascertained by the frequency of occurrence or abundance of that species at a site. In this study, presence or absence of a species was inferred by the occurrence of any record between 1990 & 2010 and this limitation should be acknowledged when using the proximity analyses to determine priority wetlands for management.

- When management decisions are based on the known distribution of vulnerable species all efforts should be made to ensure distribution and abundance records are accurate. A correlation is expected between survey effort and the number of 'at-risk' species recorded at a wetland site. A twenty year data capture period (1990-2010) was thought adequate for this project however during this period only one major flood occurred in 1993. This may have been the only opportunity over this 20 year period to capture records of many species reliant on flooding and to determine the value of habitat within the study region to these species, at a point in time when their numbers were highest and detection rate greatest. In between floods their presence is likely to be highly localised or they may migrate out of the study region and not be detected during limited survey events. The extent of survey effort during the 1993 flood event is unknown. Baseline surveys were undertaken in 2003-07 at many wetlands within the SA MDB floodplain. This was during a period of low River Murray levels and consequently a low diversity and abundance of most fauna species was reported. It is highly recommended that during the 2010-11 flood event, in particular during the spring/summer period of 2011-12, there is increased survey effort of fauna populations from all taxonomic groups to more accurately inform the future management of wetlands under predicted climate change scenarios.

References

ACT Government, 2003. Silver perch (Bidyanus bidyanus)—an endangered species. Action Plan No. 26. Environment ACT, Canberra. [Online]. Available: http://www.tams.act.gov.au/__data/assets/word_doc/0008/154619/silverperchactionplan.doc. Accessed Mon, 5 Jul 2010.

Amey, A.P. & Grigg, G.C. 1995. Lipid-reduced evaporative water loss in two arboreal hylid frogs. *Comp. Biochem. Physiol*. 111a(2): 283-291.

Anderson J., Law, B. and Tidemann, C. 2006. Stream use by the large-footed myotis *Myotis macropus* in relation to environmental variables in northern New South Wales. *Australian Mammalogy* 28: 15-26.

ANRA. 2010b. Summary report including the physical characteristics of the bioregion, a species list, and summary statistics. Australian Natural Resources Atlas. [Online]. Available from: http://www.anra.gov.au/topics/vegetation/pubs/tables/birds_mdd.xls. Accessed Tue, 9 Nov 2010.

Barker, J., Grigg, G. and Tyler, M. 1995. 'A Field Guide to Australian Frogs.' (Surrey Beatty & Sons: Chipping Norton, NSW.)

Bice , C. 2010. Literature review of the ecology of fishes of the Lower Murray, Lower Lakes and Coorong. Report to the South Australian Department for Environment and Heritage. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 81 pp. SARDI Publication No. F2010/000031-1

Blacket, M. J., Kemper, C. and Brandle, R.C. 2008. Planigales (Marsupialia: Dasyuridae) of eastern Australia's interior: a comparison of morphology, distributions and habitat preferences, with particular emphasis on South Australia. *Australian Journal of Zoology* 56: 195–205.

Booth, D. 2002. The breaking of diapause in embryonic broad-shelled river turtles Chelodina expansa. Journal of *Herpetology* 36: 304-307.

Bowen, K. D., Spencer R. J. & Janzen F. J. 2005. A comparative study of environmental factors that affect nesting in Australian and North American freshwater turtles. *Journal of Zoology* 267: 397-404.

Briggs, S.V. 1996. Native Small Mammals and Reptiles in Cropped and Uncropped Parts of Lakebeds in Semi-arid Australia. *Wildlife Research* 23: 629-36.

Briggs, S. V., and Thornton, S. A. 1999. Management of water regimes in River Red Gum *Eucalyptus camaldulensis* wetlands for waterbird breeding. *Australian Zoologist* 31:187-197.

S.V. Briggs, J.A. Seddon and S.A. Thornton 2000. Wildlife in dry lake and associated habitats in western New South Wales, *Rangel. J.* 22(2): 256-71.

Campbell, S. 2009. So long as it's near water: variable roosting behavior of the large-footed myotis (Myotis macropus) *Australian Journal of Zoology 57*: 89–98

Campbell, S., Guay, P.-J., Mitrovski, P. J. and Mulder, R. 2009. Genetic differentiation among populations of a specialist fishing bat suggests lack of suitable habitat connectivity. *Biological Conservation* 142: 2657–2664.

Campbell, S., Coulson, G. and Lumsden, L.F. 2010. Divergent microclimates in artificial and natural roosts of the large-footed myotis (*Myotis macropus*). *Acta Chiropterologica* 12(1): 173–185.

Carey, C. & Alexander, M. A. 2009. 'Climate change and amphibian declines: is there a link?'. *Diversity and Distributions*. 9: 111-121.

Carthew, S. & Reardon, T. 2009. Mammals In: J. T. Jennings (ed.) Natural History of the Riverland and Murrylands, Royal Society of South Australia Inc.

Chessman, B.C. 1983, Observations on the diet of the Broad-Shelled Turtle, Chelodina expansa (Testudines: Chelidae), *Australian Wildlife Research* 10: 169-172.

Chessman, B. C. 1984a. Evaporative water loss from three south-eastern Australian species of freshwater turtles. *Australian Journal of Zoology* 32: 649-655.

Chessman, B. C. 1984b. Food of the snake-necked turtle, Chelodina longicollis (Shaw) (Testudines: Chelidae) in the Murray Valley, Victoria and New South Wales. *Aust. Wildl. Res.* 11:573-8.

Chessman, B. C. 1986. Diet of the Murray turtle, Emydura macquarii (Gray) (Testudines: Chelidae). *Aust. Wildl. Res.* 13: 65-9.

Chessman, B. C. 1988a. Habitat preferences of freshwater turtles in the Murray Valley, Victoria and New South Wales. *Australian Wildlife Research*. 15: 485-491.

Chessman, B. 1988b. Seasonal and diel activity of freshwater turtles in the Murray Valley, Victoria and New South Wales. *Australian Wildlife Research* 15: 267-276.

Clemann, N. & Gillespie, G.R. 2010. National Recovery Plan for the Growling Grass Frog Litoria raniformis. Department of Sustainability and Environment, Melbourne.

Chinathamby, K., Reina, R. D., Bailey, P. C. E. & Lees, B. K. 2006. Effects of salinity on the survival, growth and development of tadpoles of the brown tree frog, *Litoria ewingi. Australian Journal of Zoology 54*: 97–105.

Cogger, H.G. (2000). 'Reptiles and Amphibians of Australia.' Sixth Edition. (Ed. P. Hutton.) (Reed New Holland, an imprint of New Holland Publishers (Australia) Pty Ltd: Sydney.)

Cowan, P. E., Brockie, R. E., Smith, R. N., and Hearfield, M. E. 1997. Dispersal of juvenile brushtail possums, Trichosurus vulpecula, after a control operation. *Wildlife Research* 24: 279–288.

Cowan, P.E. 2001. Responses of common brushtail possums (Trichosurus vulpecula) to translocation on farmland, southern North Island, New Zealand. *Wildlife Research* 28: 277–282

CSIRO 2007. Climate Change in Australia. CSIRO, Canberra.

CSIRO 2008. Water Availability in the Murray — Summary of a report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project

Cogger, H.G., Cameron, E.E., Sadlier R.A. & Eggler P. 1993. 'The Action Plan for Australian Reptiles'. Australian Nature Conservation Agency. Canberra, ACT.[Online]. Available: http://www.environment.gov.au/biodiversity/threatened/action/reptiles/index.html. Accessed Mon, 20 Sep 2010 12:36:48 +1000.

DEHWA. 2010d. Craterocephalus fluviatilis in Species Profile and Threats Database, Department of the Environment, Water, Heritage and the Arts, Canberra. [Online].

DENR unpublished data. Department of Environment and Natural Resources wetland monitoring data. DENR Murraylands Floodplain and Wetland Program.

Dennis, T.E & Baxter, C. I. 2006. 'The Status of the White-bellied Sea-eagle and Osprey on Kangaroo Island in 2005'. South Australian Ornithologist. Vol. (1, 2) 35: 47-51.

Denny, M. J. S. 1975. Mammals of Sturt National Park, Tiboobuma, New South Wales. Aust. Zool.18: 179-95.

Dwyer, P.D. 1970 Social organisation in the bat *Myotis adversus*. *Science* 168: 1006–1008.

Ecological Associates 2010. Literature review of the ecology of birds of The Coorong, Lakes Alexandrina and Albert Ramsar wetlands. Ecological Associates report CC-014-1-D prepared for Department for Environment and Heritage, Adelaide.

Ercolano, E. [unpublished report], Aquatic & terrestrial habitat use of the Australian freshwater turtle, *Chelodina expansa* (SIT study abroad student project).

Evans, M.C. 1992. Diet of the brushtail possum Trichosurus vulpecula (Marsupialia: Phalangeridae) in central Australia. *Australian Mammalogy* 15: 25-30.

Faulks, L. K., Gilligan, D. M. & Beheregaray, L. B. 2008. 'Phylogeography of a threatened freshwater fish (*Mogurnda adspersa*) in eastern Australia: conservation implications.' *Marine and Freshwater Research*. 59: 89–96.

Foulkes, J. 2001. The ecology and management of the common brushtail possum Trichosurus vulpecula in Central Australia. University of Canberra, Canberra -PhD thesis University of Canberra.

Foulkes J.N. and Kerle J.A. 1991. Feasibility study for the reintroduction of the brushtail possum to Uluru National Park Phase III. Final report to ANPWS, Canberra.

Garnett, S. T., & Crowley, G. M. 2000. The Action Plan for Australian Birds 2000. Birds Australia Environment Australia, ISBN 0 6425 4683 5. [Online]. Available from: http://www.environment.gov.au/biodiversity/threatened/publications/action/birds2000/recovery.html. Accessed Mon, 5 Jul 2010.

Georges, A. 1993. Setting conservation priorities for Australian freshwater turtles. In: *Herpetology in Australia: a diverse discipline* (Eds. D. Lunney and D. Ayers.) pp. 49-58. (Royal Zoological Society of New South Wales: Mossman.)

Gillam, S. and Urban, R. 2010. *Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Murraylands Region*. Department of Environment and Natural Resources, South Australia.

Goode, J. & Russell, J. 1968. Incubation of eggs of three species of chelid turtles and notes on their embryological development. *Australian Journal of Zoology* 16: 749-61.

Greer, A. 1997. *The biology and evolution of Australian snakes*. 1st Ed. Norton, NSW. Surrey Beatty & Sons Pty. Ltd.

Greer, A.E. 2003. Encyclopedia of Australian Reptiles. Australian Museum Online http://www.amonline.net.au/herpetology/research/encyclopedia.pdf Version date: 25 May 2004.

Halse, S. A., Williams, M. R., Jaensch, R. P., and Lane, J. A. K. 1993. Wetlands characteristics and waterbird use of wetlands in south-western Australia. *Wildlife Research* 20:103-126.

Hammer, M. Wedderburn, S. & van Weenen, J. 2009. Action Plan for South Australian Freshwater Fishes. Report to the South Australian Department for Environment and Heritage. Native Fish Australia (SA) Inc., Adelaide. ISBN978-0-9806503-7-2

Hammer, M. P., Adams, M., Unmack, P. J. & Walker, K. F. 2007. 'A rethink on Retropinna: conservation implications of new taxa and significant genetic sub-structure in Australian smelts (Pisces : Retropinnidae)'. *Marine and Freshwater Research.* 58: 327–341.

Harper, M.J. 1990. Waterbird Dynamics at Bool Lagoon, South Australia, 1983-87. *Australian Wildlife Research*. 17: 113-22

Healy, M., Thompson, D. & Robertson, A. 1997. Amphibian communities associated with billabong habitats on the Murrumbidgee floodplain Australia. *Australian Journal of Ecology.* 22: 270-278.

Higgins, P. J. (Eds.) 1999. 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 4. Parrots to Dollarbird'. Oxford University Press, Melbourne.

Hutchison, M, Butcher, A, Kirkwood, J, Mayer, D, Chikott, K & Backhouse, S. Mesoscale 2008. *Movements of small and medium-sized fish in the Murray-Darling Basin.* MDBC Publication No. 41/08. ISBN 978 1 921257 81 0.

Kennett, R. M. and Georges, A. 1990. Habitat utilization and its relationship to growth and reproduction of the eastern long-necked turtle, Chelodina longicollis (Testudianta: Chelidae), from Australia, *Herpetologica* 46: 22-33.

Kerle,J.A., Foulkes, J.N.,Kimber, R.G. and Papenfus, D. 1992. The Decline of the brushtail possum, *Trichosrus vulpecula* (Kerr 1798), in arid Australia. *Rangel. J.* 14(2): 107-27.

Kerle, J.A. 2001. Possums: the brushtails, ringtails and greater gliders. University of New South Wales Press, Sydney

Kerle, J.A. & How, R.A. 2008. Common Brushtail Possum, Trichosurus vulpecula. In: S. Van Dyck and R. Strahan (eds.), The mammals of Australia. Third Edition, pp. PP. Reed New Holland, Sydney, Australia.

Lauck, B,. Swain, R. & Barmuta, L. 2005. Breeding site characteristics regulating life history traits of the brown tree frog, *Litoria ewingi*. *Hydrobiologia* 537: 135–146

Law, B. and Anderson, J. 1999. A survey for the Southern Myotis, *Myotis macropus* (Vespertilionidae) and other bat species in River Red Gum *Eucalyptus camaldulensis* forests of the Murray River, New South Wales. *Australian Zoologist* 31(1): 166-174

Law B and Urquhart CA, 2000. Diet of the large-footed myotis Myotis macropus at a forest stream roost in northern New South Wales. *Australian Mammalogy* 22: 121-124.

Law, B., Chidel, M. and Towerton, A. 2001. A maternity roost of the Southern Myotis *Myotis macropus* in a rural landscape. *The Australasian Bat Society Newsletter. 17:* 13-15.

Le Mar, K. and McArthur, C. 2005. Habitat selection by common brushtail possums in a patchy eucalypt-forestry environment. *Australian Mammalogy* 27: 119-127.

Legler, J.M. 1978. Observations on behaviour and ecology in an Australian turtle, *Chelodina expansa* (Testudines: Chelidae). Canadian Journal of Zoology 56: 2449-2453.

Lintermans, M. 2007, *Fishes of the Murray-Darling Basin: An introductory guide*. MDBC Publication No. 10/07. ISBN 1 921257 20 2

McNally , J. 1960. 'The biology of the water rat, *Hydromys chrysogaster* Geoffroy (Muridae: Hydromyinae) in Victoria, *Australian Journal of Zoology* 8: 170-180.

Mac Nally, R., Horrocks, G., Lada, H., Lake, P.S., Thomson, J.R. and Taylor, A.C. 2009. Distribution of anuran amphibians in massively altered landscapes in south-eastern Australia: effects of climate change in an aridifying region. *Global Ecology and Biogeography* 18: 575-585.

McCarraher, D.B. 1979. 'Estuary perch. Fisheries and Wildlife Division, Victoria'. Freshwater Fish Newsetters. Vol. 9: 15-20.
Marchant, S., and Higgins, P. J. (Eds.) 1990b. 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 1. Rarities to Ducks. Part B Australian Pelican to Ducks'. Oxford University Press, Melbourne.

Marchant, S., and Higgins, P. J. (Eds.) 1990a. 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 1. Rarities to Ducks. Part A Rarities to Pectrals'. Oxford University Press, Melbourne.

Marchant, S., and Higgins, P. J. (Eds.) 1993. 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 2. Raptors to Lapwings'. Oxford University Press, Melbourne.

Meathrel, C. E., Suter, P. J. & Radford, N. M. 2002. Niche segregation between three species of freshwater turtle in a large billabong during flood. *Victorian Naturalist* 119:160-173.

Michael, D. & Lindenmayer, D. 2010. *Reptiles of the NSW Murray catchment. A guide to their identification, ecology and conservation*. 1st Ed. CSIRO Publishing, Collingwood, Victoria.

Miles, M. & Gonzalez, D. 2010. Impacts of Climate Change: Report on Data Preparation and analysis for the SA MDB NRM Board. A report prepared for the SA MDB NRM Board (contact: Matthew.Miles@sa.gov.au)

Muller, K. L. 2010. *Ecological Risk Assessment for the Barrages EIS: Work guidelines and templates.* Prepared for Department of Environment and Heritage, Adelaide, South Australia. KMNRM Publication 270510.

Munks, S. A., Corkrey, R. and Foley, W.J. 1996. Characteristics of Arboreal Marsupial Habitat in the Semi-arid Woodlands of Northern Queensland, *Wildlife Research* 23: 185-95

Olsen, P. & Weston, M. (Eds.) 2004. 'The State of Australia's Birds 2004: Water, wetlands and birds'. Supplement to Wingspan. Vol. 14 (4) December 2004. Birds Australia.

Olsen, P.D. 1982. 'Reproductive biology and development of the water rat, Hydromys chrysogaster in captivity', *Australian Wildlife Research* 9: 39-53.

Olsen, P.D. 2008. Water Rat, *Hydromys chrysogaster* In: S. Van Dyck and R. Strahan (eds.), The mammals of Australia. Third Edition. Reed New Holland, Sydney, Australia.

Papenfus, D. 1990. Is the common brushtail possum still common in South Australia? Unpublished Thesis, B.Appl.Sc, SACAE, Salisbury S.A.

Ralph, T.J., Spencer, J.A. & Rayner, T.S. 2010. Fish In: Rogers, K. & Ralph, T.J. (eds.) Floodplain Wetland Biota in The Murray-Darling Basin: Water and Habitat Requirements. Pp. 205-251. CSIRO Publishing, Collingwood, Victoria.

Ramsey, D., Efford, M., Cowan, P. and Coleman, J. 2002. Factors influencing annual variation in breeding by common brushtail possums (Trichosurus vulpecula) in New Zealand. *Wildlife Research*29: 39–50.

Read, D. G. 1984. Movements and Home Ranges of Three Sympatric Dasyurids, Sminthopsis crassicaudata, Planigale gilesi and P. tenuirostris (Marsupialia), in Semiarid Western New South Wales. *Australian Wildlife Research* 11: 223-34.

Read, D. G. 1987. Habitat Use by Sminthopsis crassicaudata, Planigale gilesi and P. tenuirostvis (Marsupialia : Dasyuridae) in Semiarid New South Wales. *Australian Wildlife Research* 14: 385-95.

Read, D. G. 2008. Giles' planigale, Planigale gilesi. In: S. Van Dyck and R. Strahan (eds.), The mammals of Australia. Third Edition, pp. 107-109. Reed New Holland, Sydney, Australia.

Reynolds, L.F. 1983. 'Migration patterns of five fish species in the Murray-Darling River system'. *Australian Journal of Marine and Freshwater Research*. 34: 857-871.

Richards, G.C 2008 Southern Myotis, *Myotis macropus*. In: S. Van Dyck and R. Strahan (eds), The mammals of Australia. Third Edition. Reed New Holland, Sydney, Australia.

SAAB. 2001. South Australian Aquatic Biota Database. South Australian Department for Water Resources, 2001.

SA MDB NRM unpublished data. South Australian Murray Darling Basin Natural Resources Management Board wetland monitoring data. Aquatic Biodiversity, SAMDBNRM Board.

Schultz, M.A. (2006) Distribution and Detectability of the Golden Bell Frog Litoria raniformis in the South Australian River Murray Corridor: Implications for Conservation and Management. Department for Environment and Heritage Adelaide, South Australia. Report to South Australian Murray Darling Basin Natural Resources Management Board.

Schultz, M.A. 2007.Response of the Golden Bell Frog Litoria raniformis to Environmental Watering Programs on the Chowilla Floodplain, Department for Environment and Heritage, Murraylands Region. Report prepared for the Department of Water Land Biodiversity and Conservation.

Scott, A. & Grant, T. 1997. Impacts of water management in the Murray-Darling Basin on the Platypus (Ornithorhynchus anainus) and the water rat *(Hydromys chrysogaster*), Technical Report 23/97, CSIRO Land and Water, CSIRO Australia.

