1-1-2012

The use of representative species as surrogates for wetland inundation

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Abstract

The complex task of determining the inundation requirements of large floodplain wetlands is often simplified through the use of representative, umbrella or flagship species. This subset of species is targeted based on the assumption that their collective inundation requirements serve as a surrogate for the broader suite of species found within the wetland. We tested the application of representative species commonly used in wetland and water management planning in the Murray-Darling Basin. In a review of the water requirements of 155 plants and animals, we collated information on preferred inundation timing, duration, depth, rate of rise and fall, and inter-flood period for 115 species. We then used cluster analysis to determine the extent to which ten commonly used representative species corresponded in inundation requirements to the broader suite of species. We found that the habitat surrogates of river red gum, black box, spike rush, coolibah, water couch, lignum and marsh club-rush represented only one third of species at a 60% level of similarity in inundation requirements, due mainly to the lower inundation return period and duration required by the habitat surrogates. The addition of faunal representative species facilitated the inclusion of a broader range of requirements, though primarily amongst related taxa. We recommend the inclusion of several additional indicator species to more adequately cover the inundation requirements of large wetland ecosystems.

Keywords

species, inundation, representative, surrogates, wetland

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

Publication Details

Rogers, K., Ralph, T. J. & Saintilan, N. (2012). The use of representative species as surrogates for wetland inundation. Wetlands: the journal of the Society of Wetland Scientists, 32 (2), 249-256.

The use of representative species as surrogates for wetland inundation

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ABSTRACT

The complex task of determining the inundation requirements of large floodplain wetlands is often simplified through the use of representative, umbrella or flagship species. This subset of species is targeted based on the assumption that their collective inundation requirements serve as a surrogate for the broader suite of species found within the wetland. We tested the application of representative species commonly used in wetland and water management planning in the Murray-Darling Basin. In a review of the water requirements of 155 plants and animals, we collated information on preferred inundation timing, duration, depth, rate of rise and fall, and inter-flood period for 115 species. We then used cluster analysis to determine the extent to which ten commonly used representative species corresponded in inundation requirements to the broader suite of species. We found that the habitat surrogates of river red gum, black box, spike rush, coolibah, water couch, lignum and marsh club-rush represented only one third of species at a 60% level of similarity in inundation requirements, due mainly to the lower inundation return period and duration required by the habitat surrogates. The addition of faunal representative species facilitated the inclusion of a broader range of requirements, though primarily amongst related taxa. We recommend the inclusion of several additional indicator species to more adequately cover the inundation requirements of large wetland ecosystems.

KEYWORDS

Murray-Darling Basin, floodplain wetlands, environmental water, surrogates, habitat, inundation

INTRODUCTION

Ecologically significant wetlands occur in low-lying areas of floodplains that are inundated by freshwater from rivers, creeks and distributary channels in semiarid, inland regions of Australia. The distribution of organisms across these floodplain wetlands and riverine landscapes reflects the relationship between antecedent flow history and the water dependencies of wetland biota (Lytle and Poff 2004). These ecosystems are naturally variable and are strongly influenced by the interrelationships between flood regimes, landforms, sediments and soils, as well as the internal dynamics of their ecological communities. The natural flood and flow regimes of Australian rivers are driven by climate variability and floodplain wetlands experience changes in the frequency, magnitude and duration of flooding in response to a range of large-scale ocean-atmosphere fluctuations that influence regional air pressure and circulation patterns, weather and rainfall. The compounding influence of various ocean-atmosphere fluctuations occurring at a range of timescales ensures that the hydrology of inland Australian catchments is highly-variable. For example, in the Murray-Darling Basin at least six climatic cycles influence riverine hydrology; the Indian Ocean Dipole, El Niño-Southern Oscillation , Southern Annular Mode, Interdecadal Pacific Oscillation, Madden-Julian Oscillation and Subtropical Ridge (Verdon, Wyatt, Kiem, & Franks, 2004; Drosdowsky, 2005; Verdon & Franks, 2006; Murphy & Timbal, 2008; Ummenhofer, England, McIntosh, Meyers, Pook, Risbey, Sen Gupta, & Taschettp, 2009; Nicholls, 2010). In addition, coinciding phenomena have been shown to suppress or enhance the magnitude and frequency of flood events, resulting in varying hydrological regimes. For example, large floods in the Murray-Darling Basin have been associated with positive ENSO events modulated by negative IPO phases (Ralph & Hesse, 2010). While prediction of the influence of these cycles on hydrology is challenging, it is now relatively well accepted that these phenomena play a significant role in the distribution of droughts and floods both spatially and temporally across inland Australia. This complexity also makes prediction of the effects of river flows and flood regimes problematic, especially in terms of ecohydrological relationships and water requirements of floodplain wetland biota. Similar hydrological complexity characterises other floodplain wetlands in dryland settings, for example, in southern Africa, where the ecologically diverse suite of wetlands may be permanently, seasonally or ephemerally inundated (Tooth & McCarthy, 2007).

