FACTORS INFLUENCING BIODIVERSITY IN COASTAL PLAIN WETLANDS OF SOUTHWESTERN AUSTRALIA

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Abstract

The Swan Coastal Plain, in southwestern Australia, contains over 10,000 wetlands but these are considered to represent only 30% of the wetlands present at the time of British settlement in 1829. The remainder have been drained, filled in or otherwise lost as a consequence of agricultural activities and urban development occurring over the past 170 years. Most of the wetlands are groundwater dominated and a strongly seasonal hydrological cycle dominates wetland processes. Although a number of studies have been undertaken to document the wetland resources of the region, no overview of the biological diversity of these systems exists. The objective of this paper is to describe the biodiversity of the major components of the wetland biota and to examine the factors that determined diversity within each group. A review of existing datasets revealed that small wetlands, seasonal wetlands, coloured (tannin-stained) wetlands and non-enriched wetlands supported the richest invertebrate communities. In contrast, the larger wetlands, those with a permanent water regime and eutrophic wetlands supported the richest and most abundant waterbird communities. The seasonal and ephemeral wetlands (locally known as damplands) supported the richest plant communities. Clearly different components of the biota are most diverse under different conditions of wetland size, water depth, duration of flooding, light climate and trophic status. These results clearly demonstrated that to maintain biodiversity we need to conserve and protect a range of different types of wetlands on the Swan Coastal Plain.

Introduction

The wetlands of the Swan Coastal Plain are a dominant natural feature of a region that supports approximately 80% of Western Australia's population (1.2 million people). A recent mapping and evaluation project, for part of the region, recorded 10,000 basin and flat wetlands and estimated the total area of the wetland resource to be 362,253 ha or over one quarter of the total land area (Hill et al. 1996). Of these only 17% remained fully vegetated with predominantly native species and only 45% remained more than 50% vegetated. Overall, an estimated 70% of the original wetlands have been drained, filled in or otherwise lost as a consequence of agricultural activities and urban development since British settlement in 1829 (Halse 1989).

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Water in most of wetlands of the region is derived predominantly from groundwater and water levels largely reflect the height of the water table. The region experiences a Mediterranean climate characterised by winter rainfall and warm, dry summers. Both groundwater levels and surface inflow are greatest in winter/spring and least in summer/autumn, with a mean change in wetland water depth of about 1.5m (Townley et al. 1993). The strongly seasonal hydrological cycle dominates wetland processes. Nutrients enter the wetlands in groundwater inflows and surface run-off during winter, while high rates of evaporation, coupled with little rainfall, result in the concentration of nutrients and salts during summer. Increased light and temperatures provide favourable conditions for plant growth and it is at this time that the wetlands are most productive.

Wetlands support, either directly or indirectly, most of the wildlife of the Swan Coastal Plain (Seddon 1972). Their importance however extends beyond the immediate region, as they are visited each summer by migratory shorebirds from the Northern Hemisphere, and Australia is signatory to international conventions that oblige it to protect the habitats of many of these species (Arnold and Wallis 1986, Hails 1996). Although a number of studies have been undertaken to more fully describe and document the wetland resources of the region, no overview of the biological diversity of these systems exists. The objective of this paper is to describe the biodiversity, specifically the species richness, of three major components of the wetland biota (plants, aquatic invertebrates and waterbirds) and to examine the factors that determine diversity within each group.

Methods

Information on the aquatic invertebrate fauna of Swan Coastal Plain wetlands was obtained from the study of Davis et al. (1993). They sampled forty wetlands (Figure 1), of varying nutrient status, on three occasions (summer 1989, spring 1989 and spring 1990) to obtain a classification of wetlands based on water quality and invertebrate community structure. Information on waterbirds was obtained from the work of Storey et al. (1993), which examined waterbird usage of 251 wetlands, including all but three of those studied by Davis et al. (1993). Surveys were undertaken every three months from April 1990 to January 1992 at a wide range of waterbodies including: permanent and seasonal swamps, winter wet areas, river sections, drains, estuarine lagoons and artificial wetlands. A large component of the survey work was undertaken by volunteers who were coordinated by the RAOU (now Birds Australia). Information on wetland plant communities was obtained from a floristic survey of the southern Swan Coastal Plain undertaken by Gibson et al. (1994) and a study of remnant vegetation of the eastern region of the Swan Coastal Plain by Keighery and Trudgen (1992). Only data on aquatic and wetland-associated plant species have been included in this paper. We use the term wetland-associated to refer to species growing in, or on the banks, of wetlands. Many such species are never completely submersed.

