Probable Effect of Increased Salinity on the Waterbirds of Lake Toolibin

by S.A. Halse

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Department of Conservation and Land Management, W.A.

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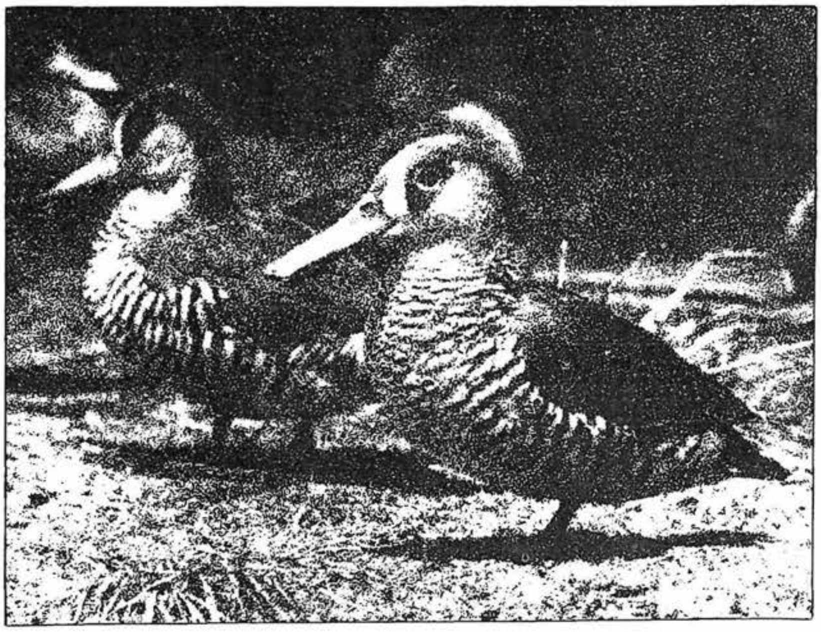

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ABSTRACT

Lake Toolibin is a fresh to brackish-water lake in the Western Australian wheatbelt that is largely covered by dense thickets of *Casuarina obesa* and *Melaleuca* spp. Forty-one species of waterbird have been recorded there, 24 of them breeding. Between 1981-85 39 species were recorded. Twenty-three species were resident and 22 bred or attempted to do so. Lake Toolibin has the highest known number of breeding waterbird species of any wetland in south-western Australia.

Over the past 15 years Lake Toolibin appears to have become more saline and some of the trees in it have died. If the trend continues and the lake becomes truly saline the number of resident and breeding species will drop by at least 50 per cent. Freckled Ducks would be particularly adversely affected by the salinization; at present the lake is the stronghold of the species in the south-west of Western Australia. They only breed in wetlands containing dense tree or scrub vegetation. Higher salinity would also cause loss of the breeding colonies of Great Cormorants, Great Egrets, Yellow-billed Spoonbills and Rufous Night Herons, all species which breed in few wetlands in south-western Australia. Some other species would also stop using the lake for breeding or would use it in lower numbers, which would result in an overall reduction in waterbird production in south-western Australia.