Such variability has encouraged a range of biotic response strategies to flow (Puckridge et al. 1998), occupying niches in space and time ranging from the micro- (tens of metres/hours), to meso- (rivers and their reaches over months to years) to macro- (regional to intercontinental over decades to centuries: Kingsford et al. 2010). The dynamism inherent in the hydrological variability and biotic response in inland Australian rivers has been regulated within the Murray-Darling Basin by hydrological modification for irrigated agriculture and domestic water supply over several decades (Kingsford 2000). As a consequence, lateral connections between river channels and floodplains have changed, the spatial extent of many floodplain wetlands has diminished, and the ecological health and biodiversity of many wetlands has declined (Kingsford, 2000a; Kingsford, 2000b; Thoms, 2003; Kingsford & Thomas, 2004; Frazier & Page, 2006). Recognition of these additional pressures and the ongoing decline of floodplain wetlands and their biota have led to state and federal government intervention in water resource allocation and management and the development of new environmental water plans in the Murray-Darling Basin.

In highly regulated systems, the provision of flow to floodplain wetland and riverine systems for ecological benefit has, with the exception of floods and tributary flows, become a management function of agencies on the advice of environmental water managers. The key challenge faced by environmental water managers is therefore to match the ecological water requirements of species with a prescribed flow regime. This is a very complex task given the myriad of species occupying large wetland complexes, their ecological and trophic dependencies and their various responses to differing aspects of the hydrograph.

In practice, the task of prescribing flow regimes to sustain ecological values within floodplain wetlands has often been simplified by the selection of a subset of 'representative' species for consideration, sometimes termed 'flagship' or 'umbrella' species (Simberloff, 1998; Kingsford, Brandis, Jenkins, Nairn, & Rayner, 2010). Representative species might be selected to represent the water requirements of a broader range of species, either being representative of a suite of similar species, or providing habitat that, if protected, might provide the requirements of species contained therein. Often these species are labelled "iconic", being associated in the public mind with the wetland, and representing key values that management agencies are tasked to maintain.

Examples of the representative species approach can be found across a range of State and Commonwealth planning documents. An ecological risk assessment of Yanga National Park (DECCW 2009) identified the primary ecological assets for targeted water management as being river red gum woodland and *Eleocharis* rush swamp, the endangered southern bell frog, and the intermediate egret, an iconic waterbird species. The Adaptive Environmental Water Management Plan for the Ramsar-listed Gwydir Wetlands (DECCW 2009) highlights the ecological significance of broadly defined ecological communities, including marsh club-rush, water couch grassland, lignum, and coolibah/black box woodland, as well as faunal species of particular significance. The Commonwealth is pursuing a similar approach, with the draft Murray-Darling Basin Plan (MDBA 2010) seeking to accommodate the water requirements of the dominant vegetation communities found within significant wetlands, such as river red gum, black box, lignum and permanent reed swamps, setting targets for inundation extent and return interval for each community.

In support of management requirements, decision support tools developed to support environmental water management have also adopted the representative species approach. For example, the Murray Flow Assessment Tool, which aimed to assess the ecological benefits/impacts of different flow scenarios along the Murray River system, included models of native fish habitat condition, floodplain vegetation habitat condition, wetland vegetation habitat condition, waterbird habitat condition and algal growth ecological assessment models that utilised indicator species (Young *et al.* 2003). Similarly, wetland Decision Support Systems developed by the NSW Office of Environment and Heritage use a subset of species to compare water scenario outcomes of the Narran Lakes, Gwydir Wetlands, Macquarie Marshes and Lowbidgee Wetlands (Saintilan et al 2009).