Smith, B.B., Conallin, A. & Vilizzi. 2009. 'Regional patterns in the distribution, diversity and relative abundance of wetland fishes of the River Murray, South Australia'. *Transactions of the Royal Society of South Australia* 33(2): 339–360

Smith, M.L., Schreiber, E.S.G., Scroggie, M.G., Kohout, M., Ough, K., Potts, J., Lennie, R., Turnbull, D., Jin, C. & Clancy, T. 2007. Associations between anuran tadpoles and salinity in a landscape mosaic of wetlands impacted by secondary salinisation, *Freshwater Biology* 52: 75–84.

Spencer, R. J. 2002. Growth patterns of two widely distributed freshwater turtles and a comparison of common methods used to estimate age. *Australian Journal of Zoology* 50:477-490.

Spencer, R.J. & Thompson, M.B. 2005. 'Experimental Analysis of the Impact of Foxes on Freshwater Turtle Populations'. *Conservation Biology* 19(3): 845-854.

Squires, Z.E., Bailey, P.C.E., Reina, R.D. & Wong, B.B.M. 2008. Environmental deterioration increases tadpole vulnerability to predation. *Biology Letters* 4: 392-394.

Statham, M. and Statham, H. L. 1997. Movements and habits of brushtail possums (Trichosurus vulpecula Kerr) in an urban area. *Wildlife Research* 24: 715-726.

Stow, A. J., Minarovic, N., Eymann, J., Cooper, D. W. and Webley, L. S. (2006). Genetic structure infers generally high philopatry and male-biased dispersal of brushtail possums (*Trichosurus vulpecula*) in urban Australia. *Wildlife Research* 33: 409–415.

Sullivan, R. 2007. 'The secret life of water rats', ABC, http://www.abc.net.au/science/articles/2007/10/04/2185999.htm

Swan, M. & Watharow, S. 2005. *Snakes, lizards and frogs of the Victorian Mallee*. 1st Ed. Collingwood, Victoria. CSIRO Publishing.

Thompson, M. B. 1993. Hypothetical considerations of the biomass of chelid turtles in the River Murray and the possible influences of predation by introduced foxes. Pp 219-224. In: *Herpetology in Australia: a diverse discipline*. (Eds. D. Lunney and D. Ayers.) (Royal Zoological Society of New South Wales: Mossman)

Tyler, M.J. 1977. Frogs of South Australia. (2nd ed). South Australian Museum, Adelaide.

Tyler, M.J. 1994. *Australian Frogs: A Natural History*. Reed New Holland Publishers (Australia) Pty Ltd: Sydney.

Tyler, M.J. 1994. Climate change and its implications for the amphibian fauna. *Transactions of the Royal Society of South Australia*. 118(1): 53-57.

Walker, S.J., Hill, B.M. and Goonan, P.M. 1999. 'Frog Census 1998. A report on community monitoring of water quality and habitat condition in South Australia using frogs as indicators.' (Environment Protection Agency: Adelaide.)

Walker, K. F., 2010. A Method to Assess the Vulnerability to Climate Change of Regional Fauna and Flora. Report prepared for the SAMDB NRM Board.

Warburg, M.R. 1965. Studies on the water economy of some Australian frogs. *Australian Journal of Zoology* 13: 317-30

Warnecke, L., Cooper, C.E., Geiser, F. and Withers, P.C. 2010. Environmental physiology of a small marsupial inhabiting arid floodplains, *Comparative Biochemistry and Physiology, Part A.* 157: 73–78.

Wassens, S., Watts, R. J., Jansen, A. & Roshier, D. 2008a. Movement patterns of southern bell frogs (*Litoria raniformis*) in response to flooding. *Wildlife Research* 35: 50 - 58.

Wassens, S., Arnaiz, O., Healy, S., Watts, R. and Maguire, J. 2008b. Hydrological and habitat requirements to maintain viable southern bell frog (Litoria raniformis) populations on the Lowbidgee floodplain- Phase 1. Final Report DECC. Queanbeyan

Wassens, S. 2011. Frogs. In Rogers, K & Ralph, T.J. (eds), Floodplain Wetland Biota in the Murray-Darling Basin Water and Habitat Requirements, pp. 253-274. CSIRO Publishing, Collingwood, Australia.

Wassens, S. & Maher, M. (2010). River Regulation Influences The Composition and Distribution of Inland Frog Communities. *River Research & Applications.*

Watkins, D. 1993. 'A National Plan for Shorebird Conservation in Australia'. Australasian Wader Studies Group, Royal Australasian Ornithologists Union and World Wide Fund for Nature, RAOU Report No. 90s, Melbourne.

Woollard, P., Vestjens, J.M. and MacLean, L. 1978. The Ecology of the Eastern Water Rat *Hydromys chrysogaster* at Griffith, N.S.W.: Food and Feeding Habits, *Australian Wildlife Research* 5: 59-73.

Appendix 1: Fauna species assessed for 'vulnerability to Climate Change'

	CLASS	Common Name	Scientific name	EPBC (Threatened)	NPW 1972 (or FMA 2007)	International - Migratory Agreement/ IUCN.
1	AMPHIBIA	eastern banjo frog	*Limnodynastes dumerili*			
2	AMPHIBIA	brown toadlet	*Pseudophryne bibroni*			
3	AMPHIBIA	Southern brown tree frog	*Litoria ewingi*			
4	AMPHIBIA	burrowing frog	*Neobatrachus pictus*			
5	AMPHIBIA	common froglet	*Crinia signifera*			
6	AMPHIBIA	long-thumbed frog	*Limnodynastes fletcheri*			
7	AMPHIBIA	Murray Valley froglet	*Crinia parinsignifera*			
8	AMPHIBIA	Peron's tree frog	*Litoria peronii*			
9	AMPHIBIA	southern bell frog	*Litoria raniformis*	Vulnerable	Vulnerable	
10	AMPHIBIA	spotted marsh frog	*Limnodynastes tasmaniensis*			
11	AMPHIBIA	striped marsh frog	*Limnodynastes peronii*			
12	AMPHIBIA	Sudell's frog	*Neobatrachus sudelli*			
13	AVES	Australian shelduck	*Tadorna tadornoides*			
14	AVES	Australasian shoveler	*Anas rhynchotis*		Rare	
15	AVES	black swan	*Cygnus atratus*			
16	AVES	blue-billed duck	*Oxyura australis*		Rare	
17	AVES	chestnut teal	*Anas castanea*			
18	AVES	freckled duck	*Stictonetta naevosa*		Vulnerable	
19	AVES	musk duck	*Biziura lobata*		Rare	
20	AVES	hoary-headed grebe	*Poliocephalus poliocephalus*			
21	AVES	Australian spotted crake	*Porzana fluminea*			
22	AVES	Baillon's crake	*Porzana pusilla*			
23	AVES	buff-banded rail	*Gallirallus philippensis*			
24	AVES	Purple Swamphen	*Porphyrio porphyrio*			
25	AVES	spotless crake	*Porzana tabuensis*		Rare	
26	AVES	black-fronted dotterel	*Elseyornis melanops*			
27	AVES	black-winged stilt	*Himantopus himantopus*			
28	AVES	red-capped plover	*Charadrius ruficapillus*			
29	AVES	red-kneed dotterel	*Erythrogonys cinctus*			
30	AVES	great egret	*Ardea alba*			CAMBA/ JAMBA
31	AVES	Australian white ibis	*Threskiornis molucca*			
32	AVES	straw-necked ibis	*Threskiornis spinicollis*			
33	AVES	yellow-billed spoonbill	*Platalea flavipes*			
34	AVES	Australasian bittern	*Botaurus poiciloptilus*		Vulnerable	IUCN Red List (Endangered).
35	AVES	nankeen night-	*Nycticorax caledonicus*			

		heron				
36	AVES	darter	*Anhinga novaehollandiae*		Rare	
37	AVES	great cormorant	*Phalacrocorax carbo*			
38	AVES	little black cormorant	*Phalacrocorax sulcirostris*			
39	AVES	little pied cormorant	*Microcarbo melanoleucos*			
40	AVES	Swamp Harrier	*Circus approximans*			
41	AVES	white-bellied sea-eagle	*Haliaeetus leucogaster*		Endangered	CAMBA
42	AVES	Australian reed warbler	*Acrocephalus stentoreus*			BONN (A2H)
43	AVES	regent parrot	*Polytelis anthopeplus*	Vulnerable	Vulnerable	
44	AVES	yellow rosella	*Platycercus elegans flaveolus (NC)*			
45	MAMMALIA	common brushtail possum	*Trichosurus vulpecula*		Rare	
46	MAMMALIA	Giles' planigale (paucident planigale)	*Planigale gilesi*			
47	MAMMALIA	southern myotis	*Myotis macropus*		Endangered	
48	MAMMALIA	Eastern water-rat	*Hydromys chrysogaster*			
49	OSTEICHTHYES	Australian smelt	*Retropinna semoni*			
50	OSTEICHTHYES	bony herring	*Nematalosa erebi*			
51	OSTEICHTHYES	golden perch (callop)	*Macquaria ambigua ambigua*			
52	OSTEICHTHYES	common galaxis	*Galaxias maculatus*			
53	OSTEICHTHYES	crimson-spotted rainbow fish	*Melanotaenia fluviatilis*			
54	OSTEICHTHYES	dwarf flathead gudgeon	*Philypnodon macrostomus*			
55	OSTEICHTHYES	estuary perch	*Maquaria colonorum*	Endangered		
56	OSTEICHTHYES	flat-headed gudgeon	*Philypnodon grandiceps*			
57	OSTEICHTHYES	fly-specked hardyhead	*Craterocephalus stercusmuscarum fulvus*			
58	OSTEICHTHYES	freshwater catfish	*Tandanus tandanus*		Protected (FMA 2007)	
59	OSTEICHTHYES	lagoon goby	*Tasmanogobius lasti*			
60	OSTEICHTHYES	Murray cod	*Maccullochella peelii*	Vulnerable	Closed fishing'	
61	OSTEICHTHYES	Murray hardyhead	*Craterocephalus fluviatilis*	Vulnerable		
62	OSTEICHTHYES	purple -spotted gudgeon	*Mogurnda adspersa*		Protected (FMA 2007)	
63	OSTEICHTHYES	short-finned eel	*Anguilla australis*			
64	OSTEICHTHYES	short-headed lamprey	*Mordacia mordax*			
65	OSTEICHTHYES	silver perch	*Bidyanus bidyanus*		Protected (FMA 2007)	

66	OSTEICHTHYES	western carp gudgeon	*Hypseleotris* spp. *(complex)*			
67	REPTILIA	broad-shelled turtle	*Chelodina expansa*		Vulnerable	
68	REPTILIA	common long-necked turtle	*Chelodina longicollis*			
69	REPTILIA	Murray Short-necked turtle	*Emydura macquarii*		Vulnerable	
70	REPTILIA	carpet python	*Morelia spilota*		Rare	
71	REPTILIA	eastern tiger snake	*Notechis scutatus*			
72	REPTILIA	red-bellied black snake	*Pseudechis porphyriacus*			
73	REPTILIA	eastern water skink	*Eulamprus quoyii*			
74	REPTILIA	lace monitor	*Varanus varius*			
75	REPTILIA	southern water skink	*Eulamprus tympanum*		Rare	

CAMBA: China - Australia Migratory Bird Agreement

JAMBA: Japan - Australia Migratory Bird Agreement

BONN: Convention on the Conservation of Migratory Species of Wild Animals - (Bonn Convention)

ROKAMBA: Republic of Korea - Australia Migratory Bird Agreement

Appendix 2: Spatial accuracy of pre-1990 distribution records

	SA Freshwater Fish			Fauna			Flora		
Spatial Accuracy	Frequency	% Records	Cum. %	Frequency	% Records	Cum. %	Frequency	% Records	Cum. %
0-5m	0	0	0	658	23	23	1329	25	25
5-50m	0	0	0	1	0	23	0	0	25
51-100m	40	14	14	45	2	24	0	0	25
101-250m	0	0	14	28	1	25	80	1	26
251-500m	144	51	65	28	1	26	0	0	26
501-1000m	10	4	68	77	3	29	1332	25	51
1-10km	45	16	84	1638	56	85	977	18	69
11-30km	3	1	85	6	0	85	0	0	69
31-125km	0	0	85	24	1	86	5	0	69
>25km	2	1	86	5	0	86	79	1	71
<625km	0	0	86	0	0	86	0	0	71
Not Entered	40	14	100	413	14	100	1556	29	100
No. Records	284			2923			5358		

Spatial accuracy of pre 1990 biological records *within the study area* from BDBSA and SA Freshwater Fish databases. Highlighted values correspond to 1st half of data (>50 Cum. %). Data as at Oct 1, 2010

Appendix 3: Example of species vulnerability assessment (Great Egret)

Scientific Name:	*Ardea alba*	**Common Name:**	great egret	
Question		**Comments/ Reference**	**Confid**	**Vul Rating**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change. Seen transitioning from fresh/brackish/saline wetlands but not hypersaline as fish (main prey) drop out if salinity gets too high. More adaptable than yellow-billed spoonbill and sufficiently habitat generalist to be considered at moderate risk (P. Wainwright 2010, pers. comm.).	Inhabits great variety of wetlands particularly in the interior (Slater et al 2001). Inland use a variety of habitats, prefer permanent water bodies on flood plains, shallow or deep permanent lakes, either open or vegetated with shrubs or trees, semi-permanent swamps will tall emergent vegetation. Regularly uses saline habitats, estuaries and mudflats mainly in summer/autumn or drought refuges (Ecological Associates 2010). *Habitat generalist reduces threat level, some reliance on aquatic vegetation for foraging and critical for breeding, preference for permanent wetlands, species should be considered at moderate risk*	**H**	**M**
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Listed under Japanese Australian Migratory Bird Agreement (JAMBA) and Chinese Australian Migratory Bird Agreement (CAMBA). Dispersive, though some seasonal movements regular, possibly migratory and sometimes irruptive (suddenly) into NZ (Ecological Associates 2010). *As a migratory species with recorded irruptive movements to coasts in times of drought, the species shows the ability to relocate if conditions become unfavourable, as such the species should be considered at low risk*	**H**	**L**
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change? No quantified studies but observed to consume fish almost exclusively in Lower Lakes and Coorong but can adapt diet to area e.g. can take marine fish, so no significant competition for food. A large, aggressive wader unlikely to suffer major interspecific competition (P. Wainwright 2010, pers. comm.).	When nesting, other species occupying branches too close to nest are ejected by displacement (Marchant and Higgins 1990). Hunts aquatic animals, principally fish but also freshwater snails, shrimp, crayfish and frogs, insects, small birds and snakes. Decline in breeding in Lower Lakes possibly associated with carp introduction (Ecological Associates 2010). *Generalist diet and territorial nature around breeding sites means species is a good competitor, breeding habitat quality outside of study area possibly affected by carp but not quantified. Species should be conservatively considered at moderate risk*	**M**	**M**

Physiology	To what extent does ***survival*** limit the ability of the regional population of the species to tolerate climate change?	Broad habitat and diet requirements, ability to switch diets and use a variety of habitats for foraging, limited tolerance to acidity (Marchant and Higgins 1990). *Varied diet means unlikely to be limited through food availability, some reliance on habitat for foraging but is not specific and uses fresh to saline wetlands. Low tolerance to acidification may pose greatest threat in River Murray system. Species should be considered at moderate risk*	**H**	**M**
	To what extent does ***growth*** limit the ability of the regional population of the species to tolerate climate change?	No detailed knowledge of growth stage. Nestlings thought to be fed predominantly fish although not many studies, diet and habitat requirements of adults are broad and can switch according to availability. Time to independence around 64 days from hatching, parents feed young until then (Marchant and Higgins 1990). Never recorded with a brood in waters with a pH < 7 suggesting no tolerance of acidic waters (Ecological Associates 2010). *Relatively long time to independence increases risk to parent and young as parental investment is required for longer periods and the young spend more time as vulnerable juveniles. Acidification of some areas of River Murray wetlands is a risk under climate raising risk to successful growth and survival. The species should be considered at moderate risk*	**H**	**M**
	To what extent does ***reproduction*** limit the ability of the regional population of the species to tolerate climate change?	Never recorded with a brood in waters with a pH < 7 suggesting no tolerance of acidic waters. Breeding decline since 1970s possibly related to carp introductions (Ecological Associates 2010). Colonial nesting in trees and swamps, sometimes apart from other egrets but often near cormorant and night herons (Slater et al 2001). Nests in living river red gums (Leslie 2001) and responds to areas that are flooded for at least 4 months (Briggs et al 1997). Vegetation is critical for breeding (Kingsford and Norman 2002). Darling Riverine Plains and Riverina breeding populations may be declining due to reduced water flow to colony sites and predicted declines in catchment rainfall (DEHWA 2010c). *Acidification and salinisation threatens critical breeding riparian woodland habitat e.g. River Red Gums. This coupled with critical dependence on flooding and long term inundation of wetlands for breeding puts species at high risk*	**H**	**H**

Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change? <u>As a colonial nesting, migratory bird the gene pool will be large as mixing occurs through formation of large breeding colonies, this also translates to good gene flow and potential for genetic flexibility by providing generic sets of gene codes that have high diversity (P. Wainwright 2010, pers. comm.).</u>	IBRA sub-regionally listed as vulnerable and in probable decline in Murray Mallee and Murray Scroll Belt (Gillam and Urban 2010). However as a cosmopolitan species the available gene pool is potentially large. Global population roughly estimated at 60000, Australian population not estimated, unlikely genuine subpopulations exist due to broad range and high mobility of species (Jaensch 2003 as cited in DEHWA 2010). The species can disperse great distances (1000's km but more commonly 100's km) (McKilligan 2005) so breeding flocks may contain individuals from different populations thus lessening the chance of gene pool limitation. *Unlikely to be limited as global populations are moderate and species has high mobility and broad ranging capacity increasing the chances of mixing of diverse gene pool despite regional threat listings. Species should be considered at low risk*	**H**	**L**
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change? <u>As a colonial nesting, migratory bird the gene pool will be large as mixing occurs through formation of large breeding colonies, this also translates to good gene flow and potential for genetic flexibility by providing generic sets of gene codes that have high diversity (P. Wainwright 2010, pers. comm.).</u>	No specific studies. Banding studies reveal movement of significant distances (to NZ in winter (Warbuton 1957 as cited in Marchant and Higgins 1990) but mixing with other populations is not quantified. Appearance of several subspecies from NZ, Japan, India and China and intermediates (Marchant and Higgins 1990) suggests some degree of population mixing. *Dispersal and cosmopolitan subspeciation raises confidence of gene flow between populations. Gene pool is also likely to be very diverse due to this character so it follows that gene flow must also occur at large scales. Species should be considered at low risk*	**H**	**L**
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change? <u>As a colonial nesting, migratory bird the gene pool will be large as mixing occurs through formation of large breeding colonies, this also translates to good gene flow and potential for genetic flexibility by providing generic sets of gene codes that have high diversity (P. Wainwright 2010, pers. comm.).</u>	Geographic variation and subspeciation apparent between Australian, NZ, and Asian populations, several subspecies identified according to size and colour of bare parts (Marchant and Higgins 1990). *No indication of driving factor behind variations at global scale but could be associated with environmental factors as well as genetic drift. Populations in Australia likely to form one phenotypic clade but diverse potential gene pool and good gene flow (population mixing) negates detrimental effects of allopatric speciation as genetic base is so strong. Phenotypic plasticity may therefore not factor in limiting the species tolerance to climate change and may be considered at low risk*	**M**	**L**