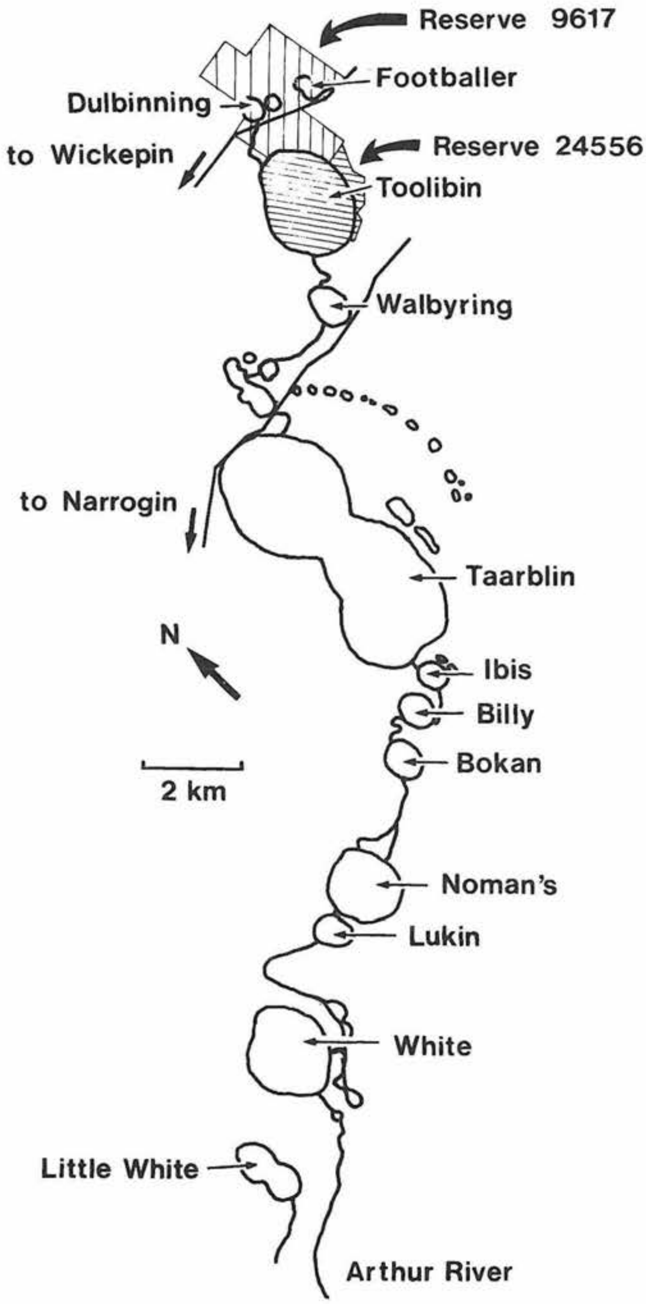

Fig. 1 Northern Arthur River wetlands. Boundaries of reserves are shown approximately.

INTRODUCTION

Lake Toolibin (32°56'S 117°11'E) is part of a chain of lakes at the head of the Arthur River, east of Narrogin, in the Western Australian wheatbelt. Other lakes in the chain include Lake Walbyring (also known as Mud Hut), Lake Taarblin, Noman's Lake and White Lake (Fig. 1). The principal feature of Lake Toolibin is the presence of extensive *Casuarina obesa* and *Melaleuca* spp. thickets and woodlands through the inundated area (Fig. 2).

Lake Toolibin has a catchment of about 440 km^2, approximately 90 per cent of which has been cleared of native vegetation (N.A.R.W.R.C. 1978). About one-third of the clearing had occurred by the mid-1930s, most of the remainder was done in the late 1940s and early 1950s. As in much of the wheatbelt (Burvill 1950; Mulcahy 1978), clearing in the Lake Toolibin catchment has resulted in secondary salinity and the occurrence of salt-affected areas. About 3 per cent of the catchment is severely salt-affected and a further 2.6 per cent is slightly affected (Watson 1978).

The salinization of the catchment has increased the salinity of run-off into Lake Toolibin (Stokes and Sheridan 1986). In addition, groundwater levels under the lake have risen about 12-15 m over the past 60 years to within 0.5 m of that part of the lake bed where all *C. obesa* are dead and to within 1-2.5 m where the vegetation is healthy (Watson 1978). This reduces the amount of salt that is leached from the lake when it contains water (Stokes and Sheridan 1986). Thus Lake Toolibin, once a fresh-water lake, is becoming brackish and, if the trend of deteriorating water quality continues, will become saline (Stokes and Sheridan 1986). This would cause death of all trees in the lake. In fact, the levels of salinity already experienced have had a deleterious effect on the lake's vegetation, especially along the more saline western shore where many trees have died (Mattiske 1978).