This pragmatic approach is not without its dangers. An assumption underpinning much environmental water application and monitoring in the Murray-Darling is that accommodating the needs of representative species, and flagship habitat species in particular, will preserve the broader ecosystem components and processes contained therein. However, constituent flora and fauna may have quite different water requirements than the flagship species, and yet still occupy the same spaces.

Previous research established five fundamental characteristics of hydrologic regimes that regulate ecological processes in riverine settings and may influence the biotic composition of wetlands; 1) magnitude of flow, 2) frequency of occurrence of flow above a given magnitude, 3) duration of flow, 4) timing or predictability of flow and 5) the rate of change of flow (Richter, Baumgartner, Powell, & Braun, 1996; Poff, Allan, Bain, Karr, Prestegaard, Richter, Sparks, & Stromberg, 1997). In this study we reviewed the flow requirements of a broader suite of 155 wetland plant and animal species to determine how well the subset of representative species commonly used in environmental water planning represented the inundation requirements of other species found in the same wetlands.

METHODS

There have been few reviews of the water requirements of biota within the Murray-Darling Basin; namely Roberts and Marston (2011), which focussed on the water regime of wetland and floodplain plants and Rogers and Ralph (2011), which reviewed the water and habitat requirements of a range of biota including plants, waterbirds, fish, frogs, crustaceans and molluscs. The review by Rogers and Ralph (2011), was based on 542 published reports, and was used as the basis for this study. Species were selected for inclusion within the review when they were generally regarded as floodplain and/or wetland species that exhibit a distinct reliance on flooding, if they were relatively widespread and/or dominant within the floodplain wetlands of the Murray-Darling Basin, and when there was sufficient information available on their water requirements. Information was derived from grey literature (e.g. agency reports), research theses and primary sources such as peer-reviewed scientific publications and books.

For this analysis we compiled information from Rogers and Ralph (2010) on the ideal flood frequency, duration, depth, timing, rate of water fall and inter-flood dry-period for the maintenance and regeneration of 54 species of wetland plant, 52 species of waterbird, 21 fish species, 15 frog species, 6 crustacean species, and 11 mollusc species. This list included species commonly used as representative species in environmental water decision-making, notably river red gum (*Eucalyptus camaldulensis*); black box (*Eucalyptus largiflorens*); marsh club rush (*Bolboschoenus fluviatilis*); tall spike rush (*Eleocharis sphacelata*); water couch (*Paspalum distichum*); lignum (*Muehlenbeckia florulenta*); coolibah (*Eucalyptus coolibah*); southern bell frog (*Litoria raniformis*); the intermediate egret (*Ardea intermedia*) and the Australian white ibis (*Threskiornis molucca*). Bray-Curtis similarity matrices were generated using the flood metrics listed above (Bray & Curtis, 1957) and cluster analyses performed using a single analysis incorporating all species. All analyses were performed using Primer Version 5 software.

RESULTS

At the 60% similarity level, eight clusters of species, or “guilds” were identified and the hydrological requirements of these species were quantified (Figure 1, Table 1). The first guild consisted primarily of ephemeral wetland herbs and sedges. The similarity in this guild was based on a lack of information regarding the environmental water requirements of the clustered species. These species may cluster within other guilds should additional information about their environmental water requirements be available. Exclusion of these species from analysis did not influence the clustering of other species. The second and third guilds both consisted of individual species, coolibah (*E. coolibah*) as guild 2, and lignum (*Muehlenbeckia florulenta*) as guild 3, both characterised by low flooding frequency requirements. The fourth guild consisted primarily of frogs with an ability to respond to flooding in both Autumn and Spring. Due to relatively consistent requirements for annual flooding to maintain species condition, guilds 5, 6, 7 and 8 were largely differentiated on the basis of flood duration and flood timing. Guild 5 requires long flood duration that ideally would occur over spring and summer, guild 6 requires shorter flood duration of less than six months, while guild 8 prefers moderate flood durations of 2 to 9 months and with flooding occurring earlier in winter and spring. Guild 7 (which includes the black box *E. largiflorens* amongst 2 species) can tolerate a longer inter-flood dry period.