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Cosmopolitan and generally plentiful with stronghold in northern Australia. In decline in Coorong and Lake Albert, variable in Murray Estuary and Lake Alexandrina (Ecological Associates 2010). Global population roughly estimated at 60000, Australian population not estimated, unlikely genuine subpopulation due to broad range and high mobility of species (Jaensch 2003 as cited in DEHWA 2010). 1545 records since 1990 within floodplain, majority (1298) in Lower Lakes, rest widely distributed across system (BDBSA 2010). Significant indicator species for Murray Estuary (Rodgers and Paton 2009). IBRA sub-regionally listed as vulnerable and in probable decline in Murray Mallee and Murray Scroll Belt (Gillam and Urban 2010). *The species is migratory and has widespread populations across Australia and appears concentrated in the Lower Lakes region in the SA MDB. Population size must be considered at the scale of the range of the species and so must include birds from all over Australia and possibly some from abroad. Population size is therefore not likely to be limiting and the species should be considered at low risk*	**H**	**L**
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Breeding season (from NSW studies) is from Nov to early May, in SA thought to be active in Nov. Clutch size generally between 2-6 eggs (frequently 3-4) incubated by both parents. Flood following drought thought to have triggered second brood in one event recorded in NSW (Marchant and Higgins 1990). *Potentially large clutch size and evidence of opportunistic breeding following flood event. Increased flow regulation to mitigate climate change effects may affect the timing and magnitude of such events to the detriment of the species unless carefully managed. Species should be considered at low risk*	**H**	**L**

	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Suggestion that immigration is not a mechanism for colony reformation. While egrets still breed in the forest, breeding numbers have generally declined by at least one order of magnitude, the number of traditional nest sites has declined and successful breeding has become increasingly less frequent and reliable. Reduced flood duration acting to decrease nest security and food availability during fledging is suggested as the main stress factor responsible for the population change (Leslie 2001). For egrets to initiate and complete breeding, and for their young to fledge, water needs to remain under nest trees for at least 5 and up to 10 months following flooding (Briggs and Thornton 1999). Breeding maturity age unknown. NSW studies have shown good success rate of fledglings, 91% of nests fledged an average of 2 chicks per successful breeding pair, in wet years the average was slightly higher (Marchant and Higgins 1990). *Recruitment appears limited to only what the population is able to brood, i.e. immigration from other populations is not likely. While species shows high breeding success rates in some regions this is associated with wet years and flooding. Loss of suitable nesting sites through altered flow regimes and reductions in flood frequency and magnitude under climate change is likely and is a major threat to recruitment. Species should be considered at high risk*	**H**	**H**

Appendix 4: Fish vulnerability & confidence ratings

	Vulnerability													Confidence												
	Ecology			Physiology			Genetics			Resilience				Ecology			Physiology			Genetics			Resilience			
	Habitat	Mobility/ Dispersal	Competition	Survival	Growth	Reproduction	Gene Pool	Gene Flow	Phenotypic Plasticity	Population Size	Reproductive Capacity	Recruitment	Vulnerability Coefficient	Habitat	Mobility/ Dispersal	Competition	Survival	Growth	Reproduction	Gene Pool	Gene Flow	Phenotypic Plasticity	Population Size	Reproductive Capacity	Recruitment	Confidence
FRESHWATER CATFISH (*Tandanus tandanus*)	H	L	H	H	H	H	H	H	H	H	H	H	0.94	H	M	M	H	H	H	H	H	H	H	H	H	94%
MURRAY COD (*Maccullochella peelii*)	H	H	H	H	H	H	H	H	M	H	M	H	0.94	H	H	H	H	H	H	H	M	L	H	M	H	89%
PURPLE-SPOTTED GUDGEON (*Mogurnda adspersa*)	H	M	H	M	H	M	H	H	H	H	H	H	0.92	H	M	M	H	H	H	H	H	H	H	H	H	94%
MURRAY HARDYHEAD (*Craterocephalus fluviatilis*)	M	M	H	M	H	M	H	H	H	H	H	H	0.89	H	L	M	H	H	H	H	H	L	H	H	H	86%
SHORT-HEADED LAMPREY (*Mordacia mordax*)	M	H	M	M	H	H	H	H	H	H	M	H	0.89	H	H	M	M	M	H	L	L	L	M	M	H	69%
ESTUARY PERCH (*Maquaria colonorum*)	H	H	H	L	M	H	H	H	H	H	L	H	0.86	M	H	H	M	M	H	H	H	M	H	H	H	89%
CALLOP (*Macquaria ambigua ambigua*)	M	H	M	M	M	H	H	H	H	H	L	H	0.83	H	M	M	H	H	H	H	H	H	H	H	H	94%
SILVER PERCH (*Bidyanus bidyanus*)	M	H	H	L	M	H	H	H	H	H	L	H	0.83	H	L	M	H	H	H	H	H	L	H	H	H	86%
COMMON GALAXIAS (*Galaxias maculatus*)	L	H	H	M	M	H	M	M	M	H	H	H	0.81	H	H	H	H	H	H	H	H	M	H	H	H	97%
DWARF FLATHEADED GUDGEON (*Philypnodon macrostomus*)	H	M	M	L	H	H	M	H	L	H	H	H	0.81	H	L	M	H	H	H	M	L	M	H	L	M	72%
CRIMSON-SPOTTED RAINBOW FISH (*Melanotaenia fluviatilis*)	H	M	H	M	H	H	M	L	M	M	H	M	0.78	H	H	H	H	M	H	H	H	L	H	H	H	92%
LAGOON GOBY (*Tasmanogobius lasti*)	L	H	M	L	L	M	H	H	L	H	H	M	0.69	H	M	M	H	H	L	H	M	M	H	L	L	72%
CARP GUDGEON (*Hypseleotris* spp. *complex*)	M	H	H	M	M	H	L	L	L	L	H	M	0.67	H	H	H	H	H	H	H	M	H	H	H	H	97%
FLYSPECKED HARDYHEAD (*Craterocephalus stercusmuscarum fulvus*)	H	M	H	L	M	M	L	L	M	L	H	M	0.64	H	M	H	H	L	L	H	H	H	M	H	M	81%
FLATHEADED GUDGEON (*Philypnodon grandiceps*)	M	H	M	L	M	M	L	L	M	L	H	M	0.61	H	H	H	H	H	H	H	H	H	H	H	H	92%
SHORT-FINNED EEL (*Anguilla australis*)	L	H	M	M	M	H	L	L	L	M	L	H	0.61	H	H	M	M	M	H	M	H	H	L	H	M	81%
AUSTRALIAN SMELT (*Retropinna semoni*)	L	M	M	L	L	L	L	H	H	L	H	M	0.58	H	M	M	H	H	H	H	H	H	H	H	H	94%
BONY BREAM (*Nematalosa erebi*)	L	H	M	M	H	H	L	L	M	L	L	L	0.58	H	L	M	H	H	H	H	H	M	H	H	H	89%

Appendix 5: Factors & variables influencing vulnerability assessments of fish species

FISH VULNERABILITY ASSESSMENT – INFUENTIAL FACTORS & VARIABLES		
	Question	**Major Factors/Variables Influencing Assessments**
Ecology	To what extent does ***habitat*** limit the ability of the regional population of the species to tolerate climate change?	SALINITY - Freshwater habitat specialists are most vulnerable; brackish water tolerance is an advantage but still may suffer some limitation; species tolerating fresh to saline/hypersaline conditions are unlikely to be limited. VEGETATION TYPE/STRUCTURE – Freshwater vegetation specialists will suffer; general vegetation requirements including snags and structures but liable to some degradation and limitation; no specific vegetation or structural requirements is unlikely to be limiting. WATER REGIME – Species requiring water level fluctuation/flow/flooding as part of essential habitat are more vulnerable.
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	GENERAL MOVEMEMENTS – Long distance movements e.g. 100kms up/down river as part of life cycle is likely to be highly limiting through increased dissconnection; short distances e.g. between main channel and wetlands may be limiting to some extent, sedentary/resident species are less likely to suffer limitations. MARINE/ESTUARY ACCESS – Strictly diadromous/anadromous species most likely to be highly limiting; diadromous/anadromous but can reproduce as landlocked populations e.g. using wetlands/tributaries likely to be limiting to some extent. LARVAL DISPERSION – Motile and well developed larvae are unlikely to be limiting as not reliant on flow for dispersal; planktonic/sessile larvae/ammocetes are likely to be limited as relies on flow/connection for effective dispersal.
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	INTRODUCED SPECIES INTERACTIONS– Native species known to be predated on, out-competed for food, displaced, or in any way negatively impacted by exotic species e.g. Redfin Perch, Carp, Mosquito Fish etc. are more vulnerable. DIET – Species with narrow diets e.g. exclusively piscivorous, are most likely to be limited through competition. DISEASE/PARASITES – Species with documented susceptibility to disease/parasites (particularly through exotic species and stressed environments) are more vulnerable. PREDATION – Species with documented high predation pressure as an egg, juvenile or adult from native or introduced species are more vulnerable. SIZE – Generally, larger species e.g. >500mm have competitive advantages over smaller species.
Physiology	To what extent does ***survival*** limit the ability of the regional population of the species to tolerate climate change?	TEMP/SALINITY TOLERANCES – Species with wide tolerances are less vulnerable; species that tolerate cold but not hot and fresh but not saline are more likely to be limited. DIET – Species with a narrow adult diet are more vulnerable as cannot switch food source if resources become scarce. OXYGEN LIMITATIONS – Species that tolerate hypoxic conditions e.g. <2mg/L, are less vulnerable. HYDRAULICS – Tolerance/preference of lentic conditions is an advantage, lotic requirements raise vulnerability.

	To what extent does ***growth*** limit the ability of the regional population of the species to tolerate climate change?	LARVAL/JUVENILE DEVELOPMENT – Rapid growth and development (typical of smaller species with a short life cycle) are less vulnerable. LARVAL/JUVENILE DIET – Species with a narrow diet in early life stages e.g. exclusively zooplankton, are more vulnerable than those with wide diets e.g. general planktivore/detritivore. TEMP/SALINITY TOLERNACES - Species with wide tolerances in early life stages are less vulnerable; species that tolerate cold but not hot and fresh but not saline are more likely to be limited. WATER REGIME – Species requiring water level fluctuation/flow/flooding in early life stages e.g. access/dispersal to appropriate feeding habitats and for food provision, are more vulnerable.
	To what extent does ***reproducti***on limit the ability of the regional population of the species to tolerate climate change?	BREEDING SITE – Species with specific requirements e.g. nest maintenance, submerged/emergent/riparian freshwater aquatic vegetation are more vulnerable; general site requirements e.g. non-specific vegetation/structure/snags are at some risk; those with pelagic/demersal randomly distributed eggs/larvae are unlikely to be limited. BREEDING WATER REGIME – Species requiring specific water regimes e.g. water level fluctuation/flow/flooding to trigger or complete breeding are more vulnerable. BREEDING SALINITY – Species breeding only in freshwater habitats are more vulnerable; brackish water breeding habitats may still be limiting; wide tolerances up to saline conditions is unlikely to be limiting. SPAWNING TEMPERATURE – Species with a narrow temperature requirement (e.g. >20°C) to trigger breeding are more likely to be affected through alterations in seasonal temperature regimes under climate change. TIMIING – Species with a short breeding season e.g. spring-summer, are more vulnerable than those with longer seasons e.g. winter-summer; species that breed opportunistically throughout the year are unlikely to be limited. EGG/LARVAL OXYGEN LIMITATIONS – Species with a low tolerance to low DO levels at egg and larval stages are more likely to be limited.
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	POPULATION BASE – Species with large effective populations are less vulnerable than rarer species as more likely to contain a varied genetic profile. DISTRIUTION – Species with widespread and contiguous distribution are less vulnerable than those with narrow or patchy distribution through an increased chance of mixing and sharing genetic information. SPAWNING MIGRATIONS – Species that undertake mass breeding migrations are less vulnerable than sedentary/resident species that do not breed in mass spawning events through an increased chance mixing between individuals from different populations.
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	POPULATION BASE – Species with large effective populations are less vulnerable than rarer species through an increased chance of mixing. DISTRIUTION – Species with widespread and contiguous distribution are less vulnerable than those with narrow or patchy distribution through an increased chance of mixing. SPAWNING MIGRATIONS – Species that undertake mass breeding migrations are less vulnerable than sedentary/resident species that do not breed in mass spawning events through an increased chance of flow between individuals from different populations.

	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	GEOGRAPHIC VARIATION – Species with an occurrence of more than one subspecies or mophological/genetic group within study area indicates clear geographic variation and are less vulnerable. POPULATION BASE – Species with large effective populations are less vulnerable than rarer species through an increased chance of a diverse gene pool and phenotypic expression. DISTRIUTION – Species with widespread and contiguous distribution throughout the study area are less likely to develop distinct phenotypes through more mixing/flow and are more vulnerable than those with narrow or patchy distribution where geographic variation may be more likely to occur through segregation. SPAWNING MIGRATIONS – Species that undertake mass breeding migrations are less likely to develop distinct phenotypes at the scale of the study area through more mixing/flow and are more vulnerable.
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	POPULATION SIZE – Species with large effective populations are less vulnerable than rarer species.
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	FECUNDITY – Species with high egg production e.g. 10000s-100000s, are more likely to be highly fecund than those with moderate (1000s-10000s) and low (100s-1000s) egg production.
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	TIME TO MATURITY – Species that reach sexual maturity earlier e.g. within their first year, are less vulnerable than those who take moderate time (2-3 years) and those who take even longer (>3 years). BREEDING FREQUENCY – Serial, protracted or repeat spawners are less vulnerable than those who spawn as a single event; species that only breed once (e.g. annual species and those who die after spawning) are highly vulnerable. POPULATION SIZE – Species with strong (abundant) effective populations are less vulnerable than rarer species. LIFESPAN – Species with a long lifespan e.g. >10 years are less vulnerable to recruitment fluctuations than those with moderate (5-10 years) and short (<5 years) lives and those that die after spawning.

Appendix 6: 'At-risk' fish-wetland associations

No. 'At-risk' Fish Species	AUS_WETNR	NAME	SAAE CLASSIFICATION
10	S0001997	RIVER MURRAY	Permanent Reach
6	S0000047	MOBILONG SWAMP	Permanent Reach
6	S0001486	ROCKY GULLY	Saline Swamp
6	S0001816	JURY SWAMP (JAENSCHS BEACH)	Permanent Swamp - Terminal Branch
5	S0001043	TAILEM BEND	Permanent Lake - Terminal Branch
5	S0001466	MURRUNDI (WELLINGTON NORTH)	Permanent Swamp - Throughflow
5	S0001811	MYPOLONGA LEVEE	Permanent Swamp - Throughflow
5	S0016022	RIVERGLADES	Permanent Swamp - Throughflow
4	S0000113	LAKE CARLET	Permanent Lake - Throughflow
4	S0000174	SWANPORT WETLAND	Permanent Swamp - Throughflow
4	S0000241	MUNDIC CREEK	Permanent Lake - Throughflow
4	S0000609	REEDY CREEK	Permanent Lake - Throughflow
4	S0000938	MUSSEL LAGOON	Permanent Lake - Terminal Branch
4	S0001182	MUNDIC CREEK	Temporary Wetland - Overbank Flow
4	S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch
4	S0001973	PILBY LAGOON	Permanent Swamp - Throughflow
4	S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch
4	S0002460	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
4	S0016023	REEDY CREEK	Permanent Lake - Throughflow
3	S0000093	CHOWILLA CREEK	Permanent Reach
3	S0000098	SLANEY WEIR BILLABONG	Temporary Wetland - Throughflow
3	S0000114	LAKE CARLET	Permanent Lake - Throughflow
3	S0000347	BERRI CAUSEWAY	Temporary Wetland - Throughflow
3	S0000355	MONOMAN CREEK	Permanent Reach
3	S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow
3	S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch
3	S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow
3	S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch
3	S0000932	BLACKFELLOWS CREEK	Permanent Reach
3	S0000933	YATCO LAGOON	Permanent Lake - Throughflow
3	S0000960	WOOLENOOK BEND COMPLEX	Permanent Swamp - Throughflow
3	S0001059	MURBKO SOUTH	Permanent Lake - Terminal Branch
3	S0001079	AJAX ACHILLIES LAKE	Permanent Lake - Throughflow
3	S0001122	CHOWILLA OXBOW	Temporary Wetland - Terminal Branch
3	S0001134	BOGGY FLAT	Permanent Lake - Throughflow
3	S0001166	MURTHO PARK COMPLEX	Permanent Swamp - Terminal Branch
3	S0001179	MURTHO PARK COMPLEX	Permanent Lake - Terminal Branch
3	S0001294	BIG HUNCHEE LITTLE HUNCHEE AND AMAZON CREEKS	Temporary Wetland - Overbank Flow
3	S0001445	GOAT ISLAND AND PARINGA PADDOCK	Permanent Lake - Terminal Branch

3	S0001584	MURBKO FLAT COMPLEX	Permanent Lake - Throughflow
3	S0001618	WERTA WERT	Temporary Wetland - Terminal Branch
3	S0001700	NIGRA CREEK	Permanent Reach
3	S0001736	SINCLAIR FLAT	Permanent Lake - Throughflow
3	S0001756	BLANCHETOWN CARAVAN PARK	Permanent Lake - Terminal Branch
3	S0001790	MAIDMENT LAGOON	Permanent Lake - Terminal Branch
3	S0001821	RIVERGLADES	Permanent Swamp - Throughflow
3	S0001822	UKEE BOAT CLUB	Permanent Swamp - Throughflow
2	S0000048	UPPER PIKE RIVER AND SNAKE CREEK	Permanent Swamp - Throughflow
2	S0000115	LAKE CARLET	Permanent Lake - Throughflow
2	S0000245	MUNDIC CREEK	Permanent Lake - Throughflow
2	S0000274	BERRI DISPOSAL BASIN COMPLEX	Saline Swamp
2	S0000283	ECKERT CREEK AND THE SPLASH	Permanent Swamp - Throughflow
2	S0000344	NELWOOD	Permanent Swamp - Terminal Branch
2	S0000366	PIPECLAY BILLABONG	Temporary Wetland - Terminal Branch
2	S0000386	HYPURNA CREEK	Permanent Reach
2	S0000644	LITTLE TOOLUNKA FLAT	Permanent Lake - Throughflow
2	S0000676	DEVON DOWNS NORTH	Permanent Lake - Throughflow
2	S0000684	MANNUM SWAMPS	Permanent Lake - Throughflow
2	S0000926	BELDORA WETLANDS	Permanent Lake - Terminal Branch
2	S0000961	WOOLENOOK BEND COMPLEX	Permanent Lake - Throughflow
2	S0001010	BLANCHETOWN FLAT	Temporary Wetland - Throughflow
2	S0001127	FORSTER LAGOON	Permanent Lake - Terminal Branch
2	S0001145	YOUNGHUSBAND WEST	Permanent Lake - Throughflow
2	S0001170	MURTHO PARK COMPLEX	Permanent Reach
2	S0001282	ECKERT CREEK AND THE SPLASH	Permanent Reach
2	S0001349	MARNE RIVER MOUTH	Temporary Wetland - Throughflow
2	S0001387	PARINGA ISLAND	Permanent Swamp - Throughflow
2	S0001399	PILBY CREEK	Permanent Swamp - Throughflow
2	S0001435	LOWER PIKE RIVER	Permanent Reach
2	S0001438	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch
2	S0001701	NIGRA CREEK	Permanent Reach
2	S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
2	S0001772	NORTH PURNONG	Permanent Lake - Terminal Branch
2	S0001800	LAKE CARLET	Temporary Wetland - Overbank Flow
1	S0000085	WALKER FLAT SOUTH	Permanent Swamp - Throughflow
1	S0000148	KATARAPKO CREEK AND KATARAPKO ISLAND	Permanent Reach
1	S0000290	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000467	WOOLENOOK BEND COMPLEX	Permanent Lake - Terminal Branch
1	S0000547	BRENDA PARK	Permanent Lake - Throughflow
1	S0000708		Temporary Wetland - Throughflow
1	S0000819	SALT CREEK AND GURRA GURRA LAKES	Ephemeral Reach
1	S0000970	MORGAN CONSERVATION	Permanent Lake - Throughflow