Lake Toolibin is one of the few wetlands containing live trees that remains in the wheatbelt and is an important breeding area for waterbirds; consequently the Northern Arthur River Wetland

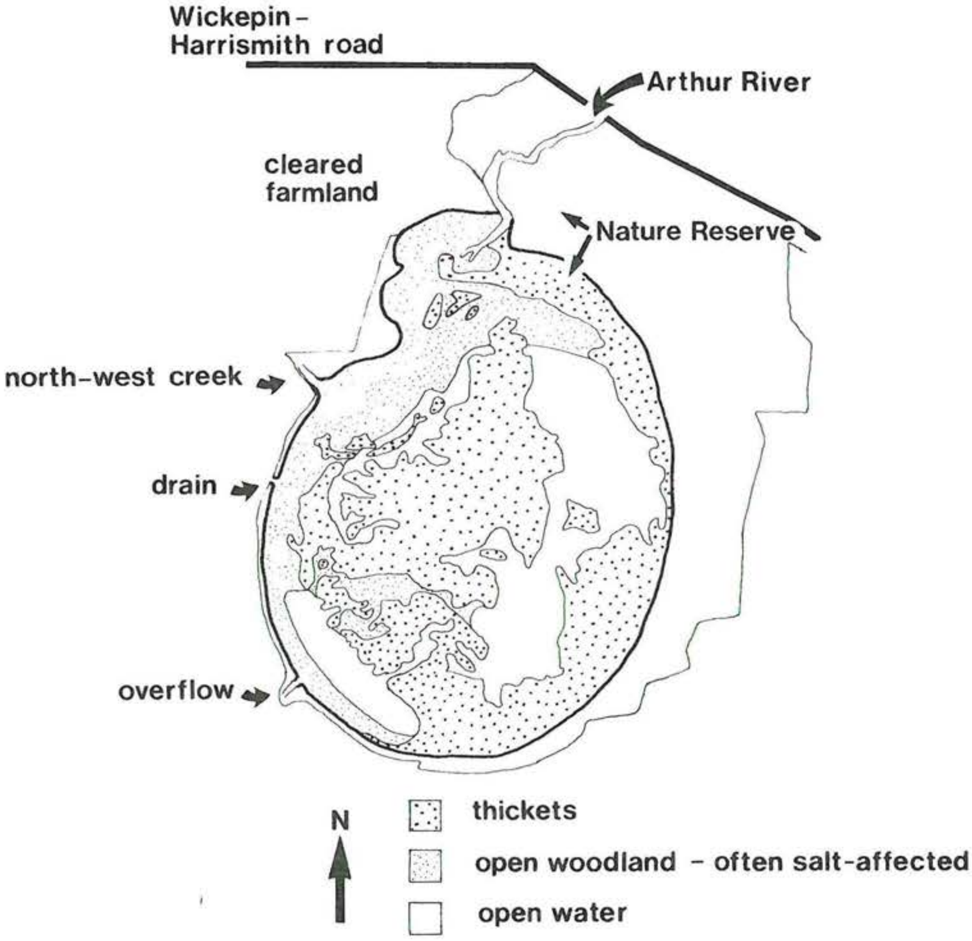

Fig. 2 Vegetation of Lake Toolibin (after Mattiske 1978).

Rehabilitation Committee was formed in 1977 to examine ways of reducing the salinity of the lake to ensure:

(1) survival of the vegetation

(2) the lake remains an important breeding area.

This report gives a brief description of Lake Toolibin and a list of the waterbirds occurring there, together with data on breeding to show that it is one of the most important breeding areas in south-western Australia. Some predictions are made about the effect of increases in salinity on its use by waterbirds.