Of the commonly used representative habitat species, river red gum represented the inundation requirements of three species with 75% similarity; these being the giant rush, the grey teal, and the masked lapwing (see Table 1 for scientific names). Marsh club rush represented the inundation characteristics required of pale rush, and the Australasian Shelduck to 75% similarity. Water couch and tall spike-rush were useful in characterising the inundation requirements of several species to 75% similarity; these being the pacific heron, the Australasian grebe, the hoary headed grebe, the straw-necked ibis, the glossy ibis, wavy marshwort, narrow-leafed cumbungi; broad-leafed cumbungi, and three species of *Vallisneria*. As suggested above, lignum, coolibah and black box were not indicative of the inundation requirements of other species within the wetlands. Overall, the seven representative species represented the requirements of 16 additional species to 75% similarity and 51 species to 60% similarity, less than one third of the total number of additional wetland species.

Of the commonly used representative faunal species, southern bell frog represented the inundation requirements of 12 other species of frog and two species of spoonbill to 75% similarity or higher. The requirements of these species were not well represented by the requirements of the vegetation habitat species, in that longer duration flooding was required to ensure breeding success for this group. The intermediate egret is the only representative species grouped in guild 6, a group of 36 species. Of these, the intermediate egret is a useful surrogate for inundation requirements of the great egret, the black swan, the little egret and the darter, and represents the inundation characteristics of the other 31 species of this guild by less than 65% similarity. Species not represented by any of the representative species include the sedges, several species of *Juncus* and *Eleocharis* rush, and most species of ducks, pelicans, herons and cormorants.

DISCUSSION AND CONCLUSION

Representative, ’iconic’, ’flagship’ or ‘umbrella’ species (Simberloff, 1998) of plants and animals are commonly used as environmental watering targets in the Murray-Darling Basin, and surrogates for the inundation requirements of a broader group of species (Kingsford et al., 2010; Saintilan, 2011). In its simplest form, this strategy takes the form of meeting the requirements of key vegetated habitats, on the assumption that the habitats will in turn look after the constituent species and ecosystem processes.

Our analysis suggests that the prevailing habitat focus may not be as useful a guide to overall biodiversity conservation within wetlands as previously thought. Of the species used as habitat surrogates, several had uniquely low flooding frequency requirements (river red gum, black box, coolibah, lignum) and the flooding requirements of the remaining habitats (marsh club rush, water couch, spike rush, river red gum) did not correspond to the majority of the associated flora and fauna.

The addition of faunal surrogates improves the representation of species, particularly species within related taxa. The intermediate egret is a good representative of other egrets, and the southern bell frog usefully represents a group of frog species within the genera of *Litoria* and *Limnodynastes*, though it is possible that on the basis of limited information the water requirements of these species have been deduced from the more closely studied southern bell frog.

Several groups of species are not well represented by currently used surrogates, in particular sedges, rushes, herons and cormorants. Not all these will occur in all wetlands, but where they do occur consideration needs to be given to their water requirements, and this might be best achieved by utilising representative species in the appropriate guild. These guilds of species grouped on the basis of hydrological requirements provide a more robust basis for determining appropriate inundation regime for the maintenance of biodiversity than the nomination of numerically dominant iconic species.

The process of condensing the information contained within Rogers and Ralph (2011) into a database highlighted the gaps in our knowledge of the response of species to water regimes. For example, there was relatively little information about the water needs for many species of frogs, crustaceans and molluscs (Jones, 2011; Wassens, 2011). The water requirements of insects were completely omitted from this analysis due to the dearth of available information, an issue that needs addressing since the loss of lower trophic level species may uncouple the trophic linkages between biota (e.g. food webs) and may have significant impacts on higher order species such as fish and waterbirds (Winder & Schindler, 2004). Similarly, flood frequency requirements for waterbirds were inferred from their wild or captive life expectancy and there is an urgent need for population viability analyses and research into the influence of wetland connectivity on waterbird populations (Rogers, 2011).