Relationships between species richness of aquatic invertebrates and waterbirds at 36 wetlands common to the studies of Davis et al. (1993) and Storey et al. (1993), and 13 environmental or biological variables measured, were examined using cor-

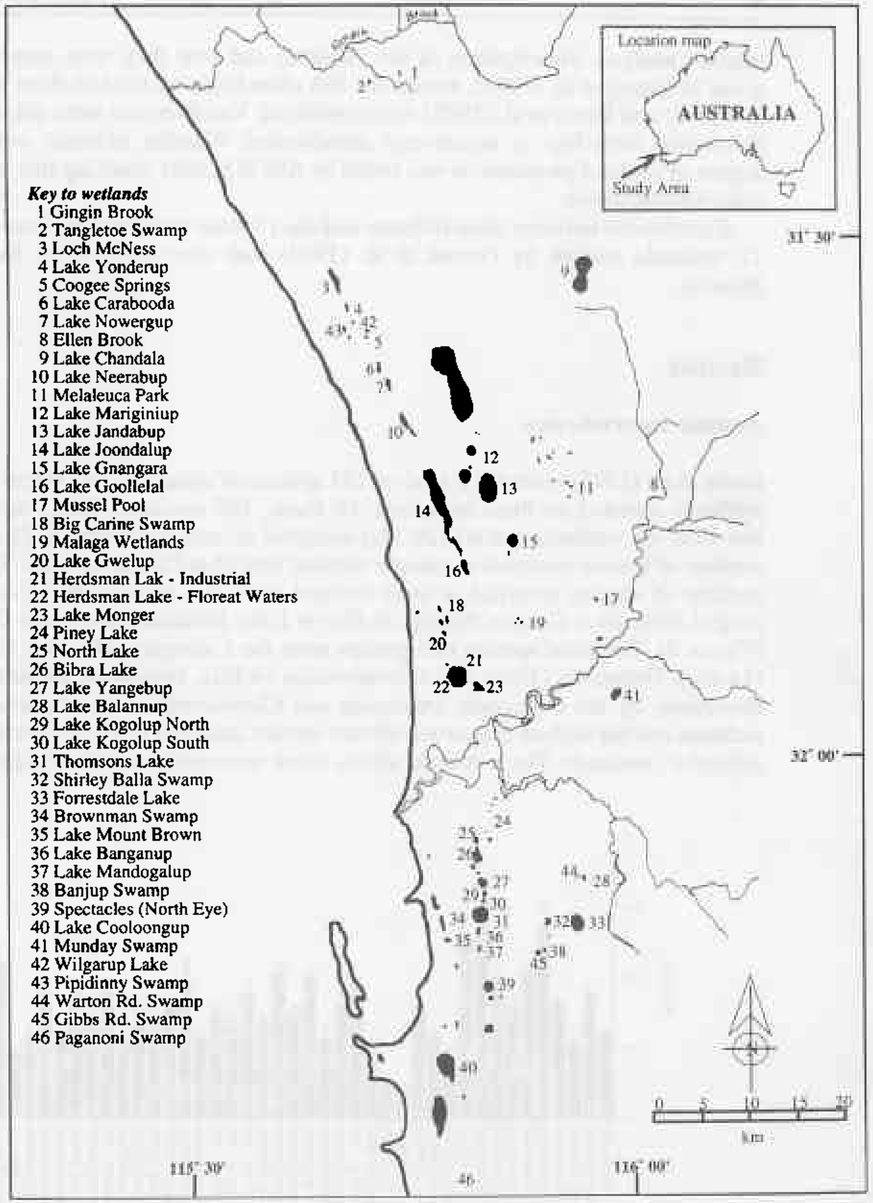

Fig. 1. Location of the wetlands sampled by Davis et al. (1993) on the Swan Coastal Plain in southwestern Australia.

relation analysis. Descriptions of the variables and how they were measured are given in Storey et al. (1993), except for fish abundance where data from Storey et al. (1993) and Davis et al. (1993) were combined. Variables that were not normally distributed were log- or square-root transformed. Whether richness varied with degree of wetland permanence was tested by ANOVA, after checking that variances were homogeneous.