LAKE TOOLIBIN

Lake Toolibin covers an area of 240 ha and is contained in Nature Reserve No. 24556, vested in the National Parks and Nature Conservation Authority. The reserve comprises only the lake and some uncleared land on the eastern side. Game Reserve No. 9617, which contains Lake Dulbinning and Footballer Lake, is adjacent on the northern side (Fig. 1). Most of the Lake Toolibin catchment area has been cleared but originally it supported open woodlands of *Eucalyptus wandoo* and *Acacia acuminata* on light gravelly soils; *E. salmonophloia*, *E. loxophleba* and *E. oleosa* on loamy, clayey soils; and *E. rudis* along drainage lines. The vegetation in the lake is dominated by *C. obesa* and *Melaleuca* spp., which grow in dense thickets over a large part of the lake as well as in more open woodlands (Fig. 2). A few *E. rudis* also occur in open woodlands (Mattiske 1978).

Water Levels in Lake

Simulation modelling using the available rainfall records shows that in the long-term Lake Toolibin is not a permanent lake although it is at least 1 m deep over 70 per cent of the time. It is about 2 m deep when full and fills about four years out of ten. There is some run-off into the lake (but insufficient to fill it) in a further three years. Because of a carry-over effect from wet years, it is rare for the lake to be completely dry even in years of no inflow (Stokes and Sheridan 1986). The area has an average annual rainfall of about 420 mm, which falls mostly in winter. Temperatures are high in summer, with maximum temperatures averaging about 30°C from December to February, so that the amount of evaporation is considerable.

The last two decades have been quite different from the long-term pattern because the lake has been dry eight years: from early 1970 until mid-1973, December 1977 until June 1981, and March 1985 until the present (September 1986) (Stokes and Sheridan 1986; Department of Conservation and Land Management unpublished data). The lake is highly unlikely to fill again before the middle of 1987.

Salinity

Complete ionic composition of the water in Lake Toolibin has never been determined but, like most Western Australian wetlands (Williams and Buckney 1976), it is dominated by sodium and chloride ions (Table 1). Perhaps as a result of being in an agricultural area, and because the water level fluctuates greatly, the concentrations of phosphate in the lake are sometimes fairly high (Table 2) and it could be classed as mildly eutrophic (Williams 1969; Congdon and McComb 1976), particularly when the water level is low.

Table 1: Analysis of water from centre of Lake Toolibin in October 1975 (Western Australian Government Chemical Laboratories).

TDS[a] (g/L)	NaCl[b] (g/L)	Colour	Odour	pH
2.70	2.56	colourless	nil	7.9

[a]By evaporation
[b]Calculated from chlorinity

Data collected from the eastern side of the lake by J.A.K. Lane (personal communication[1]) show salinity levels have varied from 0.5 - 10 ppt TDS over the last five years, being greatest when water levels were low and salts were concentrated by evaporation (Fig. 3). Data collected by Stokes and Sheridan (1986) exhibit the same pattern although the variation is slightly greater. Their data, combined with that of Froend (1983), show that frequently there are horizontal salinity gradients across the lake with concentrations being greatest along the western side. This is because inflow from the Arthur River and a small creek and drain on the western side (Fig. 2) are more saline than direct precipitation and local surface run-off (Stokes and Sheridan 1986).