The improvement of water requirements information will only occur if environmental flow monitoring programs incorporate responses of a range of biota. The temptation to default to monitoring the condition of vegetated habitats should be avoided, given the mismatch between the inundation regime sufficient to maintain these habitats and the requirements of constituent biota.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contribution of Jennifer Spencer, Skye Wassens, Hugh Jones and Tom Rayner to the database of the water requirements of floodplain wetland biota in the Murray-Darling Basin. Funding for the database was provided by the NSW Office of Environment and Heritage, and the former NSW Greenhouse Office. We also acknowledge Paul Dajuk and Daniel O’Connor from *xiion* who developed the database framework; and Matt Colloff and an anonymous reviewer for providing valuable comments on this manuscript.

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FIGURES

Figure 1: Dendrogram of Bray-Curtis cluster analysis of the environmental water requirements of floodplain wetland biota within the Murray-Darling Basin.

See table 1 for species names.

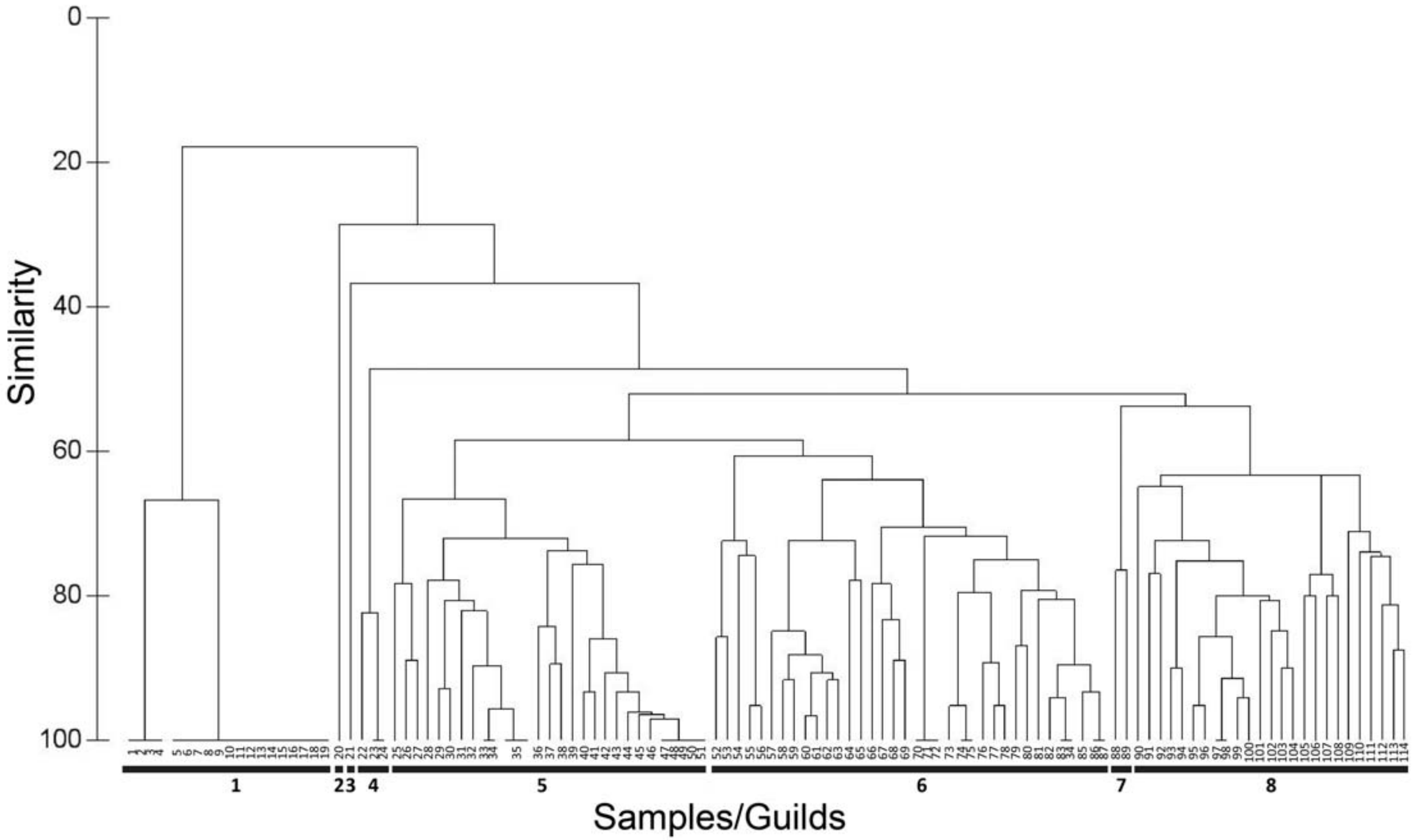

Table 1: Guilds of species and preferred flood conditions for each guild

Guild	Label	*Scientific name*	Common name	Preferred flood conditions
1	1	*Tringa stagnatilis*	Marsh sandpiper	• Requires annual flooding • Little knowledge of water needs in terms of timing and duration.
	2	*Tringa nebularia*	Common greenshank	
	3	*Limosa limosa*	Black-tailed godwit	
	4	*Calidris acuminata*	Sharp-tailed sandpiper	
	5	*Cyperus difformis*	Rice sedge	
	6	*Isotoma fluviatilis*	Swamp isotome	
	7	*Isotoma tridens*	Isotome species	
	8	*Ranunculus pumilio*	Ferny buttercup	
	9	*Ranunculus sceleratus*	Celery buttercup	
	10	*Ranunculus undosus*	Swamp buttercup	
	11	*Cyperus concinnus*	Trim flat-sedge	
	12	*Ludwigia octavalvis*	Willow primrose	
	13	*Marsilea costulifera*	Narrow-leaf nardoo	
	14	*Nymphoides geminate*	Entire marshwort	
	15	*Nymphoides indica*	Water snowflake	
	16	*Nymphoides montana*	Marshwort	
	17	*Nymphoides spinulosperma*	Marbled marshwort	
	18	*Pratia purpurascens*	Whiteroot	
	19	*Ranunculus muricatus*	Sharp buttercup	