Correlations between plant richness and the 13 other variables were examined at 12 wetlands studied by Froend et al. (1993) that were common to the faunal datasets.

Results

Aquatic Invertebrates

Davis et al. (1993) recorded a total of 253 species of aquatic invertebrates from 40 wetlands sampled on three occasions. Of these, 140 species (55.3%) occurred in less than six wetlands and 61 (24.1%) occurred in only one wetland. The highest number of species recorded at a single wetland was 95 at Coogee Springs. The mean number of species recorded at each wetland, over the three sampling occasions, ranged from 30 at Coogee Springs to five at Lake Joondalup and Lake Gnangara (Figure 2). The most species rich groups were the Coleoptera (16.6%), Cladocera (14.6%), Ostracoda (10%) and Chironomidae (9.1%). Numerical abundance was dominated by the Copepoda, Ostracoda and Chironomidae. The highest species richness and the highest proportion of rare species occurred in the coloured and less eutrophic wetlands. The wetlands which dried seasonally contained significantly

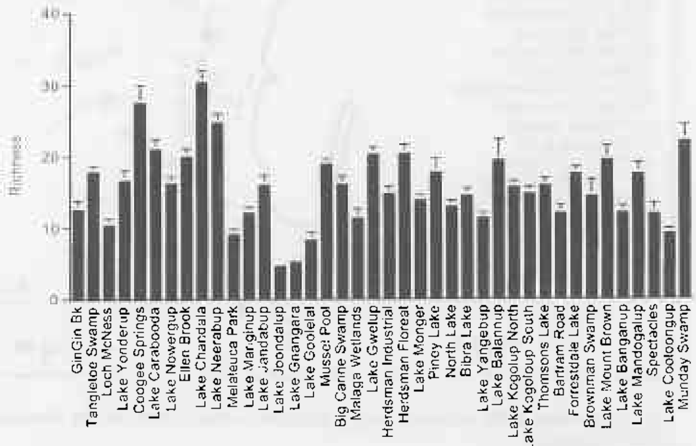

Fig. 2. Mean number of species of aquatic invertebrates recorded at selected wetlands on the Swan Coastal, in southwestern Australia, over three sampling sessions (spring and summer, 1989 and spring, 1990).

higher species richness ($P<0.05$, all sampling occasions). Invertebrate abundances were highest, but richness was reduced, in the highly eutrophic wetlands. Davis et al. (1993) concluded that the main factors affecting the composition and abundance of wetland invertebrate communities on the Swan Coastal Plain were salinity, degree of eutrophication, colour (gilvin) and water regime (seasonality). Interannual or seasonal variability was highest in the coloured and less eutrophic wetlands and least in the highly eutrophic, permanent wetlands.

Waterbirds

Storey et al. (1993) recorded 79 species of waterbirds from 251 wetlands sampled seasonally over two years. Thirty nine of these were recorded as breeding in the wetlands. The most abundant species were the Eurasian Coot *(Fulica atra)*, the Grey Teal *(Anas gibberifons)* and the Pacific Black Duck *(Anas superciliosa)*. More species were recorded in permanent wetlands than in seasonal wetlands. Three groups of wetlands were identified comprising a) high waterbird richness and abundance, b) low waterbird richness and abundance and c) intermediate levels of use. Twelve species occurred only in seasonal wetlands while two species occurred in permanent wetlands only. Waterbird usage was positively correlated with parameters related to wetland size, depth, vegetation structure and primary productivity and inversely related to colour. Regression analyses revealed that wetland area alone accounted for 44% of variation in waterbird richness while wetland area, area of emergent macrophytes (sedges or rushes), depth, pH and nitrogen levels accounted for 57%.

Forty-six waterbirds occurred frequently enough to examine environmental associations. Variables related to wetland area, vegetation structure, width of the wading zone (i.e. from shoreline to 0.3 m depth), season, depth and salinity were most often associated with the occurrence of individual species but regression analysis using these parameters could explain only 20-30% of their abundance.