		PARK	
1	S0001058	LAKE BONNEY COMPLEX	Permanent Lake - Terminal Branch
1	S0001124	KROEHNS LANDING	Permanent Lake - Throughflow
1	S0001130	WALKER FLAT SOUTH LAGOON	Permanent Swamp - Terminal Branch
1	S0001160	DEVON DOWNS SOUTH	Permanent Reach
1	S0001161	DEVON DOWNS SOUTH	Permanent Lake - Throughflow
1	S0001165	MURTHO PARK COMPLEX	Ephemeral Reach
1	S0001168	MURTHO PARK COMPLEX	Permanent Reach
1	S0001178	MURTHO PARK COMPLEX	Permanent Reach
1	S0001186	MUNDIC CREEK	Permanent Swamp - Terminal Branch
1	S0001240	SCOTT CREEK	Permanent Reach
1	S0001391	PARINGA ISLAND	Permanent Swamp - Throughflow
1	S0001437	DISHER CREEK	Saline Swamp
1	S0001484	UPSTREAM OF RIVERGLADES	Temporary Wetland - Overbank Flow
1	S0001617	PILBY CREEK	Ephemeral Reach
1	S0001672	HART LAGOON	Permanent Lake - Terminal Branch
1	S0001754	ARLUNGA	Permanent Lake - Throughflow
1	S0001757	BLANCHETOWN CARAVAN PARK	Permanent Swamp - Throughflow
1	S0001758	EDSONS FLAT	Temporary Wetland - Terminal Branch
1	S0001803	GOWLINGS WETLAND (Younghusband)	Temporary Wetland - Terminal Branch
1	S0002461	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
1	S0002742	SALT CREEK AND GURRA GURRA LAKES	Temporary Wetland - Terminal Branch
1	S0002824	WOOLENOOK BEND COMPLEX	Permanent Reach
1	S0016008	BOGGY FLAT	Permanent Lake - Terminal Branch

Appendix 7: 'At-risk' fish-KEA associations

No. 'at-risk' fish species	KEA Asset Name	KEA ID
7	Mypolonga/Toora Levee/Jury Swamp	96
6	Mobilong Swamp incl. Rocky Gully	97
6	Riverland Ramsar	1
5	Gurra Floodplain	10
5	Murrundi	106
5	Riverglades	98
5	Tailem Bend	103
4	Lake Carlet	86
4	Loveday Swamps and Mussel Lagoons	22
4	Paisley Creek/Edsons Flat	65
4	Pike-Mundic	8
4	Pompoota/Paiwalla/Sunnyside	95
4	Reedy Creek Mannum	91
4	Swanport Wetland	101
3	Ajax Achilles	12
3	Boggy Flat	43
3	Coolcha Lagoon	85
3	Devon Downs Complex	73
3	Disher Creek	6
3	Katarapko Floodplain	17
3	Loch Luna and Wachtels Lagoon	23
3	Martins Bend	11
3	Murbko Flat Complex	57
3	Murbko South Complex	58
3	Nigra/Schillers	41
3	Paringa Paddock	4
3	Sinclair Flat	63
3	Ukee Boat Club	99
3	Wongulla Lagoon/Marne Mouth	76
3	Yatco Lagoon	19
2	Big and Little Toolunka	39
2	Brenda Park / Morphetts Flat Complex	55
2	Forster Lagoon	77
2	Mannum Swamps	90
2	Moorundie Complex	66
2	Morgan East & Morgan CP	54
2	North Purnong	80
2	Spectacle Lakes / Beldora Complex	21
2	Wellington Spit	105
2	Younghusband West	88
1	Hart Lagoon	37
1	Kroehns Landing	75
1	Mason Rock	102
1	Roonka/Arlunga	64
1	Walker Flat Complex	78
1	Younghusband Complex	87

Appendix 8: 'At-risk' reptile-wetland associations

No. 'at-risk' reptile species	AUS_WETNR	NAME	WET_TYPE
6	S0001997	RIVER MURRAY	Permanent Reach
3	S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow
3	S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
2	S0000347	BERRI CAUSEWAY	Temporary Wetland - Throughflow
2	S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch
2	S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow
2	S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch
2	S0000960	WOOLENOOK BEND COMPLEX	Permanent Swamp - Throughflow
2	S0001100	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
2	S0001283	WOMBAT REST BACKWATER	Permanent Lake - Throughflow
2	S0001309	OVERLAND CORNER COMPLEX	Temporary Wetland - Overbank Flow
2	S0001359	NEAR PUNKAH HORSESHOE LAGOONS	Ephemeral Reach
2	S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch
2	S0001700	NIGRA CREEK	Permanent Reach
1	S0000002	NGAK INDAU	Temporary Wetland - Terminal Branch
1	S0000034	NGAK INDAU INLET	Ephemeral Reach
1	S0000044	LAKE LITTRA INLET	Ephemeral Reach
1	S0000098	SLANEY WEIR BILLABONG	Temporary Wetland - Throughflow
1	S0000148	KATARAPKO CREEK AND KATARAPKO ISLAND	Permanent Reach
1	S0000263	COBDOGLA BASIN	Saline Swamp
1	S0000266	WACHTELS LAGOON	Permanent Lake - Throughflow
1	S0000274	BERRI DISPOSAL BASIN COMPLEX	Saline Swamp
1	S0000282	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000283	ECKERT CREEK AND THE SPLASH	Permanent Swamp - Throughflow
1	S0000289	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000290	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000298	PUNKAH CREEK	Permanent Reach
1	S0000312	PARINGA ISLAND	Permanent Reach
1	S0000315	PUNKAH CREEK	Ephemeral Reach
1	S0000344	NELWOOD	Permanent Swamp - Terminal Branch
1	S0000355	MONOMAN CREEK	Permanent Reach
1	S0000366	PIPECLAY BILLABONG	Temporary Wetland - Terminal Branch
1	S0000385	COPPERMINE WATERHOLE	Temporary Wetland - Terminal Branch
1	S0000403	PYAP LAGOON	Permanent Lake - Throughflow
1	S0000404	PYAP HORSESHOE	Permanent Lake - Throughflow
1	S0000477	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000506	THIELE FLAT	Saline Swamp
1	S0000684	MANNUM SWAMPS	Permanent Lake - Throughflow
1	S0000707	PENNS INLET	Permanent Swamp - Terminal Branch
1	S0000735	MURBKO SOUTH	Temporary Wetland - Throughflow
1	S0000822	WINDING CREEK	Permanent Reach
1	S0000825	BLANCHETOWN CARAVAN PARK	Permanent Lake - Throughflow
1	S0000924	BELDORA WETLANDS	Temporary Wetland - Throughflow

1	S0000928	BELDORA WETLANDS	Permanent Swamp - Throughflow
1	S0000933	YATCO LAGOON	Permanent Lake - Throughflow
1	S0000935	LOVEDAY SWAMPS	Saline Swamp
1	S0000957	WOOLENOOK BEND COMPLEX	Permanent Reach
1	S0000959	WOOLENOOK BEND COMPLEX	Permanent Lake - Terminal Branch
1	S0000970	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
1	S0001058	LAKE BONNEY COMPLEX	Permanent Lake - Terminal Branch
1	S0001079	AJAX ACHILLIES LAKE	Permanent Lake - Throughflow
1	S0001103	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
1	S0001145	YOUNGHUSBAND WEST	Permanent Lake - Throughflow
1	S0001247	LYRUP CAUSEWAY EAST	Temporary Wetland - Overbank Flow
1	S0001282	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0001337	LAKE MERRETI INLET	Ephemeral Reach
1	S0001399	PILBY CREEK	Permanent Swamp - Throughflow
1	S0001434	LOWER PIKE RIVER	Permanent Reach
1	S0001438	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch
1	S0001442	PARINGA ISLAND	Permanent Swamp - Terminal Branch
1	S0001584	MURBKO FLAT COMPLEX	Permanent Lake - Throughflow
1	S0001617	PILBY CREEK	Ephemeral Reach
1	S0001618	WERTA WERT	Temporary Wetland - Terminal Branch
1	S0001636	MAIZE ISLAND COMPLEX	Temporary Wetland - Overbank Flow
1	S0001660	BANROCK SWAMP	Permanent Swamp - Throughflow
1	S0001667	YARRA COMPLEX	Permanent Lake - Terminal Branch
1	S0001672	HART LAGOON	Permanent Lake - Terminal Branch
1	S0001682	ROSS LAGOON	Permanent Lake - Throughflow
1	S0001696	BIG TOOLUNKA FLAT	Permanent Lake - Terminal Branch
1	S0001734	DONALD FLAT LAGOON	Permanent Lake - Throughflow
1	S0001740	MCBEAN POUND NORTH	Permanent Lake - Terminal Branch
1	S0001754	ARLUNGA	Permanent Lake - Throughflow
1	S0001771	NORTH CAURNAMONT	Permanent Lake - Throughflow
1	S0001793	COOLCHA LAGOON	Permanent Lake - Throughflow
1	S0001973	PILBY LAGOON	Permanent Swamp - Throughflow
1	S0002019	MARKS LANDING	Permanent Lake - Throughflow
1	S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch
1	S0016022	RIVERGLADES	Permanent Swamp - Throughflow

Appendix 9: 'At-risk' reptile-KEA associations

NO. KEAs	KEA Asset Name	KEA ID
6	Riverland Ramsar	1
4	Gurra Floodplain	10
4	Katarapko Floodplain	17
4	Morgan East & Morgan CP	54
3	Loch Luna and Wachtels Lagoon	23
3	Maize Island Complex	35
2	Banrock Ramsar Complex (inc Wigley Reach)	25
2	Brenda Park / Morphetts Flat Complex	55
2	Hart Lagoon	37
2	Lyrup Causeway	7
2	Mannum Swamps	90
2	Nigra/Schillers	41
2	Overland Corner	26
2	Paisley Creek/Edsons Flat	65
2	Pyap Complex	18
2	Spectacle Lakes / Beldora Complex	21
2	Weston Flat Lagoon	50
2	Yatco Lagoon	19
1	Ajax Achilles	12
1	Big and Little Toolunka	39
1	Boggy Flat	43
1	Complex opposite Yarra Glen	32
1	Coolcha Lagoon	85
1	Disher Creek	6
1	Donald Flat	61
1	Glen Devlin Complex	30
1	Hogwash Bend Complex	47
1	Holder Bend/Ross/Jaeschke	36
1	Island Reach	34
1	Loveday Swamps and Mussel Lagoons	22
1	Marks Landing	70
1	Martins Bend	11
1	Moorundie Complex	66
1	Murbko Flat Complex	57
1	Murbko South Complex	58
1	Mypolonga/Toora Levee/Jury Swamp	96
1	Neeta Flat Depressions	92
1	Nikalapko Complex	51
1	North Caurnamont	79
1	North West Bend	53
1	Paringa Paddock	4
1	Penns Inlet	40
1	Pike-Mundic	8
1	Ramco Lagoon	38
1	Reedy Creek Mannum	91

1	Reid Flat	44
1	Rilli Lagoons	14
1	Riverglades	98
1	Roonka/Arlunga	64
1	Sinclair Flat	63
1	Swan Reach Complex	67
1	Thiele Flat	15
1	Wigley Flat (Akuna)	29
1	Yarra Complex	33
1	Younghusband West	88

Appendix 10: Frog vulnerability ratings

	Vulnerability												
	Ecology			Physiology			Genetics			Resilience			
	Habitat	Mobility/ Dispersal	Competition	Survival	Growth	Reproduction	Gene Pool	Gene Flow	Phenotypic Plasticity	Population Size	Reproductive Capacity	Recruitment	Vulnerability Coefficient
LONG-THUMBED FROG *(Limnodynastes fletcheri)*	H	M	M	H	M	H	M	M	M	M	M	M	0.75
SOUTHERN BELL FROG *(Litoria raniformis)*	H	M	M	H	M	H	M	M	M	M	L	M	0.72
EASTERN BANJO FROG *(Limnodynastes dumerili)*	M	M	M	M	H	H	L	L	M	L	L	M	0.61
PERON'S TREE FROG *(Litoria peronii)*	M	L	M	L	H	M	M	M	M	M	L	M	0.61
BURROWING FROG/ SUDELL'S FROG *(Neobatrachus pictus/ N. sudelli)*	L	M	M	L	L	M	M	M	M	M	M	M	0.61
MURRAY VALLEY FROGLET *(Crinia parinsignifera)*	L	H	M	M	L	L	L	M	M	L	M	M	0.56
COMMON FROGLET *(Crinia signifera)*	L	H	M	M	L	L	L	M	M	L	M	M	0.56
SOUTHERN BROWN TREE FROG *(Litoria ewingi)*	M	L	M	M	L	L	L	L	M	L	M	M	0.50
SPOTTED GRASS FROG *(Limnodynastes tasmaniensis)*	L	L	M	L	L	L	L	L	M	L	L	M	0.42

Appendix 11: Notes on factors & variables influencing vulnerability assessments of frog species

FROG VULNERABILITY ASSESSMENT

Question		Major Factors/Variables Influencing Assessments
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change?	**Both refuge and breeding habitat requirements to be considered for this criteria** **Habitat type -** species that are 'generalists' and use a variety of habitats/ water bodies/ depths including natural, disturbed and manmade habitats are considered *less* limited than those that have specific requirements. **Vegetation** - species with specific vegetation requirements or use vegetation that is expected to decline under climate change (e.g. grasses, red gums, lignum) may be more vulnerable to climate change affects. **Hydrology** – Species that have more specific flooding/hydroperiod requirements or for example use only temporary wetlands for breeding are expected to be more limited. Those that can breed in permanent pool level wetlands or small rain fed pools are expected to be less limited. **Refuge –** species that require certain refuge attributes e.g. course woody debris/ logs etc for shelter may be more vulnerable to climate change effects e.g. desiccation.
	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	Species that can occur long distances from water, readily move between water bodies or appear at isolated water bodies = least likely to be limited; species with good mobility but strongly linked to rainfall or flooding= moderate limitations; species not observed to disperse/ physiological limitations documented=most likely limited.
	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	**Diet/prey capture ability–** Adults & tadpoles of species with broad diets (diversity & size of prey) and increased prey capture ability are least likely to be limited through competition. **Predation** – Species with high predation pressure as an egg, juvenile or adult from native or introduced species are more likely to be limited - *Limited evidence to suggest that there are increased predation rates on some frog species.* **Size** – It is assumed that larger size individuals-adults & tadpoles -have competitive advantages over smaller species, e.g. larger species have increased gape size, reduced risk of desiccation reduced predation risk. **Behaviour-** ability to escape or be inconspicuous to predators, e.g. adults calling from concealed locations or tadpoles that are camouflaged, sedentary, fast swimmers etc.
Physiology	To what extent does ***survival*** limit the ability of the regional population of the species to tolerate climate change?	*'Survival' refer only to adults* **S**ize– It is assumed that generally larger size individuals have increased survival tolerances over smaller species, in particular in regards to reduced desiccation risk due to larger surface area to volume ratio. **Response to dry conditions**- Species with evidence of a water conserving response such as burrowing/ aestivating, showing a resistance to water loss e.g. water conserving posture and increased temperature tolerance are likely to have increased survival tolerances and/ or rapid re-hydration. **Terrestrial requirements**- e.g. degree of moisture/ terrestrial vegetation required during dry times, some species can occur for extended periods in dryer terrestrial environments while some are more aquatic needing to be close to water at all times. **pH/ Salinity Tolerance-** Adults are likely to be less affected by water quality than eggs or tadpoles but the risk will be increased for more aquatic species.

	To what extent does ***growth*** limit the ability of the regional population of the species to tolerate climate change?	*Determining 'growth 'limitations in this process can refer to tadpoles/ metamorphs &/ or adults but for these assessments (due to lack of available information for all species) has largely concentrated on conditions required for development of tadpoles, and in particular length of the hydroperiod required and salinity tolerance of tadpoles if known (though salinity information used tentatively due to variability in study results). Flooding regime and vegetation requirements are addressed in 'Habitat' & 'Reproductive tolerances'.* **Length of Hydro-period required-** Reduced frequency and duration of flooding and increased evaporation rates are expected to reduce the average hydro-period of temporary wetlands within the study region. Permanent pool level wetlands may decline in level and have reduced fluctuations. Tadpoles requiring extended hydro-periods are expected to be at increased risk of desiccation from wetlands drying prematurely. **Salinity Tolerance -** Increased wetland salinity is expected under climate change with most impact on tadpoles with lowest salinity tolerance (documented tolerances are variable from lab to field studies and the period of time a tadpole can tolerate elevated salinity also is variable).
	To what extent does ***reproduction*** limit the ability of the regional population of the species to tolerate climate change?	*'Reproductive' limitations were concentrated on the conditions required to initiate breeding/ spawning.* **Hydrology Requirements** – Dependence on certain flooding regime for reproduction / triggering breeding e.g. species that only breed in temporary wetlands with long hydro-periods are considered most at risk under climate change scenarios. Species that require only short hydro-periods or can breed in permanent pool level wetlands considered less at risk (though increased risks of predation for all species expected from introduced fish in pool level wetlands). **Spawning Requirements**– depth and vegetation requirements (with reduced flooding reduction in shallow well vegetated wetlands expected). **Breeding Season**- Opportunistic breeders are expected to less at risk as can take advantage of unseasonal climatic conditions and breed at any time of year.
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	Little genetic information was available so the size/diversity of a species gene pool within the study region has been inferred by looking at information on population size, abundance and distribution. A species that is common and widespread within the study region is presumed to have a large diverse gene pool.
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	To determine extent of gene flow the abundance and distribution of a species was considered but also a species mobility and connectedness to populations outside the study region were taken into consideration.
	To what extent does ***phenotypic plasticity*** limit the ability of the regional population of the species to tolerate climate change?	Frogs in general are described to posses the ability to increase their rate of development with deteriorating environmental conditions though it is not clear if variable rate of development automatically infers phenotypic plasticity and how to rate it e.g. different degrees of phenotypic plasticity.

Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	Population size was determined by the abundance and distribution of the species within the study region through recent surveys, documented accounts and official conservation listings . Common and widespread species were not expected to be limited by population size. Species that are widespread but in low abundance are expected to be moderately limited and a major limitation would be expected for an uncommon species confined to small area of study region.
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	Reproductive capacity was determined by a combination of reproductive traits, primarily: Number of eggs per clutch; Frequency of breeding/Evidence of re-clutching where known.
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	Information on recruitment rates was limited It was anticipated that recruitment could be inferred from a combination of the below factors but this information also is not known for all species in sufficient detail to be able to determine recruitment success. **Time of breeding age (if known):** Short time to maturity results in increased rate of recruitment of new individuals (could be inferred from time to metamorphosis) **Life span (if known):** Long life span results in increased time to recruit new individuals **Population base:** Higher number of breeding individuals from which to recruit **Predation pressure (if known):** Increased predation leads to reduced recruitment success (if not documented size may give some indication of risk of predation, but also another of other traits) **Reproductive capacity:** Re-clutching and frequent breeding increase the chance of recruitment

Appendix 12: 'At-risk' frog-wetland associations

No. 'at-risk' frog species	AUS_WETNR	NAME	SAAE Classification
2	S0000039	NGAK INDAU OUTLET	Ephemeral Reach
2	S0000098	SLANEY WEIR BILLABONG	Temporary Wetland - Throughflow
2	S0000106	PILBY CREEK	Permanent Swamp - Throughflow
2	S0000271	MARTIN BEND COMPLEX	Saline Swamp
2	S0000344	NELWOOD	Permanent Swamp - Terminal Branch
2	S0000355	MONOMAN CREEK	Ephemeral Reach
2	S0000366	PIPECLAY BILLABONG	Temporary Wetland - Terminal Branch
2	S0000443	RILLI LAGOONS	Temporary Wetland - Terminal Branch
2	S0000510	THIELE FLAT	Saline Swamp
2	S0000877	CHOWILLA	Temporary Wetland - Terminal Branch
2	S0000923	MARTIN BEND COMPLEX	Permanent Swamp - Terminal Branch
2	S0000928	BELDORA WETLANDS	Permanent Swamp - Throughflow
2	S0000949	OVERLAND CORNER INLET	Permanent Reach
2	S0001100	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
2	S0001166	MURTHO PARK COMPLEX	Permanent Swamp - Terminal Branch
2	S0001179	MURTHO PARK COMPLEX	Permanent Lake - Terminal Branch
2	S0001295	MURTHO PARK COMPLEX	Permanent Lake - Terminal Branch
2	S0001381	WHIRLPOOL CORNER	Permanent Swamp - Throughflow
2	S0001446	BERRI CAUSEWAY	Temporary Wetland - Terminal Branch
2	S0001477	WALL SWAMP	Permanent Lake - Throughflow
2	S0001478	WALL LEVEE	Temporary Wetland - Overbank Flow
2	S0001617	PILBY CREEK	Ephemeral Reach
2	S0001618	WERTA WERT	Temporary Wetland - Terminal Branch
2	S0001623	BUNYIP HOLE	Temporary Wetland - Overbank Flow
2	S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch
2	S0001775	CAURNAMONT	Permanent Lake - Terminal Branch
2	S0001793	COOLCHA LAGOON	Permanent Lake - Throughflow
2	S0001973	PILBY LAGOON	Permanent Swamp - Throughflow
2	S0001974	PILBY CREEK	Temporary Wetland - Terminal Branch
2	S0001975	LOCK 6 DEPRESSION	Permanent Lake - Throughflow
2	S0001997	MURRAY RIVER	Permanent Reach
1	S0000002	NGAK INDAU	Temporary Wetland - Terminal Branch
1	S0000034	NGAK INDAU INLET	Ephemeral Reach
1	S0000047	MOBILONG SWAMP	Permanent Reach
1	S0000053	YOUNGHUSBAND	Permanent Swamp - Throughflow
1	S0000092	PUNKAH CREEK	Ephemeral Reach
1	S0000093	CHOWILLA CREEK	Permanent Reach
1	S0000095	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow
1	S0000114	LAKE CARLET	Permanent Lake - Throughflow
1	S0000152	LYRUP FOREST	Saline Swamp
1	S0000174	SWANPORT WETLAND	Permanent Swamp - Throughflow
1	S0000176	LYRUP EAST	Temporary Wetland - Overbank Flow
1	S0000200	MURBPOOK LAGOON COMPLEX	Permanent Swamp - Throughflow
1	S0000251	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Overbank Flow
1	S0000258	SPECTACLE LAKES	Temporary Wetland - Throughflow
1	S0000283	ECKERT CREEK AND THE SPLASH	Permanent Swamp - Throughflow
1	S0000298	PUNKAH CREEK	Permanent Reach

1	S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow
1	S0000431	MARTIN BEND COMPLEX	Saline Swamp
1	S0000435	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow
1	S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch
1	S0000477	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000485	BRANDY BOTTLE WATERHOLE	Temporary Wetland - Throughflow
1	S0000547	BRENDA PARK	Permanent Lake - Throughflow
1	S0000675	DEVON DOWNS NORTH	Temporary Wetland - Overbank Flow
1	S0000676	DEVON DOWNS NORTH	Permanent Lake - Throughflow
1	S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow
1	S0000718	LYRUP EAST	Permanent Swamp - Terminal Branch
1	S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch
1	S0000926	BELDORA WETLANDS	Permanent Lake - Terminal Branch
1	S0000933	YATCO LAGOON	Permanent Lake - Throughflow
1	S0000935	LOVEDAY SWAMPS	Saline Swamp
1	S0000938	MUSSEL LAGOON	Permanent Lake - Terminal Branch
1	S0000960	WOOLENOOK BEND COMPLEX	Permanent Swamp - Throughflow
1	S0000970	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
1	S0000973	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow
1	S0000974	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow
1	S0001028	LOXTON FLOODPLAIN	Temporary Wetland - Terminal Branch
1	S0001029	LOXTON FLOODPLAIN	Temporary Wetland - Throughflow
1	S0001060	MURBPOOK LAGOON COMPLEX	Permanent Lake - Terminal Branch
1	S0001074	MURTHO PARK COMPLEX	Ephemeral Reach
1	S0001103	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
1	S0001125	WONGULLA LAGOON	Permanent Lake - Throughflow
1	S0001134	BOGGY FLAT	Permanent Lake - Throughflow
1	S0001145	YOUNGHUSBAND WEST	Permanent Lake - Throughflow
1	S0001167	MURTHO PARK COMPLEX	Temporary Wetland - Terminal Branch
1	S0001168	MURTHO PARK COMPLEX	Permanent Reach
1	S0001283	WOMBAT REST BACKWATER	Permanent Lake - Throughflow
1	S0001308	COMPLEX OPPOSITE YARRA GLEN	Temporary Wetland - Throughflow
1	S0001337	LAKE MERRETI INLET	Ephemeral Reach
1	S0001363	COPPERMINE WATERHOLE	Temporary Wetland - Throughflow
1	S0001374	BULYONG ISLAND BASIN	Permanent Reach
1	S0001387	PARINGA ISLAND	Permanent Swamp - Throughflow
1	S0001399	PILBY CREEK	Permanent Swamp - Throughflow
1	S0001434	LOWER PIKE RIVER	Permanent Reach
1	S0001438	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch
1	S0001439	PARINGA ISLAND	Permanent Swamp - Throughflow
1	S0001445	GOAT ISLAND AND PARINGA PADDOCK	Permanent Lake - Terminal Branch
1	S0001465	EAST WELLINGTON	Temporary Wetland - Terminal Branch
1	S0001466	MURRUNDI (WELLINGTON NORTH)	Permanent Swamp - Throughflow
1	S0001486	ROCKY GULLY	Saline Swamp
1	S0001558	YARRAMUNDI NORTH	Permanent Swamp - Throughflow
1	S0001672	HART LAGOON	Permanent Lake - Terminal Branch
1	S0001684	RAMCO LAGOON	Saline Swamp
1	S0001701	NIGRA CREEK	Permanent Reach
1	S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
1	S0001722	NEAR WACHTELS LAGOON	Permanent Swamp - Throughflow
1	S0001736	SINCLAIR FLAT	Permanent Lake - Throughflow

1	S0001777	SALTBUSH FLAT	Permanent Lake - Terminal Branch
1	S0001811	MYPOLONGA LEVEE	Permanent Swamp - Throughflow
1	S0001821	RIVERGLADES	Permanent Swamp - Throughflow
1	S0001822	UKEE BOAT CLUB	Permanent Swamp - Throughflow
1	S0001988	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow
1	S0001989	YOUNGHUSBAND	Temporary Wetland - Overbank Flow
1	S0001992	BOGGY FLAT	Temporary Wetland - Terminal Branch
1	S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch
1	S0002461	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
1	S0002826	BOAT CREEK	Temporary Wetland - Overbank Flow
1	S0016023	REEDY CREEK	Permanent Lake - Throughflow

Appendix 13: 'At-risk' frog-KEA associations

No. 'at-risk' frog species	KEA Asset Name	KEA ID
2	Caurnamont	81
2	Coolcha Lagoon	85
2	Gurra Floodplain	10
2	Katarapko Floodplain	17
2	Loch Luna and Wachtels Lagoon	23
2	Lyrup East	9
2	Martins Bend	11
2	Mypolonga/Toora Levee/Jury Swamp	96
2	Overland Corner	26
2	Paringa Paddock	4
2	Rilli Lagoons	14
2	Riverland Ramsar	1
2	Spectacle Lakes / Beldora Complex	21
2	Thiele Flat	15
2	Wall Levee/Wood Lane	94
2	Wall Swamp	93
2	Wellington Spit	105
2	Younghusband Complex	87
1	Boggy Flat	43
1	Brenda Park / Morphetts Flat Complex	55
1	Complex opposite Yarra Glen	32
1	Devon Downs Complex	73
1	Hart Lagoon	37
1	Lake Carlet	86
1	Loveday Swamps and Mussel Lagoons	22
1	Loxton Floodplain	16
1	Maize Island Complex	35
1	Mobilong Swamp incl. Rocky Gully	97
1	Moorundie Complex	66
1	Morgan East & Morgan CP	54
1	Murbpook Lagoon	59
1	Murrundi	106
1	Nigra/Schillers	41
1	opp. Ukee	100
1	Pike-Mundic	8
1	Pompoota/Paiwalla/Sunnyside	95

1	Pyap Complex	18
1	Ramco Lagoon	38
1	Reedy Creek Mannum	91
1	Riverglades	98
1	Saltbush Flat	82
1	Sinclair Flat	63
1	Swanport Wetland	101
1	Ukee Boat Club	99
1	Wellington Complex	104
1	Wongulla Lagoon/Marne Mouth	76
1	Yatco Lagoon	19
1	Younghusband West	88

Appendix 14: 'At-risk' mammal-wetland associations

No. 'at-risk' mammal species	AUS_WETNR	NAME	SAAE Classification
3	S0001997	RIVER MURRAY	Permanent Reach
2	S0001103	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
2	S0001104	DOUBLE THOOKLE THOOKLE LAGOONS	Temporary Wetland - Overbank Flow
1	S0000001	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000002	NGAK INDAU	Temporary Wetland - Terminal Branch
1	S0000034	NGAK INDAU INLET	Ephemeral Reach
1	S0000039	NGAK INDAU OUTLET	Ephemeral Reach
1	S0000048	UPPER PIKE RIVER AND SNAKE CREEK	Permanent Swamp - Throughflow
1	S0000133	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000148	KATARAPKO CREEK AND KATARAPKO ISLAND	Permanent Reach
1	S0000269	IRWIN FLAT	Temporary Wetland - Terminal Branch
1	S0000290	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000305	COMPLEX OPPOSITE YARRA GLEN	Temporary Wetland - Throughflow
1	S0000306	YARRA COMPLEX	Temporary Wetland - Throughflow
1	S0000326	WOOLSHED CREEK	Ephemeral Reach
1	S0000405	GERARD SWAMPS	Temporary Wetland - Overbank Flow
1	S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow
1	S0000435	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow
1	S0000443	RILLI LAGOONS	Temporary Wetland - Terminal Branch
1	S0000477	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000496	ECKERT CREEK AND THE SPLASH	Temporary Wetland - Overbank Flow
1	S0000541	ECKERT CREEK AND THE SPLASH	Temporary Wetland -

			Overbank Flow
1	S0000564	RAL RAL CREEK AND RAL RAL WIDEWATERS	Temporary Wetland - Throughflow
1	S0000681	REEDY CREEK SWAMP	Temporary Wetland - Throughflow
1	S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow
1	S0000762	PELLARING FLAT	Permanent Lake - Terminal Branch
1	S0000928	BELDORA WETLANDS	Permanent Swamp - Throughflow
1	S0000933	YATCO LAGOON	Permanent Lake - Throughflow
1	S0000960	WOOLENOOK BEND COMPLEX	Permanent Swamp - Throughflow
1	S0000972	WESTON FLAT LAGOON	Temporary Wetland - Throughflow
1	S0000973	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow
1	S0001049	WIGLEY REACH	Ephemeral Reach
1	S0001059	MURBKO SOUTH	Permanent Lake - Terminal Branch
1	S0001100	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
1	S0001194	SALT CREEK AND GURRA GURRA LAKES	Permanent Swamp - Terminal Branch
1	S0001257	ON MARKARANKA FLOODPLAIN	Temporary Wetland - Overbank Flow
1	S0001258	HOGWASH BEND	Temporary Wetland - Terminal Branch
1	S0001281	SWAN REACH COMPLEX	Permanent Reach
1	S0001283	WOMBAT REST BACKWATER	Permanent Lake - Throughflow
1	S0001315	ISLAND REACH	Temporary Wetland - Throughflow
1	S0001486	ROCKY GULLY	Saline Swamp
1	S0001504	ECKERT CREEK AND THE SPLASH	Ephemeral Reach
1	S0001614	SPECTACLE LAKES SOUTH	Ephemeral Reach
1	S0001619	WERTA WEST	Temporary Wetland - Overbank Flow
1	S0001637	MAIZE ISLAND COMPLEX	Ephemeral Reach
1	S0001662	WIGLEY REACH	Temporary Wetland - Throughflow
1	S0001670	BANROCK CREEK	Permanent Reach
1	S0001681	COMPLEX OPPOSITE YARRA GLEN	Temporary Wetland - Overbank Flow
1	S0001684	RAMCO LAGOON	Saline Swamp
1	S0001700	NIGRA CREEK	Permanent Reach
1	S0001701	NIGRA CREEK	Permanent Reach
1	S0001705	MARKARANKA SOUTH	Temporary Wetland - Throughflow
1	S0001712	MOLO FLAT	Temporary Wetland - Terminal Branch
1	S0001717	NIKALAPKO	Temporary Wetland - Throughflow
1	S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow

1	S0001741	MCBEAN POUND SOUTH	Permanent Swamp - Throughflow
1	S0001771	NORTH CAURNAMONT	Permanent Lake - Throughflow
1	S0001798	YOUNGHUSBAND	Permanent Lake - Terminal Branch
1	S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch
1	S0002748	KIA WETLAND?	Temporary Wetland - Overbank Flow
1	S0016022	RIVERGLADES	Permanent Swamp - Throughflow

Appendix 15: 'At-risk' mammal-KEA associations

No. 'at-risk' mammal species	KEA Asset Name	KEA ID
3	Kroehns Landing	75
3	Riverland Ramsar	1
2	Caurnamont	81
2	Neeta Flat Depressions	92
2	Nigra/Schillers	41
1	Banrock Ramsar Complex (inc Wigley Reach)	25
1	Brenda Park / Morphetts Flat Complex	55
1	Cadell Complex	52
1	Complex opposite Yarra Glen	32
1	Disher Creek	6
1	Greenways Landing	74
1	Gurra Floodplain	10
1	Hogwash Bend Complex	47
1	Holder Bend/Ross/Jaeschke	36
1	Irwin Flat	60
1	Island Reach	34
1	Katarapko Floodplain	17
1	Loch Luna and Wachtels Lagoon	23
1	Maize Island Complex	35
1	Markaranka Complex	46
1	Mobilong Swamp incl. Rocky Gully	97
1	Moorundie Complex	66
1	Morgan East & Morgan CP	54
1	Murbko South Complex	58
1	Nikalapko Complex	51
1	North Caurnamont	79
1	North West Bend	53
1	Overland Corner	26
1	Paisley Creek/Edsons Flat	65
1	Paringa Paddock	4
1	Pike-Mundic	8
1	Punyelroo	71
1	Pyap Complex	18
1	Qualco Swamp	45
1	Ramco Lagoon	38
1	Reedy Creek Mannum	91
1	Rilli Lagoons	14
1	Riverglades	98
1	Roonka/Arlunga	64
1	Spectacle Lakes / Beldora Complex	21
1	Swan Reach Complex	67
1	Taworri Complex	89
1	Wall Levee/Wood Lane	94
1	Weston Flat Lagoon	50
1	Yarra Complex	33

1	Yatco Lagoon	19
1	Younghusband Complex	87
1	Younghusband West	88
1	opp. Hogwash Bend	48
1	opp. Murbko Flat (d/s end)	62

Appendix 16: Bird vulnerability & confidence ratings

	Vulnerability													Confidence												
	Ecology			Physiology			Genetics			Resilience				Ecology			Physiology			Genetics			Resilience			
	Habitat	Mobility/ Dispersal	Competition	Survival	Growth	Reproduction	Gene Pool	Gene Flow	Phenotypic Plasticity	Population Size	Reproductive Capacity	Recruitment	Vulnerability Coefficient	Habitat	Mobility/ Dispersal	Competition	Survival	Growth	Reproduction	Gene Pool	Gene Flow	Phenotypic Plasticity	Population Size	Reproductive Capacity	Recruitment	Confidence
WHITE-BELLIED SEA EAGLE *(Haliaeetus leucogaster)*	H	L	H	M	H	M	H	H	H	H	H	H	0.89	H	M	H	M	L	M	H	H	H	H	H	H	86%
YELLOW-BILLED SPOONBILL *(Platalea flavipes)*	M	M	M	M	H	H	H	H	H	H	H	H	0.89	H	L	M	H	H	H	M	M	M	M	L	M	72%
AUTRALASIAN BITTERN *(Botaurus poiciloptilus)*	H	M	L	H	H	H	H	H	H	H	M	M	0.86	H	H	H	H	H	H	H	H	H	H	L	L	89%
BAILLON'S CRAKE *(Porzana pusilla)*	M	L	H	L	M	M	H	H	H	H	M	H	0.78	H	H	H	H	M	M	M	M	H	H	L	L	78%
SPOTLESS CRAKE *(Porzana tabuensis)*	M	L	M	M	M	M	H	H	M	H	M	H	0.75	H	M	H	H	H	H	H	H	M	H	H	H	94%
MUSK DUCK *(Biziura lobata)*	H	L	L	M	M	H	M	M	M	H	H	H	0.75	H	M	M	H	L	M	M	M	L	H	M	L	67%
REGENT PARROT *(Polytelis anthopeplus)*	M	M	M	L	M	M	H	H	M	H	M	M	0.72	H	H	M	H	H	H	H	H	L	H	L	L	81%
AUSTRALIAN SPOTTED CRAKE *(Porzana fluminea)*	M	L	M	L	L	M	H	H	H	H	M	H	0.72	H	H	H	H	L	M	M	L	H	H	L	L	72%
BLACK-FRONTED DOTTEREL *(Elseyornis melanops)*	M	H	M	M	H	H	M	M	H	L	L	L	0.69	H	H	H	H	H	H	H	H	H	H	H	H	100%
NANKEEN NIGHT HERON *(Nycticorax caledonicus)*	H	H	L	M	M	H	L	L	L	H	H	M	0.69	H	L	H	H	M	H	M	M	H	M	L	L	72%
BLUE-BILLED DUCK *(Oxyura australis)*	M	M	L	L	M	M	H	M	M	H	M	M	0.69	M	H	M	M	L	M	M	M	L	H	L	M	64%
YELLOW ROSELLA *(Platycercus elegans flaveolus)*	L	L	M	L	M	M	H	M	L	H	H	H	0.67	H	H	H	H	H	H	H	L	H	H	H	H	94%
BUFF-BANDED RAIL *(Gallirallus philippensis)*	M	L	M	L	L	L	H	H	H	H	M	M	0.67	H	M	H	H	H	M	H	H	M	H	H	H	92%
SWAMP HARRIER *(Circus approximans)*	M	L	M	M	M	M	M	M	H	M	M	M	0.67	H	H	H	H	H	H	M	H	M	M	H	L	86%
DARTER *(Anhinga melanogaster novaehollandiae)*	M	L	L	M	M	M	L	L	H	M	H	H	0.64	H	H	H	H	M	H	H	H	H	H	M	L	89%
RED-KNEED DOTTEREL *(Erythrogonys cinctus)*	M	L	L	M	M	H	M	L	M	M	M	H	0.64	M	H	H	H	H	M	H	H	M	H	M	M	86%
AUSTRALIAN REED WARBLER *(Acrocephalus stentoreus)*	H	L	M	M	H	H	L	L	H	L	L	M	0.64	M	M	H	H	H	H	H	M	M	H	H	M	86%
AUSTRALIAN SHELDUCK *(Tadorna tadornoides)*	M	L	M	L	M	H	L	M	M	M	M	H	0.64	H	H	M	H	M	H	M	M	L	H	M	H	81%
GREAT CORMORANT *(Phalacrocorax carbo)*	M	L	L	M	M	M	L	L	M	M	M	H	0.58	H	H	H	H	M	M	H	H	L	H	H	M	86%
GREAT EGRET *(Ardea alba)*	M	L	M	M	M	H	L	L	L	L	L	H	0.56	H	H	M	H	H	H	H	H	M	H	H	H	94%
FRECKLED DUCK *(Stictonetta naevosa)*	M	L	M	L	M	L	M	M	M	H	L	L	0.56	M	H	L	M	L	H	L	M	L	H	H	H	69%
BLACK-WINGED STILT *(Himantopus himantopus)*	M	L	L	M	M	M	L	L	L	L	M	H	0.53	H	H	H	H	M	H	H	H	H	H	H	M	94%
PURPLE SWAMPHEN *(Porphyrio porphyrio)*	M	L	L	L	L	M	M	L	M	M	L	H	0.53	H	M	H	H	H	H	H	H	M	H	H	H	94%
BLACK SWAN *(Cygnus atratus)*	M	L	L	L	M	H	L	L	M	L	L	H	0.53	H	H	H	H	H	M	H	M	L	H	H	M	86%
LITTLE PIED CORMORANT *(Microcarbo melanoleucos)*	M	L	M	L	H	H	L	L	M	L	L	L	0.53	H	H	H	H	M	H	M	M	L	M	M	M	78%
AUSTRALASIAN SHOVELER *(Anas rhynchotis)*	M	L	M	L	M	L	M	M	L	H	L	L	0.53	H	M	M	M	L	H	M	M	L	H	H	H	58%
AUSTRALIAN WHITE IBIS *(Threskiornis molucca)*	L	L	L	L	H	M	L	L	M	M	L	M	0.50	H	H	H	H	H	H	H	H	L	H	H	M	92%
CHESTNUT TEAL *(Anas castanea)*	M	M	L	L	L	L	M	M	M	M	L	L	0.50	M	L	M	H	M	H	M	L	L	H	H	H	72%
STRAW-NECKED IBIS *(Threskiornis spinicollis)*	M	L	L	L	M	L	L	L	L	M	M	M	0.47	H	H	H	H	L	H	H	H	H	H	L	L	83%
LITTLE BLACK CORMORANT *(Phalacrocorax sulcirostris)*	M	L	L	L	M	H	L	L	M	L	L	L	0.47	H	H	H	H	M	M	M	M	L	H	M	M	78%
RED-CAPPED PLOVER *(Charadrius ruficapillus)*	L	L	L	L	L	L	L	L	L	M	M	H	0.44	H	H	H	H	M	H	H	M	L	H	M	M	83%
HOARY-HEADED GREBE *(Poliocephalus poliocephalus)*	M	L	L	L	L	H	L	L	L	L	L	L	0.42	H	M	M	H	M	M	M	M	M	M	M	M	72%