[1]J.A.K. Lane, Department of Conservation and Land Management

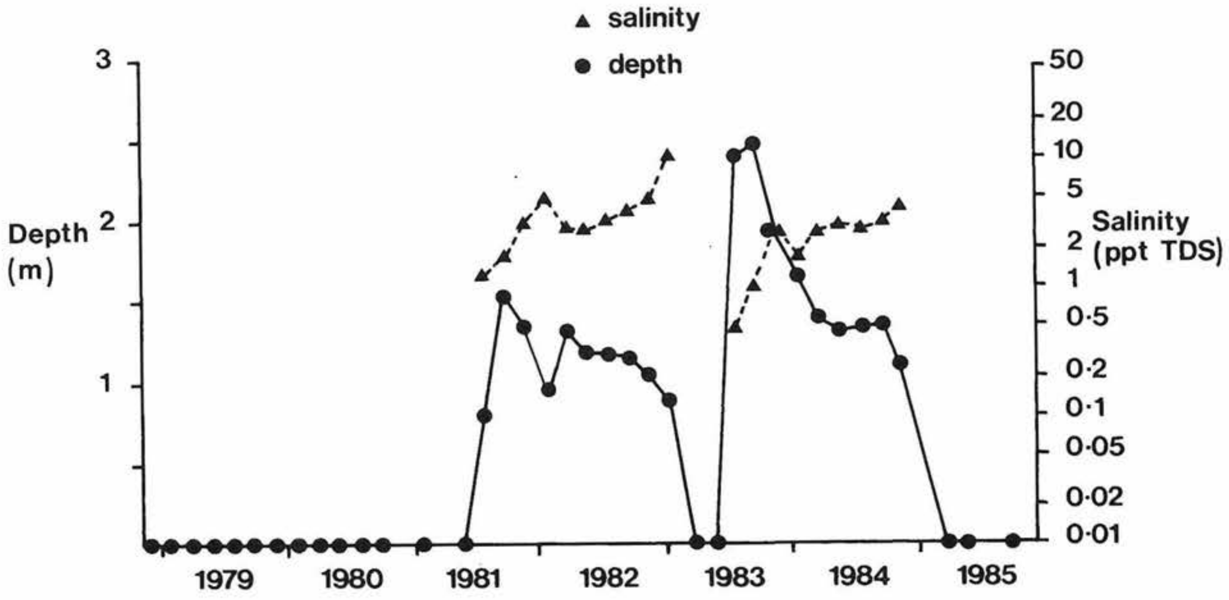

Fig. 3 Variation in salinity (1981-85) and depth (1979-85) in Lake Toolibin.

Water table

Because annual agricultural crops and pastures transpire much less water than natural woodland vegetation the water table has risen and now is within 0.5 m of some parts of the lake bed (Watson 1978). As the water table rose salt stored in the soil profile was mobilized, resulting in a water table that is highly saline as well as shallow (Martin 1986). Rainfall was the original source of this salt, which has accumulated over geological time in the soil profile chiefly because rainfall was too light to leach the salt to the deep underground drainage system (Mulcahy 1978).

The shallow saline water table under the lake contributes directly to salinization in two ways: capillary rise of salts and reduction in leaching. Salt is deposited in the soil and on the surface of the lake bed when the lake is dry as a result of groundwater rising through capillary action and evaporating. This increases the total quantity of salt in the lake. The shallow saline water table reduces the amount of salt that is leached out of the lake when it is full and there is downward movement of lake water through the lake bed (Stokes and Sheridan 1986). The salt load of Lake Toolibin is only reduced substantially when the lake overflows and the salt dissolved in the outflowing water is lost.

Surface run-off also contributes to salinization of the lake. When soil becomes saturated after heavy rain there is often lateral, downhill movement of water in the upper soil layers into creeks and drainage lines (Martin 1986). Because the upper soil layers in low-lying areas around Toolibin contain salt (Froend *et al*. 1987) the river and creek water which flows into the lake is often saline, particularly during the first rains of winter or when flow rates are low.

Table 2: Total phosphorus content of water collected from Lake Toolibin in 1984-85 (data provided by J.A.K. Lane, analysis by Government Chemical Laboratories).

	DATE		
	18 July 1984	7 November 1984	29 January 1985
Total P (mg/L)	0.06	0.22	0.04

Vegetation

The vegetation of the lake has been described in detail by Mattiske (1978, 1982). Over two-thirds of it contains woodlands or thickets of *C. obesa* or *Melaleuca* spp. *Eucalyptus rudis* occurs in some of the open woodlands in inundated areas. There is a large expanse of open water along the eastern side of the lake (Fig. 2). The most common tree species in inundated parts of the lake is *C. obesa*. The main *Melaleuca* growing there is an undescribed species although *M. laterifolia* and *M. viminaria* also occur. The sedge *Chorizandra endodis* is common in some areas. *Allocasuarina huegeliana, M. uncinata, E. rudis* and *Acacia acuminata* form the fringing woodland around the lake, with *E. loxophleba* growing on sandy ridges farther from water.