Plant communities

Keighery and Trudgen (1992) found that the ephemeral wetlands (which contained water for less than six months each year) on the eastern Swan Coastal Plain (SCP) were major centres of endemism for terrestrial plant communities. Gibson et al. (1994) found that the seasonal wetlands on the southern SCP were the most heterogenous with respect to plant communities. Both studies were however, concerned primarily with habitats where both terrestrial floras overlap the wetland flora, significantly increasing the species richness. Little information is available on the diversity of aquatic macrophytes and fringing wetland vegetation over the range of Swan Coastal Plain wetlands. Work conducted by Pettit and Froend (1999) and Ladd (1999) on the fringing vegetation of 13 SCP wetlands, indicated that for seasonal and semi-permanent wetlands, there is no significant relationship between plant species richness and water permanence. As these studies concentrated on fringing rather than aquatic species, the influence of the surrounding terrestrial flora on species richness cannot be discounted. The classification of fringing flora as "wetland" species is dependent on the demarcation of artificial boundaries based on species' association with aquatic habitats. Species with broad tolerance ranges may be classified as being both wetland and terrestrial. It is these species which significantly increase the native species richness of fringing vegetation and over-ride differences in richness that might otherwise be evident if aquatic macrophytes alone were considered. In comparison, 23 wetlands throughout the south west of WA (of which the SCP is part) assessed by Gurner et al. (1999) also showed no significant relationship between richness, water permanence and salinity. These wetlands covered a very broad range of hydrologic regimes, soil types and floras.

Pettit and Froend (1999) also noted the importance of exotic species in the fringing vegetation of the SCP. In some cases over 50% of the species composition was comprised of annual and perennial exotic herbaceous and woody plants. The distribution and cover of annual exotic plants altered significantly in accordance with annual patterns in wetland water levels.

Relationships between invertebrate and waterbird richness and environmental parameters

At the 36 wetlands common to the studies of Davis et al. (1993) and Storey et al. (1993), there was no correlation between the species richness of invertebrates and waterbirds (Table 1); nor was there any correlation between invertebrate, waterbird or plant richness at the 12 wetlands for which plant data were available (Froend et al. 1993). Waterbird abundance was highly correlated with waterbird species richness but invertebrate richness and biomass were not. Plant richness was not related to percentage cover but was significantly correlated with number of life forms. Ranking of the 20 wetlands at which the highest number of species of waterbirds were recorded revealed that these were rarely the most important wetlands with respect to invertebrate species richness (Table 2). Thomsons Lake, which is a Ramsar site, contained the second highest number of species (43) of waterbirds but ranked only 18/40 with respect to invertebrate species richness. A comparison of ranks based on mean richness of waterbirds and invertebrates at the 20 most important waterbird sites revealed that only one wetland, Herdsman Lake, was important for both waterbird and invertebrate richness (Table 2).

Waterbirds and invertebrates often responded in different ways to the same parameters (Table 1). For example, while invertebrate species richness was negatively correlated with area, waterbird richness and abundance were positively related to this parameter. Similarly, invertebrate richness and waterbird abundance responded in opposite ways to the colour and percentage cover of the emergent vegetation. While waterbird richness and abundance increased with depth, invertebrate richness did not. Waterbird richness and abundance also varied with the related variable, period of inundation (F=8.82 and 9.10 respectively, P<0.001), with richness and abundance being lower in seasonal wetlands than semi-permanent or permanent ones (P<0.05, Duncan's multiple range test).

The effect of eutrophication was less clear. Waterbirds and invertebrate biomass were correlated with chlorophyll levels (a measure of primary productivity and commonly used measure of eutrophication) but not nutrients, while invertebrate richness was correlated with total soluble phosphorus concentrations but not chlorophyll. Phosphorus concentrations were highly correlated with colour, to

Table 1. Correlations (P values are the lower number in each cell) between number of invertebrate and waterbird species, average waterbird numbers and invertebrate biomass in Perth wetlands (N = 36). Data provided by the studies of Davis et al. (1993) and Storey et al. (1993a).