Appendix 17: Factors & variables influencing vulnerability of bird species

BIRD VULNERABILITY ASSESSMENT

Question		Major Factors/Variables Influencing Assessments
Ecology	To what extent does ***habitat*** preference limit the ability of the regional population of the species to tolerate climate change?	**Artificial habitat use-** Use of only natural habitat = more likely to be limited; use of both natural and artificial habitat = less likely to be limited **Salinity-** Occurs on fresh waters only=most likely to be limited; Occurs on fresh-brackish waters = moderate limitations; Occurs on fresh-saline or saline-hypersaline waters - least likely to be limited. **Vegetation type/ structure-** Requires vegetation that only occurs in freshwater or wetlands with specific water regime, e.g. wetting / drying cycles = most likely to be limited; General vegetation requirements= moderate limitations; No vegetation requirements = least likely limited. **Water regime-** Specific water regime requirements, e.g. more abundant on temporary wetlands with fluctuating water levels or natural wetting / drying cycles**=** most limited; No specific water regime requirements, e.g. use stable permanent pool level wetlands or river channel = less likely to be limited.
Ecology	To what extent does ***mobility and dispersal*** limit the ability of the regional population of the species to tolerate climate change?	**Breeding/ Seasonal Movements-** Breeding & seasonal migrations (large influxes/ irruptions over long distances) less likely to be limited; No breeding/ seasonal migrations-more likely to be limited **Post-breeding dispersion** – High Post-breeding dispersion= As dispersive unlikely to be limited; No/ poor pos-breeding dispersion= Does not disperse well so more likely to be limited. **General Movements-** Sedentary/ resident = more likely to be limited; Nomadic/ mobile/ irruptions =less likely to be limited.
Ecology	To what extent does ***competition*** limit the ability of the regional population of the species to tolerate climate change?	**Aggression/ territoriality -** Aggressive/ highly territorial= less likely to be displaced; Non-aggressive/ non- territorial = Most likely to suffer competition and displacement. **Diet-** Wide omnivorous diet = can take wide variety of food sources & can switch diet depending on resources available, less likely to be limited ; Narrow diet = less diet options increased competition, more likely to be limited. **Predation**- High predation pressure=most likely to suffer limitation; Low predation pressure=least likely to suffer limitation. **Size**-Large size=bigger animals have competitive advantage; Small size= small animals more likely to suffer competition. **Social** - Structure-Cryptic/ secretive=posses competitive advantages e.g. hard to see/suffer less predation; Gregarious/colonial=competitive advantages through strength in numbers; Conspicuous/ solitary=on own easier target for predators.
Physiology	To what extent does ***survival*** limit the ability of the regional population of the species to tolerate climate change?	**Adult diet**- Narrow diet=higher risk as cannot switch diet if food becomes limited through degraded conditions; broad diet=less risk as able to switch diet and utilize range of food resources. **Vegetation**- Require vegetation growing only in freshwater or under certain water regime for cover/ foraging=most limited; General vegetation requirements / or uses vegetation that grows under stable water levels or in saline waters= moderately limited; no vegetation requirements=least limited. **Water Regime**- Specific water regime requirements e.g. water level fluctuations/wetting/ drying cycle/ flowing waters=most limited; No specific water regime requirements, e.g. uses permanent pool level wetlands/ stable water levels=least limited. **Salinity-** Occurs only on fresh waters = most likely to be limited; Occurs on fresh-brackish waters = moderate limitations; Occurs on fresh-saline or saline-hypersaline waters = least likely to be limited.

	To what extent does ***growth*** limit the ability of the regional population of the species to tolerate climate change?	**Juvenile Development**- Poorly developed young at hatching=increased load on parents -most limited; well developed young at hatching=decreased load on parents-least limited. **Parental investment-** Parental care (long)=increased parental care raises risk to parents and young, most limited; parental care (short)=decreased parental care reduces risk to parents and young but still some reliance; no parental care=least risk as young able to fend for themselves from birth. **Salinity effect on growth/development-** salinity limits growth/ development=most likely to suffer; salinity does not limit growth/ development=unlikely to suffer **Water Regime**- specific water regime required for successful growth/ development e.g. flow/ flooding regime=most limited; No specific water regime required = least limited.
	To what extent does ***reproduction*** limit the ability of the regional population of the species to tolerate climate change?	**Breeding site-** Specific nest/ breeding site requirements=most at risk if dependent on diverse, dense freshwater vegetation or vegetation requiring water regime that will decline under climate change; general nest/ breeding site requirements= reduced risk if can use vegetation that is salt tolerant/ or thrives in stable water levels e.g. *Typha* spp; No specific nest/ breeding site requirements=least limited. **Breeding water regime-** Requires specific water regime for breeding, e.g. flooding/ fluctuating water levels=most limited; No specific water regime for breeding, e.g. breeds on stable water levels/ does not require flooding=least limited. **Salinity in breeding site**-Breeds in freshwater only=most limited; Breeds in fresh-brackish waters-moderate limitation; breeds fresh-saline=least limited **Timing of breeding**- short breeding season =restricted opportunities and most likely to suffer limitation; long breeding season=some limitation but broad seasonal requirements reduce risk; opportunistic breeding=least likely to be limited under climate change as can breed at any time of year.
Genetics	To what extent does ***gene pool*** limit the ability of the regional population of the species to tolerate climate change?	**Breeding strategy**- Sustained monogamy= life-long monogamy limits potential for genetic diversity; Seasonal Monogamy=better chance of genetic mixing than sustained monogamy but still limiting; Polygamous/ promiscuous=best chance of genetic mixing/ diversity. **Distribution-** distribution continuous=widely distributed species have better chance of 'healthy' genetics; narrow, patchy dispersal/ distribution=more likely to be restrict ed. **Population base**- Abundance high=increases chance of diverse gene pool, flow and plasticity; Abundance moderate = some genetic limitations; abundance low=most likely to have limited genetic characteristics. **Social structure-** sedentary/ solitary = sedentary and solitary animals more likely to be genetically segregated; mobile/ small groups= mobile solitary, nomadic or small groups are likely to be limited to some extent; colonial/ migratory= least likely to be limited as greater chance of mixing in larger breeding groups.
	To what extent does ***gene flow*** limit the ability of the regional population of the species to tolerate climate change?	**Dispersal –** species with high mobility and wide dispersal have best chance of good gene **flow;** more sedentary species have reduced opportunities for gene flow. **Breeding strategy**- Sustained monogamy= life-long monogamy limits potential for gene flow Seasonal Monogamy=better chance of gene flow than sustained monogamy but still limiting; Polygamous/ promiscuous=best chance of gene flow. **Distribution**- species with wide distribution have best chance of good gene flow; species with patchy/ narrow distribution have reduced gene flow. **Population base**- abundance high=increases chance of gene flow; abundance moderate = moderate gene flow; abundance low=most likely to have limited gene flow.
	To what extent does ***phenotypic plasticity*** limit the ability of the regional	If no obvious reference to displays of phenotypic plasticity the following factors may give some indication of a species capacity for phenotypic variation: **Geographic variation-** polytypic species= indicates clear geographic variation; monotypic species=less geographic variation less likely to be limited.

	population of the species to tolerate climate change?	**Population base**- Abundance high=increases chance of phenotypic variation; Abundance moderate = moderate chance of phenotypic variation; abundance low=low chance of phenotypic variation **Distribution-** wide distribution in study area=reduced chance of different phenotypes being delineated; narrow distribution in study area = increased chance of different phenotypes being delineated. **Breeding strategy**- Sustained monogamy= life-long monogamy increased chance of genetic segregation and delineation of phenotypes; Seasonal Monogamy=better chance of mixing than sustained monogamy but still limiting; Polygamous/ promiscuous=increased chance of mixing and reduced phenotypic plasticity.
Resilience	To what extent does ***population size*** limit the ability of the regional population of the species to tolerate climate change?	**Relative abundance**-comparatively high abundance = least likely to be limited; comparatively moderate = some limitations; comparatively low = most likely to be limited.
	To what extent does ***reproductive capacity*** limit the ability of the regional population of the species to tolerate climate change	**Fecundity-** large clutch size =least likely to be limited; moderate clutch size = moderate limitation; small clutch size =most likely to be limited **Frequency of breeding**- single brooding=highly limits fecundity; double brooding=increases potential fecundity; multiple brooding=significantly increases potential fecundity.
	To what extent does ***recruitment*** limit the ability of the regional population of the species to tolerate climate change?	**Breeding maturity**- breeds at <1 year=short generation time and better recruitment potential for population; breeds at 2-3 years=moderate generation time, some limitations; breeds at >3years=long generation time, highly limiting. **Lifespan-** long life span=may have many offspring over life; moderate life span=moderately long lived ad may have a reasonable number of offspring over its life; short life-span= limited time to reproduce restricted to few generations. **Population base-** Abundance high=least likely to be limited as contains healthy population base; Abundance moderate = moderate limitation; abundance low=most likely to be limited as population base is small. **Replacement clutches-** re-nests or lays replacement eggs=increases potential for recruitment; does not re-nest or re-place eggs=reduces potential for recruitment. Success Rate- High success rate = increases recruitment rate significantly; moderate/ unknown recruitment rate; Low success rate=reduces recruitment rate significantly.

Appendix 18: 'At-risk' bird-wetland associations

No. 'At-Risk' Bird Species	AUS_WETNR	NAME	SAAE Wetland Type
10	S0001997	RIVER MURRAY	Permanent Reach
10	S0002461	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
6	S0000266	WACHTELS LAGOON	Permanent Lake - Throughflow
6	S0000970	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
6	S0001481	SUNNYSIDE CONSERVATION PARK AND PAIWALLA SWAMP	Permanent Swamp - Throughflow
6	S0001660	BANROCK SWAMP	Permanent Swamp - Throughflow
6	S0002460	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch
5	S0000034	NGAK INDAU INLET	Ephemeral Reach
5	S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch
5	S0000928	BELDORA WETLANDS	Permanent Swamp - Throughflow
5	S0000938	MUSSEL LAGOON	Permanent Lake - Terminal Branch
5	S0001465	EAST WELLINGTON	Temporary Wetland - Terminal Branch
5	S0001486	ROCKY GULLY	Saline Swamp
5	S0001670	BANROCK CREEK	Permanent Reach
5	S0001672	HART LAGOON	Permanent Lake - Terminal Branch
5	S0001721	MORGAN CONSERVATION PARK	Temporary Wetland - Terminal Branch
4	S0000002	NGAK INDAU	Temporary Wetland - Terminal Branch
4	S0000148	KATARAPKO CREEK AND KATARAPKO ISLAND	Permanent Reach
4	S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch
4	S0001058	LAKE BONNEY COMPLEX	Permanent Lake - Terminal Branch
4	S0001263	BANROCK INLETS	Temporary Wetland - Throughflow
4	S0001477	WALL SWAMP	Permanent Lake - Throughflow
4	S0001617	PILBY CREEK	Ephemeral Reach
4	S0001618	WERTA WERT	Temporary Wetland - Terminal Branch
4	S0001705	MARKARANKA SOUTH	Temporary Wetland - Throughflow
4	S0001708	MARKARANKA EAST	Temporary Wetland - Terminal Branch
4	S0001776	SALTBUSH FLAT	Permanent Lake - Throughflow
4	S0001973	PILBY LAGOON	Permanent Swamp - Throughflow
3	S0000174	SWANPORT WETLAND	Permanent Swamp - Throughflow
3	S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow
3	S0000443	RILLI LAGOONS	Temporary Wetland - Terminal Branch
3	S0000676	DEVON DOWNS NORTH	Permanent Lake - Throughflow
3	S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow
3	S0001124	KROEHNS LANDING	Permanent Lake - Throughflow
3	S0001134	BOGGY FLAT	Permanent Lake - Throughflow
3	S0001161	DEVON DOWNS SOUTH	Permanent Lake - Throughflow
3	S0001345		Permanent Swamp - Terminal Branch
3	S0001437	DISHER CREEK	Saline Swamp
3	S0001572	RILLI LAGOONS	Temporary Wetland - Throughflow
3	S0001575	KATARAPKO BASIN	Saline Swamp

3	S0001647	PUNYELROO	Permanent Lake - Terminal Branch
3	S0001684	RAMCO LAGOON	Saline Swamp
3	S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow
2	S0000093	CHOWILLA CREEK	Permanent Reach
2	S0000098	SLANEY WEIR BILLABONG	Temporary Wetland - Throughflow
2	S0000113	LAKE CARLET	Permanent Lake - Throughflow
2	S0000152	LYRUP FOREST	Saline Swamp
2	S0000290	ECKERT CREEK AND THE SPLASH	Permanent Reach
2	S0000298	PUNKAH CREEK	Permanent Reach
2	S0000335	KATARAPKO BASIN	Temporary Wetland - Overbank Flow
2	S0000366	PIPECLAY BILLABONG	Temporary Wetland - Terminal Branch
2	S0000403	PYAP LAGOON	Permanent Lake - Throughflow
2	S0000471	WOOLENOOK BEND COMPLEX	Temporary Wetland - Terminal Branch
2	S0000608	REEDY CREEK SWAMP	Temporary Wetland - Overbank Flow
2	S0000609	REEDY CREEK	Permanent Lake - Throughflow
2	S0000638	LITTLE TOOLUNKA FLAT	Permanent Lake - Throughflow
2	S0000675	DEVON DOWNS NORTH	Temporary Wetland - Overbank Flow
2	S0000678	KROEHNS LANDING	Temporary Wetland - Overbank Flow
2	S0000681	REEDY CREEK SWAMP	Temporary Wetland - Throughflow
2	S0000684	MANNUM SWAMPS	Permanent Lake - Throughflow
2	S0000926	BELDORA WETLANDS	Permanent Lake - Terminal Branch
2	S0000933	YATCO LAGOON	Permanent Lake - Throughflow
2	S0000944	LOVEDAY SWAMPS	Saline Swamp
2	S0001010	BLANCHETOWN FLAT	Temporary Wetland - Throughflow
2	S0001059	MURBKO SOUTH	Permanent Lake - Terminal Branch
2	S0001060	MURBPOOK LAGOON COMPLEX	Permanent Lake - Terminal Branch
2	S0001074	MURTHO PARK COMPLEX	Ephemeral Reach
2	S0001099	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
2	S0001125	WONGULLA LAGOON	Permanent Lake - Throughflow
2	S0001145	YOUNGHUSBAND WEST	Permanent Lake - Throughflow
2	S0001162	DEVON DOWNS SOUTH	Permanent Lake - Terminal Branch
2	S0001179	MURTHO PARK COMPLEX	Permanent Lake - Terminal Branch
2	S0001283	WOMBAT REST BACKWATER	Permanent Lake - Throughflow
2	S0001296	HORSESHOE SWAMP	Permanent Lake - Throughflow
2	S0001342	KINGSTON COMMON	Temporary Wetland - Overbank Flow
2	S0001377	RAL RAL CREEK AND RAL RAL WIDEWATERS	Temporary Wetland - Overbank Flow
2	S0001391	PARINGA ISLAND	Permanent Swamp - Throughflow
2	S0001399	PILBY CREEK	Permanent Swamp - Throughflow
2	S0001445	GOAT ISLAND AND PARINGA PADDOCK	Permanent Lake - Terminal Branch
2	S0001551	MOLO FLAT	Temporary Wetland - Throughflow
2	S0001557	YARRAMUNDI	Permanent Reach
2	S0001573	RILLI LAGOONS	Temporary Wetland - Throughflow
2	S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch
2	S0001692	DELVINS POUND	Permanent Swamp - Terminal Branch
2	S0001734	DONALD FLAT LAGOON	Permanent Lake - Throughflow
2	S0001746	ROONKA	Temporary Wetland - Overbank Flow

2	S0001775	CAURNAMONT	Permanent Lake - Terminal Branch
2	S0001793	COOLCHA LAGOON	Permanent Lake - Throughflow
2	S0001797	YOUNGHUSBAND POINT	Temporary Wetland - Throughflow
2	S0001988	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow
2	S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch
2	S0016022	RIVERGLADES	Permanent Swamp - Throughflow
2	S0016023	REEDY CREEK	Permanent Lake - Throughflow
2	S0016030	KATARAPKO CREEK AND KATARAPKO ISLAND	Ephemeral Reach
1	S0000015	EMU GULLY	Temporary Wetland - Overbank Flow
1	S0000035	ECKERT CREEK AND THE SPLASH	Permanent Reach
1	S0000047	MOBILONG SWAMP	Permanent Reach
1	S0000048	UPPER PIKE RIVER AND SNAKE CREEK	Permanent Swamp - Throughflow
1	S0000049	OLD LOXTON ROAD LAGOON	Ephemeral Reach
1	S0000096	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow
1	S0000115	LAKE CARLET	Permanent Lake - Throughflow
1	S0000175	LYRUP EAST	Temporary Wetland - Throughflow
1	S0000220	GOAT ISLAND AND PARINGA PADDOCK	Temporary Wetland - Throughflow
1	S0000241	MUNDIC CREEK	Permanent Lake - Throughflow
1	S0000258	SPECTACLE LAKES	Temporary Wetland - Throughflow
1	S0000263	COBDOGLA BASIN	Saline Swamp
1	S0000274	BERRI DISPOSAL BASIN COMPLEX	Saline Swamp
1	S0000283	ECKERT CREEK AND THE SPLASH	Permanent Swamp - Throughflow
1	S0000305	COMPLEX OPPOSITE YARRA GLEN	Temporary Wetland - Throughflow
1	S0000344	NELWOOD	Permanent Swamp - Terminal Branch
1	S0000406	SPECTACLE LAKES SOUTH	Temporary Wetland - Throughflow
1	S0000427	SALT CREEK AND GURRA GURRA LAKES	Temporary Wetland - Terminal Branch
1	S0000431	MARTIN BEND COMPLEX	Saline Swamp
1	S0000434	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow
1	S0000457	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Overbank Flow
1	S0000495	PERRES FLOODPLAIN	Saline Swamp
1	S0000498	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow
1	S0000531	BOOKMARK CREEK	Temporary Wetland - Throughflow
1	S0000546	YARRAMUNDI	Permanent Reach
1	S0000592	MARKARANKA	Ephemeral Reach
1	S0000594	SWAN REACH COMPLEX	Permanent Lake - Terminal Branch
1	S0000596	Reedy Creek Swamp	Temporary Wetland - Throughflow
1	S0000619	GOAT ISLAND AND PARINGA PADDOCK	Temporary Wetland - Overbank Flow
1	S0000643	LITTLE TOOLUNKA FLAT	Temporary Wetland - Terminal Branch
1	S0000644	LITTLE TOOLUNKA FLAT	Permanent Lake - Throughflow
1	S0000679	REEDY CREEK SWAMP	Temporary Wetland - Overbank Flow
1	S0000712	KINGSTON COMMON	Permanent Swamp - Throughflow