Aquatic macrophytes *Potamogeton* and *Lepilaena* also grow in the lake (Mattiske 1982; personal observation) but, because they tolerate higher salinities than emergent vegetation (Brock and Lane 1983), they were not studied.

Unhealthy trees were first noted in Lake Toolibin in the early 1970s and there has been a continued decline in the vigour of trees in the lake since that time (Mattiske 1978), especially along the western shore. Most of the *E. rudis* in the lake have died as well as some *C. obesa* and *Melaleuca* spp. Froend *et al.* (1987) regard salinity in the soil of parts of the lake bed as the cause of the decline. High soil salinity is the result of the shallow saline water table and, to a lesser extent, the brackish or saline quality of the water flowing into the lake. Indigenous plants cannot survive in such high salinity.

However, even in its present condition the lake contains an extensive area of dense vegetation. When it is flooded the healthy thickets and woodlands provide nesting sites for many waterbirds. Besides providing nesting sites, the vegetation affords protection to young birds from predators, roosting sites for young and adults, and foraging areas for some species with specific habitat requirements.

WATERBIRDS

Sources of data

Data on the waterbirds of Lake Toolibin come from three sources : the Royal Australasian Ornithologist's Union (R.A.O.U.) Waterbird Survey, Department of Conservation and Land Management files, and published literature (e.g. Garstone 1973). The R.A.O.U. Waterbird Survey ran from mid-1981 until mid-1985. Observers visited various lakes in the South-west and Eucla Land Divisions, including Lake Toolibin, at irregular although often frequent intervals and recorded as many of the waterbird species present as possible. In addition the number of individuals of each species was counted and breeding activity was recorded.

Number of species

The term 'waterbird' is used loosely here to refer to those species that complete a substantial part of their life cycle in wetlands. Ninety-nine such species occur in south-western Australia (Jaensch in press). Between 1981-85 41 were seen in Lake Toolibin, of which breeding activity was observed for 22 (Table 3). During the 1960s the Darter *Anhinga melanogaster* was seen occasionally in the lake and it bred there in 1965 (Garstone 1973). Hardheads, which were regularly seen between 1981-85 but not recorded breeding, did so in the 1960s (Garstone 1973). Thus, over the past 20 years 42 species of waterbird have been recorded in Lake Toolibin and 24 are known to have bred there. However, for the remainder of the report only those species recorded between 1981-85 will be considered.

The R.A.O.U. surveys showed that the waterbirds of Lake Toolibin fall fairly clearly into two categories : resident species and those that occur only occasionally or as vagrants (Table 3). There are 24 resident species, of which 22 breed at the lake : six bred each year between 1981-85, six bred three years, six bred two years and four bred one year. The non-breeding residents, according to R.A.O.U. surveys, are the Hardhead and Marsh Harrier although it is possible that Hardheads breed at the lake. Three species occur occasionally,

Table 3: Waterbirds recorded at Lake Toolibin in R.A.O.U. surveys between 1981-1985.