	Invertebrate Richness	Waterbird Richness	No. of Waterbird	Biomass of invertebrates	Wetland area	Depth	Salinity	Colour	% cover of vegetation	No of life forms	Fish abundance	Macrophyte abundance	Total N	Total P	Chlorophyll
Invertebrate Richness	1.00	-0.169	-0.151	-0.689	*-0.394*	-0.138	-0.156	*0.420*	*0.330*	0.010	0.016	0.032	-0.207	*0.537*	-0.145
		0.381	0.381	0.690	*0.018*	0.424	0.362	*0.011*	*0.050*	0.952	0.924	0.853	0.225	*0.001*	0.399
Waterbird Richness		1.00	*0.921*	0.078	*0.404*	*0.431*	0.077	-0.200	-0.178	0.004	0.172	-0.057	0.201	0.149	*0.532*
			0.001	0.651	*0.015*	*0.009*	0.654	0.241	0.298	0.981	0.316	0.741	0.240	0.386	*0.001*
No. of Waterbirds			1.00	0.099	*0.444*	*0.359*	0.144	*-0.346*	*-0.357*	-0.001	0.130	-0.095	0.219	0.098	*0.459*
				0.564	*0.007*	*0.032*	0.401	*0.038*	*0.032*	0.994	0.449	0.582	0.200	0.572	*0.005*
Biomass of Invertebrates				1.00	-0.149	0.008	*0.408*	0.165	0.023	-0.036	-0.061	0.296	0.312	0.147	*0.344*
					0.386	0.964	*0.014*	0.336	0.896	0.836	0.724	0.079	0.064	0.393	*0.040*
Wetland area					1.00	0.255	0.023	*-0.477*	-0.149	-0.089	-0.049	-0.122	0.142	-0.110	0.063
						0.133	0.892	*0.003*	0.384	0.607	0.775	0.477	0.408	0.522	0.715
Depth						1.00	-0.301	-0.311	0.118	0.113	*0.418*	*-0.380*	-0.277	-0.158	0.231
							0.074	0.065	0.492	0.513	*0.011*	*0.022*	0.101	0.358	0.176
Salinity							1.00	0.170	-0.116	-0.310	-0.249	*0.604*	*0.510*	0.087	0.011
								0.321	0.499	0.066	0.142	*0.001*	*0.002*	0.614	0.948
Colour								1.00	*0.427*	-0.113	-0.076	0.215	*0.438*	*0.693*	0.027
									0.009	0.513	0.660	0.208	*0.008*	*0.001*	0.874
Percent cover of vegetation									1.00	0.121	0.108	0.097	-0.160	0.261	-0.227
										0.481	0.530	0.572	0.351	0.124	0.183
No of lifeforms										1.00	0.190	0.121	-0.272	-0.074	0.030
											0.267	0.480	0.108	0.668	0.862
Fish abundance											1.00	*-0.336*	-0.230	-0.072	-0.094
												0.045	0.178	0.675	0.584
Macrophyte abundance												1.00	0.181	0.017	0.051
													0.291	0.920	0.769
Total N													1.00	*0.474*	0.148
														0.004	0.389
Total P														1.00	0.189
															0.270
Chlorophyll															

Table 2. Comparison of ranks based on the total number of species of waterbirds and invertebrates recorded at the 20 most important waterbird sites. Data provided by the studies of Davis et al. (1993) and Storey et al. (1993).

Wetland	No. of Species of Waterbirds	Waterbird Rank	No. of Species of invertebrates	Invertebrate Rank
Lake McLarty	51	1	ns	ns
Thomsons Lake	47	2	53	18
Lake Forrestdale	43	3	62	12
Alfred Cove	41	4	ns	ns
Herdsman Lake	40	5	60	14
Hurstview Lake	39	6	ns	ns
Kogolup Lake	39	7	50	22
Lake Mealup	39	8	ns	ns
Barrett-Leonard Lake	37	9	ns	ns
Lake Yangebup	36	10	31	36
Bibra Lake	35	11	43	27
Joondalup South	34	12	ns	ns
Namming Lake	34	13	ns	ns
Belmont Claypits	33	14	ns	ns
Joondalup North	33	15	18	40
Lake Monger	33	16	35	33
Nicolson-Oxley	33	17	ns	ns
The Spectacles	33	18	49	23
Blyths Lake	33	19	ns	ns
Lake Chittering	30	20	ns	ns

which invertebrate richness was also related, and it is possible that colour (or another factor related to high phosphorus concentrations) is the causal link between invertebrate richness and phosphorus. Invertebrate biomass increased with salinity.

Further examination of Table 1 highlights that few variables correlated with invertebrate or waterbird richness can be viewed in isolation. Colour was inversely related to wetland area, nutrients, and extent and structural diversity of vegetation; macrophyte biomass was negatively related to fish and positively related to salinity. Nitrogen and phosphorus were correlated, while fish abundance was negatively related to depth.