2	**20**	***Eucalyptus coolabah***	**Coolibah**	• Very low flood frequency, greater than 10 years
3	**21**	***Muehlenbeckia florulenta***	**Lignum**	• Low flood frequency, 3 to 10 years
4	22	*Cyclorana platycephala*	Water-holding frog	• Requires annual flooding • Prefers flood duration of 3 to 6 months • Dual flood timing of March to April and September to November
	23	*Cyclorana verrucosa*	Rough frog	
	24	*Cyclorana alboguttata*	Striped burrowing frog	
5	25	*Ardea pacifica*	Pacific heron	• Generally prefer annual flooding to maintain condition • Requires long flood durations of up to 12 months
	26	*Tachybaptus novaehollandiae*	Australasian grebe	

	27	*Poliocephalus poliocephalus*	Hoary-headed grebe	• Preferred flood timing of spring to summer
	28	***Paspalum distichum***	**Water couch**	
	29	*Threskiornis spinicollis*	Straw-necked ibis	
	30	*Plegadis falcinellus*	Glossy ibis	
	31	***Eleocharis sphacelata***	**Tall spike-rush**	
	32	*Nymphoides crenata*	Wavy marshwort	
	33	*Typha domingensis*	Narrow-leaved cumbungi	
	34	*Typha orientalis*	Broafleaf cumbungi	
	35	*Vallisneria spp.*	Vallisneria	
	36	*Egretta novaehollandiae*	White-faced heron	
	37	***Threskiornis molucca***	**Australian white ibis**	
	38	*Platalea regia*	Royal spoonbill	
	39	*Platalea flavipes*	Yellow-billed spoonbill	
	40	*Limnodynastes dumerili*	Eastern banjo frog	
	41	*Larus novaehollandiae*	Silver gull	
	42	*Crinia signifera*	Common eastern froglet	
	43	*Litoria rubella*	Desert tree frog	
	44	*Limnodynastes interioris*	Giant banjo frog	
	45	*Litoria peronii*	Peron's tree frog	
	46	*Limnodynastes tasmaniensis*	Spotted marsh frog	
	47	*Limnodynastest fletcheri*	Barking marsh frog	
	48	*Limnodynastes terrareginae*	Northern banjo frog	
	49	*Crinia parinsignifera*	Eastern sign-bearing froglet	
	50	***Litoria raniformis***	**Southern bell frog**	
	51	*Litoria latopalmata*	Broad palmed frog	
6	52	*Egretta garzetta*	Little egret	• Generally prefer annual flooding to maintain condition • Prefers flooding of less than 6 months, but species prefer permanent flood conditions • Preferred flood timing of spring to summer, but may occur as late as autumn
	53	*Anhinga melanogaster*	Darter	
	54	*Cygnus atratus*	Black swan	
	55	***Ardea intermedia***	**Intermediate egret**	
	56	*Ardea alba*	Great egret	