Species	No of years recorded	No of years breeding	Period of occurrence	Period of breeding	Status	Maximum number recorded
Great Crested Grebe *Podiceps cristatus*	4	1	all year	Nov	resident	6
Hoary-headed Grebe *Poliocephalus poliocephalus*	4	2	all year	Nov-Dec	resident	135
Australasian Grebe *Tachybaptus novaehollandiae*	4	1	all year	Oct	resident	31
Australian Pelican *Pelecanus conspicillatus*	1	-	?		vagrant	1
Great Cormorant *Phalacrocorax carbo*	4	3	all year	May-Aug	resident	27
Pied Cormorant *Phalacrocorax varius*	2	-	winter/ spring		occasional	3
Little Black Cormorant *Phalacrocorax sulcirostris*	4	2	all year	Oct-Jan	resident	50
Little Pied Cormorant *Phalacrocorax melanoleucos*	4	4	all year	Aug-Mar	resident	100
Pacific Heron *Ardea pacifica*	4	2	all year	Oct-Nov	resident	15
White-faced Heron *Ardea novaehollandiae*	4	4	all year	Sep-Mar	resident	111
Great Egret *Egretta alba*	4	2	all year	Nov-Feb	resident	35
Rufous Night Heron *Nycticorax caledonicus*	4	3	all year	Oct-Mar	resident	31
Sacred Ibis *Threskiornis aethiopica*	3	-	all year		occasional	16
Straw-necked Ibis *Threskiornis spinicollis*	2	-	spring/ summer		occasional	15
Yellow-billed Spoonbill *Platalea flavipes*	4	4	all year	Sep-Apr	resident	20
Black Swan *Cygnus atratus*	4	3	all year	May-Jan	resident	70
Freckled Duck *Stictonetta naevosa*	4	3	all year	Oct-Nov	resident	600
Australian Shelduck *Tadorna tadornoides*	4	4	all year	May-Dec	resident	200
Pacific Black Duck *Anas superciliosa*	4	2	all year	May-Dec	resident	100
Grey Teal *Anas gibberifrons*	4	3	all year	Anytime	resident	1100
Chestnut Teal *Anas castanea*	1	-	?		vagrant	1
Australasian Shoveler *Anas rhynchotis*	4	1	all year	Dec	resident	50
Pink-eared Duck *Malacorhynchus membranaceus*	4	4	all year	anytime	resident	150
Hardhead *Aythya australis*	4	-	all year		resident	275
Maned Duck *Chenonetta jubata*	4	1	all year	Dec	resident	91

Species	No of years recorded	No of years breeding	Period of occurrence	Period of breeding	Status	Maximum number recorded
Blue-billed Duck *Oxyura australis*	4	2	all year	Mar-July	resident	15
Musk Duck *Biziura lobata*	4	3	all year	Apr-Dec	resident	10
Marsh Harrier *Circus aeruginosus*	3	-	all year		resident	2
Black-tailed Native-hen *Gallinula ventralis*	1	-	?		vagrant	1
Purple Swamphen *Porphyrio porphyrio*	1	-	?		vagrant	1
Eurasian Coot *Fulica atra*	4	4	all year	Sep-Jan	resident	370
Red-kneed Dotterel *Erythrogonys cinctus*	1	-	?		vagrant	1
Oriental Plover *Charadrius veredus*	1	-	summer		vagrant	1
Red-capped Plover *Charadrius ruficapillus*	1	-	summer		vagrant	19
Black-fronted Plover *Charadrius melanops*	2	-	?		vagrant	3
Black-winged Stilt *Himantopus himantopus*	1	-	?		vagrant	41
Banded Stilt *Cladorhynchus leucocephalus*	1	-	?		vagrant	3
Greenshank *Tringa nebularia*	1	-	summer		vagrant	1
Sharp-tailed Sandpiper *Calidris acuminata*	1	-	summer		vagrant	2
Silver Gull *Larus novaehollandiae*	1	-	?		vagrant	1
Whiskered Tern *Chlidonias hybrida*	1	-	?		vagrant	1

the Pied Cormorant, Sacred Ibis and Straw-necked Ibis, and a further 14 species occur as vagrants. Only resident species were recorded breeding at the lake.

Number of individuals

Birds are difficult to find in Lake Toolibin because it is densely vegetated and bird counts undoubtedly under-estimate population sizes for most species. Nevertheless R.A.O.U. surveys suggest the lake does not act as an important drought-refuge, even in years when it retains deep water throughout summer and autumn. The number of birds in the lake is never really high and there is no peak in late summer and autumn (Fig. 4). The maximum recorded was 1 650 birds in January 1982 in contrast with 17 500 in Lake Forrestdale in January 1983, 25 000 in Lake Dumbleyung in March 1985 and 17 000 in Lake Warden in November 1982. Large numbers of birds occur in many other lakes, especially near the coast (see Gentilli and Bekle 1983).