1	S0000745	BANROCK INLETS	Temporary Wetland - Overbank Flow
1	S0000747	OVERLAND CORNER COMPLEX	Temporary Wetland - Overbank Flow
1	S0000755	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Swamp - Throughflow
1	S0000762	PELLARING FLAT	Permanent Lake - Terminal Branch
1	S0000780	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow
1	S0000800	GOAT ISLAND AND PARINGA PADDOCK	Permanent Reach
1	S0000877	CHOWILLA COMPLEX	Temporary Wetland - Terminal Branch
1	S0000900	GERARD SWAMP	Temporary Wetland - Terminal Branch
1	S0000971	NIKALAPKO WEST	Temporary Wetland - Throughflow
1	S0000972	WESTON FLAT LAGOON	Temporary Wetland - Throughflow
1	S0000973	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow
1	S0001026	LAKE WOOLPOLOOL	Saline Swamp
1	S0001079	AJAX ACHILLIES LAKE	Permanent Lake - Throughflow
1	S0001100	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
1	S0001101	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Swamp - Throughflow
1	S0001103	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach
1	S0001110	BURRA CREEK	Permanent Swamp - Throughflow
1	S0001127	FORSTER LAGOON	Permanent Lake - Terminal Branch
1	S0001130	WALKER FLAT SOUTH LAGOON	Permanent Swamp - Terminal Branch
1	S0001135	REID FLAT	Temporary Wetland - Terminal Branch
1	S0001137	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow
1	S0001168	MURTHO PARK COMPLEX	Permanent Reach
1	S0001175	MURTHO PARK COMPLEX	Permanent Reach
1	S0001194	SALT CREEK AND GURRA GURRA LAKES	Permanent Swamp - Terminal Branch
1	S0001258	HOGWASH BEND	Temporary Wetland - Terminal Branch
1	S0001260	BANROCK INLETS	Temporary Wetland - Overbank Flow
1	S0001261	BANROCK SWAMP	Temporary Wetland - Terminal Branch
1	S0001271	MOLO FLAT	Ephemeral Reach
1	S0001309	OVERLAND CORNER COMPLEX	Temporary Wetland - Overbank Flow
1	S0001315	ISLAND REACH	Temporary Wetland - Throughflow
1	S0001316	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow
1	S0001349	MARNE RIVER MOUTH	Temporary Wetland - Throughflow
1	S0001438	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch
1	S0001439	PARINGA ISLAND	Permanent Swamp - Throughflow
1	S0001444	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch
1	S0001451	MARTIN BEND COMPLEX	Temporary Wetland - Throughflow
1	S0001452	MURBKO FLAT COMPLEX	Temporary Wetland - Throughflow
1	S0001466	MURRUNDI (WELLINGTON NORTH)	Permanent Swamp - Throughflow
1	S0001482	SUNNYSIDE CONSERVATION PARK AND PAIWALLA SWAMP	Permanent Swamp - Throughflow

1	S0001543	SCHILLERS LAGOON	Permanent Lake - Throughflow
1	S0001547	MARKARANKA	Temporary Wetland - Terminal Branch
1	S0001553	CADELL TRAINING CENTRE	Temporary Wetland - Terminal Branch
1	S0001554	PENFOLDS LAGOON	Permanent Lake - Throughflow
1	S0001584	MURBKO FLAT COMPLEX	Permanent Lake - Throughflow
1	S0001614	SPECTACLE LAKES SOUTH	Ephemeral Reach
1	S0001619	WERTA WEST	Temporary Wetland - Overbank Flow
1	S0001620	HANCOCK CREEK	Ephemeral Reach
1	S0001634	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow
1	S0001642	SWAN REACH FERRY	Permanent Lake - Throughflow
1	S0001663	MAIZE ISLAND COMPLEX	Temporary Wetland - Overbank Flow
1	S0001664	JAESCHKE LAGOON	Permanent Lake - Throughflow
1	S0001666	PASCHKES FLAT	Temporary Wetland - Terminal Branch
1	S0001675	MAIZE ISLAND COMPLEX	Temporary Wetland - Terminal Branch
1	S0001696	BIG TOOLUNKA FLAT	Permanent Lake - Terminal Branch
1	S0001700	NIGRA CREEK	Permanent Reach
1	S0001703	QUALCO SWAMP	Temporary Wetland - Terminal Branch
1	S0001717	NIKALAPKO	Temporary Wetland - Throughflow
1	S0001719	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow
1	S0001720	MORGAN CONSERVATION PARK	Temporary Wetland - Terminal Branch
1	S0001749	ROONKA	Permanent Swamp - Throughflow
1	S0001756	BLANCHETOWN CARAVAN PARK	Permanent Lake - Terminal Branch
1	S0001758	EDSONS FLAT	Temporary Wetland - Terminal Branch
1	S0001765	SCRUBBY FLAT	Temporary Wetland - Terminal Branch
1	S0001772	NORTH PURNONG	Permanent Lake - Terminal Branch
1	S0001807	REEDY CREEK SWAMP	Temporary Wetland - Overbank Flow
1	S0001822	UKEE BOAT CLUB	Permanent Swamp - Throughflow
1	S0001974	PILBY CREEK	Temporary Wetland - Terminal Branch
1	S0001985	TEMPLETON	Temporary Wetland - Terminal Branch
1	S0001986	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow
1	S0001989	YOUNGHUSBAND	Temporary Wetland - Overbank Flow
1	S0001990	YOUNGHUSBAND	Temporary Wetland - Terminal Branch
1	S0001992	BOGGY FLAT	Temporary Wetland - Terminal Branch

Appendix 19: 'At-risk' bird-KEA associations

No. 'At-Risk' Bird Species	KEA Name	KEA_ID
10	Pompoota/Paiwalla/Sunnyside	95
8	Hart Lagoon	37
8	Riverland Ramsar	1
7	Banrock Ramsar Complex (inc Wigley Reach)	25
7	Katarapko Floodplain	17
7	Loch Luna and Wachtels Lagoon	23
7	Martins Bend	11
6	Gurra Floodplain	10
6	Morgan East & Morgan CP	54
5	Devon Downs Complex	73
5	Loveday Swamps and Mussel Lagoons	22
5	Mobilong Swamp incl. Rocky Gully	97
5	Moorundie Complex	66
5	Reedy Creek Mannum	91
5	Spectacle Lakes / Beldora Complex	21
5	Wellington Complex	104
4	Boggy Flat	43
4	Donald Flat	61
4	Markaranka Complex	46
4	Ramco Lagoon	38
4	Rilli Lagoons	14
4	Saltbush Flat	82
4	Swanport Wetland	101
4	Wall Swamp	93
3	Big and Little Toolunka	39
3	Disher Creek	6
3	Kroehns Landing	75
3	Loxton Floodplain	16
3	Murrundi	106
3	Nigra/Schillers	41
3	Overland Corner	26
3	Paringa Paddock	4
3	Punyelroo	71
3	Pyap Complex	18
3	Roonka/Arlunga	64
2	Brenda Park / Morphetts Flat Complex	55
2	Caurnamont	81
2	Coolcha Lagoon	85
2	Devlins Pound	31
2	Holder Bend/Ross/Jaeschke	36
2	Kingston Common	20
2	Lake Carlet	86
2	Lyrup Causeway	7
2	Maize Island Complex	35
2	Mannum Swamps	90
2	Murbko South Complex	58

2	Murbpook Lagoon	59
2	Nelwart / Bookmark	5
2	Nikalapko Complex	51
2	North Caurnamont	79
2	North West Bend	53
2	Paisley Creek/Edsons Flat	65
2	Riverglades	98
2	Wellington Spit	105
2	Wongulla Lagoon/Marne Mouth	76
2	Yatco Lagoon	19
2	Younghusband Complex	87
2	Younghusband West	88
2	opp. Swan Reach Complex	68
1	Ajax Achilles	12
1	Big Bend	72
1	Bow Hill	84
1	Cadell Complex	52
1	Clarks Sandbar	13
1	Complex opposite Yarra Glen	32
1	Craignook	83
1	Forster Lagoon	77
1	Glen Lee	56
1	Hogwash Bend Complex	47
1	Island Reach	34
1	Lyrup East	9
1	Murbko Flat Complex	57
1	North Purnong	80
1	Pike-Mundic	8
1	Qualco Swamp	45
1	Reid Flat	44
1	Swan Reach Complex	67
1	Swan Reach Ferry	69
1	Taworri Complex	89
1	Ukee Boat Club	99
1	Walker Flat Complex	78
1	Weston Flat Lagoon	50
1	Yarra Complex	33
1	opp. Hogwash Bend	48
1	opp. Murbko Flat (d/s end)	62

Appendix 20: 'At-risk' all species-wetland associations (all taxonomic groups)

AUS_WETNR	Name	SAAE Classification	No. 'At-Risk' Species
S0001997	MURRAY RIVER	Permanent Reach	31
S0001486	ROCKY GULLY	Saline Swamp	13
S0002461	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch	12
S0000425	SALT CREEK AND GURRA GURRA LAKES	Permanent Lake - Throughflow	11
S0000821	CAUSEWAY LAGOON	Permanent Lake - Terminal Branch	11
S0001973	PILBY LAGOON	Permanent Swamp - Throughflow	11
S0000466	LAKE MERRETI	Permanent Lake - Terminal Branch	10
S0000711	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow	10
S0000938	MUSSEL LAGOON	Permanent Lake - Terminal Branch	10
S0001618	WERTA WERT	Temporary Wetland - Terminal Branch	10
S0001626	LAKE LITTRA	Temporary Wetland - Terminal Branch	10
S0001718	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow	10
S0002460	PAIWALLA WETLAND	Temporary Wetland - Terminal Branch	10
S0000928	BELDORA WETLANDS	Permanent Swamp - Throughflow	9
S0000970	MORGAN CONSERVATION PARK	Permanent Lake - Throughflow	9
S0002020	LITTLE DUCK LAGOON	Permanent Swamp - Terminal Branch	9
S0016022	RIVERGLADES	Permanent Swamp - Throughflow	9
S0000034	NGAK INDAU INLET	Ephemeral Reach	8
S0000047	MOBILONG SWAMP	Permanent Reach	8
S0000098	SLANEY WEIR BILLABONG	Temporary Wetland - Throughflow	8
S0000174	SWANPORT WETLAND	Permanent Swamp - Throughflow	8
S0000933	YATCO LAGOON	Permanent Lake - Throughflow	8
S0001617	PILBY CREEK	Ephemeral Reach	8
S0001672	HART LAGOON	Permanent Lake - Terminal Branch	8
S0000002	NGAK INDAU	Temporary Wetland - Terminal Branch	7
S0000148	KATARAPKO CREEK AND KATARAPKO ISLAND	Permanent Reach	7
S0000266	WACHTELS LAGOON	Permanent Lake - Throughflow	7
S0000366	PIPECLAY BILLABONG	Temporary Wetland - Terminal Branch	7
S0000960	WOOLENOOK BEND COMPLEX	Permanent Swamp - Throughflow	7
S0001134	BOGGY FLAT	Permanent Lake - Throughflow	7
S0001179	MURTHO PARK COMPLEX	Permanent Swamp - Terminal Branch	7
S0001466	MURRUNDI (WELLINGTON NORTH)	Permanent Swamp - Throughflow	7
S0001660	BANROCK SWAMP	Permanent Swamp - Throughflow	7
S0001700	NIGRA CREEK	Permanent Reach	7
S0016023	REEDY CREEK	Permanent Swamp - Throughflow	7
S0000093	CHOWILLA CREEK	Permanent Reach	6
S0000113	LAKE CARLET	Permanent Lake - Throughflow	6
S0000344	NELWOOD	Permanent Swamp - Terminal Branch	6
S0000355	MONOMAN CREEK	Ephemeral Reach	6
S0000443	RILLI LAGOONS	Temporary Wetland - Terminal Branch	6
S0000609	REEDY CREEK	Permanent Lake - Throughflow	6
S0000676	DEVON DOWNS NORTH	Temporary Wetland - Overbank Flow	6
S0001058	LAKE BONNEY COMPLEX	Permanent Lake - Terminal Branch	6
S0001059	MURBKO SOUTH	Permanent Lake - Terminal Branch	6

S0001100	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach	6
S0001145	YOUNGHUSBAND WEST	Permanent Lake - Throughflow	6
S0001283	WOMBAT REST BACKWATER	Permanent Lake - Throughflow	6
S0001399	PILBY CREEK	Permanent Swamp - Throughflow	6
S0001445	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch	6
S0001465	EAST WELLINGTON	Temporary Wetland - Terminal Branch	6
S0001477	WALL SWAMP	Permanent Lake - Throughflow	6
S0001481	SUNNYSIDE CONSERVATION PARK AND PAIWALLA SWAMP	Permanent Swamp - Throughflow	6
S0001670	BANROCK CREEK	Permanent Reach	6
S0001811	MYPOLONGA LEVEE	Permanent Swamp - Throughflow	6
S0001816	JURY SWAMP (JAENSCHS BEACH)	Permanent Swamp - Terminal Branch	6
S0000241	MUNDIC CREEK	Permanent Lake - Throughflow	5
S0000283	ECKERT CREEK AND THE SPLASH	Permanent Swamp - Throughflow	5
S0000290	ECKERT CREEK AND THE SPLASH	Permanent Swamp - Throughflow	5
S0000347	BERRI CAUSEWAY	Temporary Wetland - Terminal Branch	5
S0000684	MANNUM SWAMPS	Permanent Lake - Throughflow	5
S0000926	BELDORA WETLANDS	Permanent Lake - Terminal Branch	5
S0001043	TAILEM BEND	Permanent Lake - Terminal Branch	5
S0001079	AJAX ACHILLIES LAKE	Permanent Lake - Throughflow	5
S0001103	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach	5
S0001166	MURTHO PARK COMPLEX	Permanent Swamp - Terminal Branch	5
S0001438	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch	5
S0001584	MURBKO FLAT COMPLEX	Permanent Lake - Throughflow	5
S0001684	RAMCO LAGOON	Saline Swamp	5
S0001705	MARKARANKA SOUTH	Temporary Wetland - Throughflow	5
S0001721	MORGAN CONSERVATION PARK	Temporary Wetland - Terminal Branch	5
S0001793	COOLCHA LAGOON	Permanent Lake - Throughflow	5
S0001822	UKEE BOAT CLUB	Permanent Swamp - Throughflow	5
S0000048	UPPER PIKE RIVER AND SNAKE CREEK	Permanent Swamp - Throughflow	4
S0000114	LAKE CARLET	Permanent Lake - Throughflow	4
S0000274	BERRI DISPOSAL BASIN COMPLEX	Saline Swamp	4
S0000298	PUNKAH CREEK	Permanent Reach	4
S0001010	BLANCHETOWN FLAT	Temporary Wetland - Throughflow	4
S0001124	KROEHNS LANDING	Permanent Lake - Throughflow	4
S0001161	DEVON DOWNS SOUTH	Permanent Lake - Throughflow	4
S0001182	MUNDIC CREEK	Temporary Wetland - Overbank Flow	4
S0001263	BANROCK INLETS	Temporary Wetland - Throughflow	4
S0001437	DISHER CREEK	Saline Swamp	4
S0001701	NIGRA CREEK	Permanent Reach	4
S0001708	MARKARANKA EAST	Temporary Wetland - Terminal Branch	4
S0001736	SINCLAIR FLAT	Permanent Lake - Throughflow	4
S0001756	BLANCHETOWN CARAVAN PARK	Permanent Lake - Terminal Branch	4
S0001775	CAURNAMONT	Permanent Lake - Terminal Branch	4
S0001776	SALTBUSH FLAT	Permanent Lake - Throughflow	4
S0001821	RIVERGLADES	Permanent Swamp - Throughflow	4
S0000039	NGAK INDAU OUTLET	Ephemeral Reach	3
S0000115	LAKE CARLET	Permanent Lake - Throughflow	3
S0000152	LYRUP FOREST	Saline Swamp	3

S0000403	PYAP LAGOON	Permanent Lake - Throughflow	3
S0000477	ECKERT CREEK AND THE SPLASH	Permanent Reach	3
S0000644	LITTLE TOOLUNKA FLAT	Permanent Lake - Throughflow	3
S0000675	DEVON DOWNS NORTH	Temporary Wetland - Overbank Flow	3
S0000681	REEDY CREEK SWAMP	Temporary Wetland - Throughflow	3
S0000877	CHOWILLA	Temporary Wetland - Terminal Branch	3
S0000932	BLACKFELLOWS CREEK	Permanent Reach	3
S0000973	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow	3
S0001060	MURBPOOK LAGOON COMPLEX	Permanent Lake - Terminal Branch	3
S0001074	MURTHO PARK COMPLEX	Ephemeral Reach	3
S0001122	CHOWILLA OXBOW	Temporary Wetland - Terminal Branch	3
S0001125	WONGULLA LAGOON	Permanent Lake - Throughflow	3
S0001127	FORSTER LAGOON	Permanent Lake - Terminal Branch	3
S0001168	MURTHO PARK COMPLEX	Permanent Reach	3
S0001282	ECKERT CREEK AND THE SPLASH	Permanent Reach	3
S0001294	BIG HUNCHEE LITTLE HUNCHEE AND AMAZON CREEKS	Temporary Wetland - Overbank Flow	3
S0001309	OVERLAND CORNER COMPLEX	Temporary Wetland - Overbank Flow	3
S0001345	ON ISLAND ADJACENT KINGSTON COMMON	Permanent Swamp - Terminal Branch	3
S0001349	MARNE RIVER MOUTH	Temporary Wetland - Throughflow	3
S0001387	PARINGA ISLAND	Permanent Swamp - Throughflow	3
S0001391	PARINGA ISLAND	Permanent Swamp - Throughflow	3
S0001572	RILLI LAGOONS	Temporary Wetland - Throughflow	3
S0001575	KATARAPKO BASIN	Saline Swamp	3
S0001647	PUNYELROO	Permanent Lake - Terminal Branch	3
S0001734	DONALD FLAT LAGOON	Permanent Lake - Throughflow	3
S0001772	NORTH PURNONG	Permanent Lake - Terminal Branch	3
S0001790	MAIDMENT LAGOON	Permanent Lake - Terminal Branch	3
S0001974	PILBY CREEK	Temporary Wetland - Terminal Branch	3
S0001988	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow	3
S0000106	PILBY CREEK	Semi-connected	2
S0000245	MUNDIC CREEK	Permanent Lake - Throughflow	2
S0000258	SPECTACLE LAKES	Temporary Wetland - Throughflow	2
S0000263	COBDOGLA BASIN	Saline Swamp	2
S0000271	MARTIN BEND COMPLEX	Temporary Wetland - Overbank Flow	2
S0000305	COMPLEX OPPOSITE YARRA GLEN	Temporary Wetland - Throughflow	2
S0000335	KATARAPKO BASIN	Temporary Wetland - Overbank Flow	2
S0000386	HYPURNA CREEK	Permanent Reach	2
S0000431	MARTIN BEND COMPLEX	Saline Swamp	2
S0000435	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow	2
S0000471	WOOLENOOK BEND COMPLEX	Temporary Wetland - Terminal Branch	2
S0000510	THIELE FLAT		2
S0000608	REEDY CREEK SWAMP	Temporary Wetland - Overbank Flow	2
S0000638	LITTLE TOOLUNKA FLAT	Permanent Lake - Throughflow	2
S0000678	KROEHNS LANDING	Temporary Wetland - Overbank Flow	2
S0000762	PELLARING FLAT	Permanent Lake - Terminal Branch	2
S0000923	MARTIN BEND COMPLEX	Permanent Swamp - Terminal Branch	2
S0000935	LOVEDAY SWAMPS	Saline Swamp	2
S0000944	LOVEDAY SWAMPS	Saline Swamp	2
S0000949	OVERLAND CORNER INLET	Permanent Reach	2
S0000961	WOOLENOOK BEND COMPLEX	Permanent Lake - Throughflow	2