Discussion

The data obtained for aquatic invertebrates, waterbirds and wetland-associated vegetation of wetlands on the Swan Coastal Plain illustrated the varied responses of the different biotic groups to wetland environments and the underlying fact that different types of wetlands are important for biodiversity in different biotic groups. The role of different water regimes in maintaining biodiversity was also apparent. Seasonal wetlands supported the richest invertebrate communities. In contrast, more permanent wetlands supported the richest and most abundant waterbird communities. However, it must also be noted that large shallow wetlands that dry seasonally are very important for migratory waders/shorebirds. Three large and shallow wetlands on the Swan Coastal Plain (Thomsons, Forrestdale and McLarty Lakes) have been listed as Ramsar sites because of their importance as habitats for migratory waders/shorebirds (Blackey et al. 1996). These are species for which the

width of the wading zone is important. Shallow, ephemeral wetlands (known locally as damplands) support the richest wetland-associated plant communities.

It is important to recognise that the variables appearing to influence wetland communities are often dependent on regional setting. For example, while many individual waterbird species responded to salinity on the Swan Coastal Plain, the range of salinities (0.1-8 g L^{-1}) was insufficient to affect waterbird richness, whereas Halse et al. (1993) showed that salinity was major determinant of waterbird richness at salinities greater than about 10 g L^{-1}.

The different responses demonstrated to wetland area, colour, extent of emergent vegetation, water regime and primary productivity are probably representative of a much larger array of environmental parameters to which different biotic groups respond differently. The implication for management is that to maintain biodiversity on the Swan Coastal Plain we need to protect and conserve a range of different types of wetland. Halse et al. (2000) demonstrated the same phenomenon in wetlands on Western Australian rangelands.

It is difficult to compare the invertebrate richness of Perth wetlands with those elsewhere in Australia, or on other continents, as few studies using comparable sampling methods, similar sampling effort and similar taxomonic discrimination are available. A study by Growns and Growns (1997), which examined species and family richness recorded in 34 datasets from predominantly lotic sites in all states of Australia indicated that the total number of species from Swan Coastal Plain wetlands was approximately midway between the poorest and richest sites. They noted that there was some evidence of regional differences in that lotic systems in NSW had very high species richness while lotic systems in southwest Western Australia were relatively species poor. Bunn and Davies (1990) suggested that reasons for the depauperate stream fauna included the geographically isolated nature of the southwest, the previous history of aridity and the low primary productivity of these systems. While these factors may also apply to the wetlands of the region, it seems that the same degree of impoverishment is not present in the wetland invertebrate fauna, particularly microcrustaceans (Storey et al. 1993b, Halse et al. 2000). Reasons for the apparent richness of micro-crustaceans and some other wetland invertebrate groups in southwest Western Australia need further investigation, although there appears to be a parallel with vascular plant diversity (see Doing 1981).

The southwest of Western Australia has been recognised as one of the 25 most diverse regions of the world with respect to floral richness (12th in Myers et al. 2000). The limited number of studies conducted on the semi-aquatic and terrestrial flora of seasonal and ephemeral wetlands of the region indicate that diversity in these habitats is high. However there is little that can be concluded with respect to the richness of the truly aquatic flora as few studies exist.

Waterbird richness of Perth wetlands is probably similar to that of coastal wetlands elsewhere in Australia of the same type and condition but comparisons have limited validity because the number of waterbird species recorded at a site is strongly influenced by the number of surveys (particularly if few have occurred), number of seasons over which they were conducted (Halse et al. 1993) and observer expertise. These problems are analagous to the difficulties comparing invertebrate and, to a lesser extent, plant surveys.

It can be said with more confidence that Perth wetlands, on average, contain more waterbird species than more inland wetlands, in lower rainfall zones, of southwest Western Australia. Five of the Perth wetlands surveyed by Storey et al. (1993a) were among 95 wetlands throughout all southwest Western Australia surveyed over a five year period by Jaensch et al. (1988)). In terms of species richness, the average rank of the five wetlands was 4.5 when in Jaensch et al.'s study and 10.4 in Storey et al.'s (Table 3). There are two caveats: firstly, survey effort was higher in Perth wetlands than elsewhere in Jaensch et al.'s study but this is unlikely to have altered rankings greatly. More importantly, the waterbird value of Jandabup Lake and, to a lesser extent Joondalup Lake, appeared to decline between the studies of Jaensch et al. (1988) and Storey et al. (1993). This coincided with drawdown of the aquifer under Jandabup Lake for water supply and the lake becoming shallower and reinforces the importance of water regime to waterbirds.