	57	*Marsilea drummondii*	Common nardoo	
	58	*Malacorhynchus membranaceus*	Pink-eared duck	
	59	*Cyperus exaltatus*	Tall flat-sedge	
	60	*Bolboschoenus medianus*	Marsh club rush	
	61	*Cyperus gymnaucolos*	Spiny flat-sedge	
	62	*Cyperus rigidellus*	Curly flat-sedge	
	63	*Eleocharis acuta*	Common spike-rush	
	64	*Litoria caerulea*	Common green tree frog	
	65	*Podiceps cristatus*	Great crested grebe	
	66	*Chlidonias hybridus*	Hoary-headed grebe	
	67	*Sterna nilotica*	Whiskered tern	
	68	*Dendrocygna eytoni*	Plumed whistling-duck	
	69	*Pelecanus conspicillatus*	Australian pelican	
	70	*Bolboschoenus caldwellii*	Marsh club rush	
	71	*Isotoma axillaris*	Rock isotome	
	72	*Pratia concolor*	Poison pratia	
	73	*Phalacrocorax varius*	Pied cormorant	
	74	*Eleocharis plana*	Flat spike-rush	
	75	*Eleocharis pusilla*	Small-spike rush	
	76	*Phalacrocorax sulcirostris*	Little black cormorant	
	77	*Nycticorax caledonicus*	Rufous night heron	
	78	*Phalacrocorax melanoleucos*	Little pied cormorant	
	79	*Elseyornis melanops*	Black-fronted dotterel	
	80	*Recurvirostra novaehollandiae*	Red-necked avocet	
	81	*Oxyura australis*	Blue-billed duck	
	82	*Juncus aridicola*	Tussock rush	
	83	*Juncus flavidus*	Gold rush	
	84	*Juncus usitatus*	Billabong rush	
	85	*Sterna caspia*	Caspian tern	
	86	*Cyperus bifax*	Downs nutgrass	

	87	*Eleocharis pallens*	Pale spike-rush	
7	88 **89**	*Phalacrocorax carbo* ***Eucalyptus largiflorens***	Great cormorant **Black box**	• Do not require annual flooding to maintain condition • Prefers moderate flood durations or 2 to 9 months • Preferred flood timing of winter to spring.
8	90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 **108** 109 110 111 **112** 113 114	*Anas superciliosa* *Anas castanea* *Phragmites australis* *Gallinula ventralis* *Fulica atra* *Biziura lobata* *Aythya australis* *Porphyrio porphyrio* *Anas rhynchotis* *Erythrogonys cinctus* *Himantopus himantopus* *Chenonetta jubata* *Stictonetta naevosa* *Charadrius ruficapillus* *Grus rubicunda* *Vanellus miles* *Anas gracilis* *Juncus ingens* ***Eucalyptus camaldulensis*** *Ludwigia peploides* *Ranunculus inundatus* *Vanellus tricolor* ***Bolboschoenus fluviatilis*** *Tadorna tadornoides* *Juncus pallidus*	Pacific black duck Chestnut teal Common reed Black-tailed native-hen Eurasian coot Musk duck Hardhead Purple swamphen Australasian shoveler Red-kneed dotterel Black-winged stilt Maned duck Freckled duck Red-capped plover Brolga Masked lapwing Grey teal Giant rush **River red gum** Water primrose River buttercup Banded lapwing **Marsh club rush** Australasian shelduck Pale rush	• Generally prefer annual flooding to maintain condition • Prefers moderate flood durations or 2 to 9 months • Preferred flood timing of winter to spring.