S0000972	WESTON FLAT LAGOON	Temporary Wetland - Throughflow	2
S0001099	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Reach	2
S0001104	DOUBLE THOOKLE THOOKLE LAGOONS	Temporary Wetland - Overbank Flow	2
S0001130	WALKER FLAT SOUTH LAGOON	Permanent Swamp - Terminal Branch	2
S0001162	DEVON DOWNS SOUTH	Permanent Lake - Terminal Branch	2
S0001170	MURTHO PARK COMPLEX	Permanent Reach	2
S0001194	SALT CREEK AND GURRA GURRA LAKES	Permanent Swamp - Terminal Branch	2
S0001258	HOGWASH BEND	Temporary Wetland - Terminal Branch	2
S0001295	MURTHO PARK COMPLEX	Permanent Lake - Terminal Branch	2
S0001296	HORSESHOE SWAMP	Permanent Lake - Throughflow	2
S0001315	ISLAND REACH	Temporary Wetland - Throughflow	2
S0001337	LAKE MERRETI INLET	Ephemeral Reach	2
S0001342	KINGSTON COMMON	Temporary Wetland - Overbank Flow	2
S0001359	NEAR PUNKAH HORSESHOE LAGOONS	Ephemeral Reach	2
S0001377	RAL RAL CREEK AND RAL RAL WIDEWATERS	Temporary Wetland - Overbank Flow	2
S0001381	WHIRLPOOL CORNER	Permanent Swamp - Throughflow	2
S0001434	LOWER PIKE RIVER	Permanent Reach	2
S0001435	LOWER PIKE RIVER	Permanent Reach	2
S0001439	PARINGA ISLAND	Permanent Swamp - Throughflow	2
S0001446	BERRI CAUSEWAY	Temporary Wetland - Terminal Branch	2
S0001478	WALL LEVEE	Temporary Wetland - Overbank Flow	2
S0001551	MOLO FLAT	Temporary Wetland - Throughflow	2
S0001557	YARRAMUNDI	Permanent Reach	2
S0001573	RILLI LAGOONS	Temporary Wetland - Throughflow	2
S0001614	SPECTACLE LAKES SOUTH	Ephemeral Reach	2
S0001619	WERTA WEST	Temporary Wetland - Overbank Flow	2
S0001623	BUNYIP HOLE	Temporary Wetland - Overbank Flow	2
S0001692	DELVINS POUND	Permanent Swamp - Terminal Branch	2
S0001696	BIG TOOLUNKA FLAT	Permanent Lake - Terminal Branch	2
S0001717	NIKALAPKO	Temporary Wetland - Throughflow	2
S0001746	ROONKA	Temporary Wetland - Overbank Flow	2
S0001754	ARLUNGA	Permanent Lake - Throughflow	2
S0001758	EDSONS FLAT	Temporary Wetland - Terminal Branch	2
S0001771	NORTH CAURNAMONT	Permanent Lake - Throughflow	2
S0001797	YOUNGHUSBAND POINT	Temporary Wetland - Throughflow	2
S0001800	LAKE CARLET	Temporary Wetland - Overbank Flow	2
S0001975	LOCK 6 DEPRESSION	Permanent Lake - Throughflow	2
S0001989	YOUNGHUSBAND	Temporary Wetland - Overbank Flow	2
S0001992	BOGGY FLAT	Temporary Wetland - Terminal Branch	2
S0016030	KATARAPKO CREEK AND KATARAPKO ISLAND	Ephemeral Reach	2
S0000001	ECKERT CREEK AND THE SPLASH	Permanent Reach	1
S0000015	EMU GULLY	Temporary Wetland - Overbank Flow	1
S0000035	ECKERT CREEK AND THE SPLASH	Permanent Reach	1
S0000044	LAKE LITTRA INLET	Ephemeral Reach	1
S0000049	OLD LOXTON ROAD LAGOON	Ephemeral Reach	1
S0000053	YOUNGHUSBAND	Permanent Swamp - Throughflow	1
S0000085	WALKER FLAT SOUTH LAGOON	Permanent Swamp - Throughflow	1
S0000092	PUNKAH CREEK	Ephemeral Reach	1
S0000095	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow	1

S0000096	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow	1
S0000133	ECKERT CREEK AND THE SPLASH	Permanent Reach	1
S0000175	LYRUP EAST	Temporary Wetland - Throughflow	1
S0000176	LYRUP EAST	Temporary Wetland - Overbank Flow	1
S0000200	MURBPOOK LAGOON COMPLEX	Permanent Swamp - Throughflow	1
S0000220	GOAT ISLAND AND PARINGA PADDOCK	Temporary Wetland - Throughflow	1
S0000251	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Overbank Flow	1
S0000269	IRWIN FLAT	Temporary Wetland - Terminal Branch	1
S0000282	ECKERT CREEK AND THE SPLASH	Permanent Reach	1
S0000289	ECKERT CREEK AND THE SPLASH	Permanent Reach	1
S0000306	YARRA COMPLEX	Temporary Wetland - Throughflow	1
S0000312	PARINGA ISLAND	Permanent Reach	1
S0000315	PUNKAH CREEK	Ephemeral Reach	1
S0000326	WOOLSHED CREEK	Ephemeral Reach	1
S0000385	COPPERMINE WATERHOLE	Temporary Wetland - Terminal Branch	1
S0000404	PYAP HORSESHOE	Permanent Lake - Throughflow	1
S0000405	GERARD SWAMPS	Temporary Wetland - Overbank Flow	1
S0000406	SPECTACLE LAKES SOUTH	Temporary Wetland - Throughflow	1
S0000427	SALT CREEK AND GURRA GURRA LAKES	Temporary Wetland - Terminal Branch	1
S0000434	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow	1
S0000457	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Overbank Flow	1
S0000467	WOOLENOOK BEND COMPLEX	Permanent Lake - Terminal Branch	1
S0000485	BRANDY BOTTLE WATERHOLE	Temporary Wetland - Throughflow	1
S0000495	PERRES FLOODPLAIN	Saline Swamp	1
S0000496	ECKERT CREEK AND THE SPLASH	Temporary Wetland - Overbank Flow	1
S0000498	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow	1
S0000506	THIELE FLAT	Saline Swamp	1
S0000531	BOOKMARK CREEK	Temporary Wetland - Throughflow	1
S0000541	ECKERT CREEK AND THE SPLASH	Temporary Wetland - Overbank Flow	1
S0000546	YARRAMUNDI	Permanent Reach	1
S0000547	BRENDA PARK	Permanent Lake - Throughflow	1
S0000564	RAL RAL CREEK AND RAL RAL WIDEWATERS	Temporary Wetland - Throughflow	1
S0000592	ON MARKARANKA FLOODPLAIN	Ephemeral Reach	1
S0000594	SWAN REACH COMPLEX	Permanent Lake - Terminal Branch	1
S0000596	REEDY CREEK SWAMP	Temporary Wetland - Throughflow	1
S0000619	GOAT ISLAND AND PARINGA PADDOCK	Temporary Wetland - Overbank Flow	1
S0000643	LITTLE TOOLUNKA FLAT	Temporary Wetland - Terminal Branch	1
S0000679	REEDY CREEK SWAMP	Temporary Wetland - Overbank Flow	1
S0000707	PENNS INLET	Permanent Swamp - Terminal Branch	1
S0000708	NIGRA CREEK	Temporary Wetland - Throughflow	1
S0000712	KINGSTON COMMON	Permanent Swamp - Throughflow	1
S0000718	LYRUP EAST	Permanent Swamp - Terminal Branch	1
S0000735	MURBKO SOUTH	Temporary Wetland - Throughflow	1
S0000745	BANROCK INLETS	Temporary Wetland - Overbank Flow	1
S0000747	OVERLAND CORNER COMPLEX	Temporary Wetland - Overbank Flow	1
S0000755	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Swamp - Throughflow	1

S0000780	KATARAPKO CREEK AND KATARAPKO ISLAND	Temporary Wetland - Throughflow	1
S0000800	GOAT ISLAND AND PARINGA PADDOCK	Permanent Reach	1
S0000819	SALT CREEK AND GURRA GURRA LAKES	Ephemeral Reach	1
S0000822	WINDING CREEK	Permanent Reach	1
S0000825	BLANCHETOWN CARAVAN PARK	Permanent Lake - Throughflow	1
S0000900	GERARD SWAMPS	Temporary Wetland - Terminal Branch	1
S0000924	BELDORA WETLANDS	Temporary Wetland - Throughflow	1
S0000957	WOOLENOOK BEND COMPLEX	Permanent Reach	1
S0000959	WOOLENOOK BEND COMPLEX	Permanent Lake - Terminal Branch	1
S0000971	NIKALAPKO WEST	Temporary Wetland - Throughflow	1
S0000974	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow	1
S0001026	LAKE WOOLPOLOOL	Saline Swamp	1
S0001028	LOXTON FLOODPLAIN	Temporary Wetland - Terminal Branch	1
S0001029	LOXTON FLOODPLAIN	Temporary Wetland - Throughflow	1
S0001049	WIGLEY REACH	Ephemeral Reach	1
S0001101	RAL RAL CREEK AND RAL RAL WIDEWATERS	Permanent Swamp - Throughflow	1
S0001110	BURRA CREEK	Permanent Swamp - Throughflow	1
S0001135	REID FLAT	Temporary Wetland - Terminal Branch	1
S0001137	LOCH LUNA AND NOCKBURRA CREEK	Permanent Lake - Throughflow	1
S0001160	DEVON DOWNS SOUTH	Permanent Reach	1
S0001165	MURTHO PARK COMPLEX	Ephemeral Reach	1
S0001167	MURTHO PARK COMPLEX	Temporary Wetland - Terminal Branch	1
S0001175	MURTHO PARK COMPLEX	Permanent Reach	1
S0001178	MURTHO PARK COMPLEX	Permanent Reach	1
S0001186	MUNDIC CREEK	Permanent Swamp - Terminal Branch	1
S0001240	SCOTT CREEK	Permanent Reach	1
S0001247	LYRUP CAUSEWAY EAST	Temporary Wetland - Overbank Flow	1
S0001257	ON MARKARANKA FLOODPLAIN	Temporary Wetland - Overbank Flow	1
S0001260	BANROCK INLETS	Temporary Wetland - Overbank Flow	1
S0001261	BANROCK SWAMP	Temporary Wetland - Terminal Branch	1
S0001271	MOLO FLAT	Ephemeral Reach	1
S0001281	SWAN REACH COMPLEX	Permanent Reach	1
S0001308	COMPLEX OPPOSITE YARRA GLEN	Temporary Wetland - Throughflow	1
S0001316	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow	1
S0001363	COPPERMINE WATERHOLE	Temporary Wetland - Throughflow	1
S0001374	BULYONG ISLAND BASIN	Permanent Reach	1
S0001442	PARINGA ISLAND	Permanent Swamp - Terminal Branch	1
S0001444	GOAT ISLAND AND PARINGA PADDOCK	Permanent Swamp - Terminal Branch	1
S0001451	MARTIN BEND COMPLEX	Temporary Wetland - Throughflow	1
S0001452	MURBKO FLAT COMPLEX	Temporary Wetland - Throughflow	1
S0001482	SUNNYSIDE CONSERVATION PARK AND PAIWALLA SWAMP	Permanent Swamp - Throughflow	1
S0001484	UPSTREAM OF RIVERGLADES	Temporary Wetland - Overbank Flow	1
S0001504	ECKERT CREEK AND THE SPLASH	Ephemeral Reach	1
S0001543	SCHILLERS LAGOON	Permanent Lake - Throughflow	1
S0001547	MARKARANKA	Temporary Wetland - Terminal Branch	1
S0001553	CADELL TRAINING CENTRE	Temporary Wetland - Terminal Branch	1
S0001554	PENFOLDS LAGOON	Permanent Lake - Throughflow	1
S0001558	YARRAMUNDI NORTH	Permanent Swamp - Throughflow	1

S0001620	HANCOCK CREEK	Ephemeral Reach	1
S0001634	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow	1
S0001636	MAIZE ISLAND COMPLEX	Temporary Wetland - Overbank Flow	1
S0001637	MAIZE ISLAND COMPLEX	Ephemeral Reach	1
S0001642	SWAN REACH FERRY	Permanent Lake - Throughflow	1
S0001662	WIGLEY REACH	Temporary Wetland - Throughflow	1
S0001663	MAIZE ISLAND COMPLEX	Temporary Wetland - Overbank Flow	1
S0001664	JAESCHKE LAGOON	Permanent Lake - Throughflow	1
S0001666	PASCHKES FLAT	Temporary Wetland - Terminal Branch	1
S0001667	YARRA COMPLEX	Permanent Lake - Terminal Branch	1
S0001675	MAIZE ISLAND COMPLEX	Temporary Wetland - Terminal Branch	1
S0001681	COMPLEX OPPOSITE YARRA GLEN	Temporary Wetland - Overbank Flow	1
S0001682	ROSS LAGOON	Permanent Lake - Throughflow	1
S0001703	QUALCO SWAMP	Temporary Wetland - Terminal Branch	1
S0001712	MOLO FLAT	Temporary Wetland - Terminal Branch	1
S0001719	MORGAN CONSERVATION PARK	Temporary Wetland - Throughflow	1
S0001720	MORGAN CONSERVATION PARK	Temporary Wetland - Terminal Branch	1
S0001722	NEAR WACHTELS LAGOON	Permanent Swamp - Throughflow	1
S0001740	MCBEAN POUND NORTH	Permanent Lake - Terminal Branch	1
S0001741	MCBEAN POUND SOUTH	Permanent Swamp - Throughflow	1
S0001749	ROONKA	Permanent Swamp - Throughflow	1
S0001757	BLANCHETOWN CARAVAN PARK	Permanent Swamp - Throughflow	1
S0001765	SCRUBBY FLAT	Temporary Wetland - Terminal Branch	1
S0001777	SALTBUSH FLAT	Permanent Lake - Terminal Branch	1
S0001798	YOUNGHUSBAND	Permanent Lake - Terminal Branch	1
S0001803	GOWLINGS WETLAND (Younghusband)	Temporary Wetland - Terminal Branch	1
S0001807	REEDY CREEK SWAMP	Temporary Wetland - Overbank Flow	1
S0001985	TEMPLETON	Temporary Wetland - Terminal Branch	1
S0001986	OVERLAND CORNER COMPLEX	Temporary Wetland - Throughflow	1
S0001990	YOUNGHUSBAND	Temporary Wetland - Terminal Branch	1
S0002019	MARKS LANDING	Permanent Lake - Throughflow	1
S0002742	SALT CREEK AND GURRA GURRA LAKES	Temporary Wetland - Terminal Branch	1
S0002748	KIA WETLAND?	Temporary Wetland - Overbank Flow	1
S0002824	WOOLENOOK BEND COMPLEX	Permanent Reach	1
S0002826	BOAT CREEK	Permanent Lake - Terminal Branch	1

Appendix 21: 'At-risk' all species-KEA associations (all taxonomic groups)

KEA Asset Name	KEA ID	No. 'At-Risk' Species	No. Taxonomic groups
Riverland Ramsar	1	25	5
Gurra Floodplain	10	18	5
Katarapko Floodplain	17	17	5
Loch Luna and Wachtels Lagoon	23	16	5
Pompoota/Paiwalla/Sunnyside	95	15	3
Morgan East & Morgan CP	54	14	5
Martins Bend	11	13	4
Mobilong Swamp incl. Rocky Gully	97	13	4
Hart Lagoon	37	12	4
Reedy Creek Mannum	91	12	5

Spectacle Lakes / Beldora Complex	21	12	5
Loveday Swamps and Mussel Lagoons	22	11	4
Nigra/Schillers	41	11	5
Moorundie Complex	66	10	5
Mypolonga/Toora Levee/Jury Swamp	96	10	3
Paringa Paddock	4	10	5
Riverglades	98	10	5
Boggy Flat	43	9	4
Devon Downs Complex	73	9	3
Murrundi	106	9	3
Paisley Creek/Edsons Flat	65	9	4
Swanport Wetland	101	9	3
Yatco Lagoon	19	9	5
Banrock Ramsar Complex (inc Wigley Reach)	25	8	3
Brenda Park / Morphetts Flat Complex	55	8	5
Coolcha Lagoon	85	8	4
Disher Creek	6	8	4
Overland Corner	26	8	4
Pike-Mundic	8	8	5
Rilli Lagoons	14	8	4
Kroehns Landing	75	7	3
Lake Carlet	86	7	3
Maize Island Complex	35	7	4
Murbko South Complex	58	7	4
Pyap Complex	18	7	4
Ramco Lagoon	38	7	4
Younghusband West	88	7	5
Big and Little Toolunka	39	6	3
Caurnamont	81	6	3
Mannum Swamps	90	6	3
Roonka/Arlunga	64	6	4
Wall Swamp	93	6	2
Wellington Complex	104	6	2
Wellington Spit	105	6	3
Wongulla Lagoon/Marne Mouth	76	6	3
Younghusband Complex	87	6	4
Donald Flat	61	5	2
Markaranka Complex	46	5	2
Murbko Flat Complex	57	5	3
Saltbush Flat	82	5	2
Sinclair Flat	63	5	3
Tailem Bend	103	5	1
Ukee Boat Club	99	5	3
Ajax Achilles	12	4	3
Complex opposite Yarra Glen	32	4	4
Holder Bend/Ross/Jaeschke	36	4	3
Loxton Floodplain	16	4	2
Lyrup Causeway	7	4	2
Nikalapko Complex	51	4	3
North Caurnamont	79	4	3
North West Bend	53	4	3
Weston Flat Lagoon	50	4	3
Forster Lagoon	77	3	2

Hogwash Bend Complex	47	3	3
Island Reach	34	3	3
Lyrup East	9	3	2
Murbpook Lagoon	59	3	2
Neeta Flat Depressions	92	3	2
North Purnong	80	3	2
Swan Reach Complex	67	3	3
Thiele Flat	15	3	2
Wall Levee/Wood Lane	94	3	2
Yarra Complex	33	3	3
Cadell Complex	52	2	2
Devlins Pound	31	2	1
Kingston Common	20	2	1
Nelwart / Bookmark	5	2	1
opp. Hogwash Bend	48	2	2
opp. Murbko Flat (d/s end)	62	2	2
opp. Swan Reach Complex	68	2	1
Punyelroo	71	2	2
Qualco Swamp	45	2	2
Reid Flat	44	2	2
Taworri Complex	89	2	2
Walker Flat Complex	78	2	2
Big Bend	72	1	1
Bow Hill	84	1	1
Clarks Sandbar	13	1	1
Craignook	83	1	1
Glen Devlin Complex	30	1	1
Glen Lee	56	1	1
Greenways Landing	74	1	1
Irwin Flat	60	1	1
Marks Landing	70	1	1
Mason Rock	102	1	1
opp. Ukee	100	1	1
Penns Inlet	40	1	1
Swan Reach Ferry	69	1	1
Wigley Flat (Akuna)	29	1	1