Threats to wetland biodiversity in southwestern Australia include: altered water regimes, degraded water quality, loss of habitats, invasive and exotic species and fragmentation and loss of connectivity (Davis and Froend 1999). These threats are probably more important on the coastal plain than inland, where secondary salinisation is a major environmental issue.

Damplands appear to be most at risk as the ephemeral nature of the water regime means that they are easily ignored as aquatic habitats. As the urban expansion of Perth continues both northwards and southwards along the Swan Coastal Plain, the damplands in particular are under severe pressure from developers wishing to drain the land to create more areas for housing. The issue of how much land surrounding a wetland should be preserved to act as a buffer between dryland and wetland zones is also one that needs more attention, especially as land prices within urban areas become increasingly more expensive.

Our review of existing studies has clearly indicated the gaps in our knowledge of biodiversity in Swan Coastal Plain wetlands. No systematic surveys have been undertaken to identify the most important wetlands with respect to frogs or fish. Similarly there is still much that we do not know regarding the richness of algae, diatoms and submerged and floating macrophytes at these wetlands.

The use of data obtained in studies undertaken for other purposes has enabled us to reach some conclusions regarding the factors influencing waterbird and invertebrate species richness in wetlands on the Swan Coastal Plain, Western Australia.

Table 3. Number of waterbird species recorded at five Perth wetlands during 1981-85 (Jaensch et al. 1989) and 1990-92 (Storey et al. 1993a), their relative rankings in each survey and survey effort.

	Species richness and rank		No. of surveys
	1990-92	1981-85	1981-85
Thomsons	47 *(1)*	60 *(2)*	151
Forrestdale	43 *(2)*	62 *(1)*	97
Chandala	28 *(11)*	38 *(11.5)*	41
Joondalup	27 *(13)*	52 *(3)*	66
Jandabup	13 *(25)*	43 *(5)*	41
Mean ranking	*10.4*	*4.5*	

More importantly perhaps, from a conservation perspective, the different responses demonstrated to wetland area, colour, extent of emergent vegetation, water regime and primary productivity indicate that to maintain biodiversity on the Swan Coastal Plain we need to protect and conserve a range of different wetland types.

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WETLANDS OF EAST AFRICA: BIODIVERSITY, EXPLOITATION, AND POLICY PERSPECTIVES

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Abstract

Wetlands are extensively distributed in East Africa and provide many valuable functions (e.g., flood alleviation, ground water recharge, retention and regulation of pollutants and water plant nutrients); products (e.g., fish, fuelwood, timber, crafts, herbal medicines, rich sediments for agriculture); refugia for fish and other fauna; and other attributes (biodiversity, aesthetic beauty for tourists, cultural heritage). Permanent swamps, dominated by papyrus (*Cyperus papyrus*) are inhabited by unique assemblages of plants and animals with extraordinary adaptations to the extreme conditions (low dissolved oxygen, high levels of carbon dioxide, reducing conditions) imposed by the dense swamp environment. Ecotonal areas tend to be richer faunistically than the dense interior of permanent swamps. However, the permanent swamps may still be very important in the maintenance of faunal structure and diversity; and their degradation may precipitate declines in the diversity and richness of swamp taxa through loss of habitat, faunal mixing, and loss of refugia. In East Africa, humans have lived with and within wetlands throughout history. However, since the 1950s, large-scale swamp conversion and population pressure on small wetlands has threatened the integrity of many African wetlands, precipitated local declines in indigenous wetland organisms, and altered ecosystem functions. The overall goal of setting policies by the East African governments is to promote the wise use and conservation of the East African wetlands so that their ecological and socio-economic functions are sustained for the present and future well being of the people. The Government of Uganda, recently launched such a policy, the first of its kind in Africa to have been formulated in accordance with the Ramsar Convention. It encompasses wetlands in protected and non-protected areas and offers a good example in Africa of a strong political will to conserve wetlands and their biodiversity.

Introduction

The term 'biodiversity' is more than just the number of species; it includes the complexity, the richness and abundance of nature at all levels, from the genetic variation to the layout of communities and systems across terrestrial landscapes and within the water (Baskin 1997). The whole concept of conserving biodiversity

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