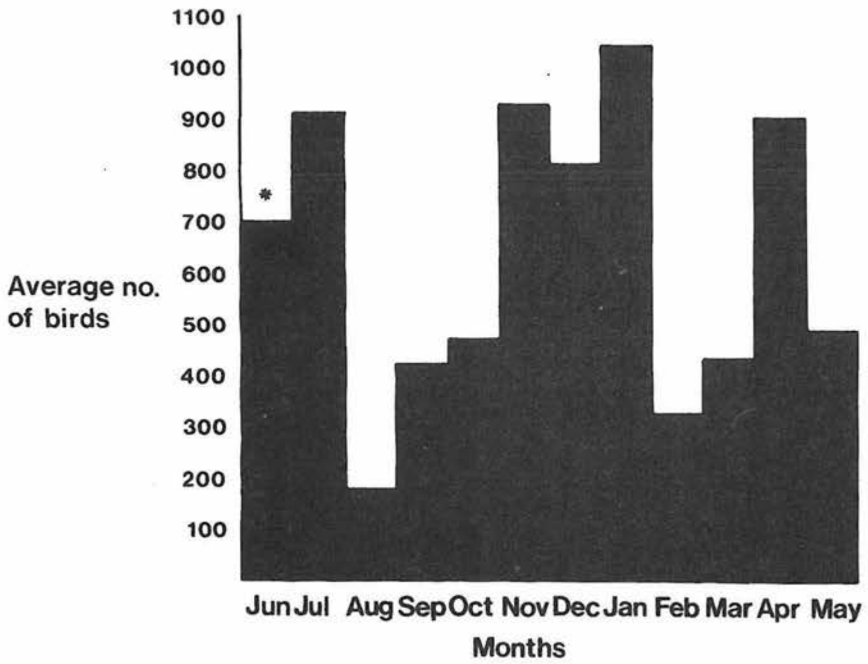

Fig. 4 Average number of birds present each month when there was water in Lake Toolibin based on 25 surveys by the R.A.O.U. between 1981-85. *No surveys were carried out in June and number of birds was estimated from May and July values.

The species for which the largest counts were made at Lake Toolibin between 1981-85 were the Grey Teal (1 100 birds), Freckled Duck (600) and Eurasian Coot (350) (Table 3).

The total number of birds using Lake Toolibin remains comparatively constant through the year (provided there is water in the lake), but there is variation between years that cannot be attributed to water depth or salinity alone. More birds were recorded between 1981-83 than 1983-85. In this context it should be realised that the term 'resident species' is used here in reference to species that are recorded in most surveys; individual birds may only spend short periods at the lake.

Feeding

The waterbirds of Lake Toolibin occupy eight loosely-defined feeding guilds (Table 4). Almost 50 per cent of the species and over 90 per cent of the individuals are 'swimming' birds that obtain food principally by dabbling or diving. The dabbling species generally have a mixed diet of plants and animals although Black Swans are almost completely vegetarian and Pink-eared Ducks and Australasian Shovelers feed mostly on invertebrates (Frith 1977; Briggs *et al.* 1985). In shallow water dabbling birds feed by submerging their bill, or head and neck, or by upending. In deeper water they feed only on the surface, either by filtering or by pecking at floating plant material and animals (Frith 1977).

The diving species probably prefer water at least 1 m deep (see Frith 1977 pp. 297, 311; Blakers *et al.* 1984 p. 41) although little information is available on this aspect of their biology. The data from Lake Toolibin show that water depth has little effect on numbers of diving birds when the lake contains 1 m or more of water but that numbers decline rapidly, and most species are absent, when it contains less. This relationship applies for all diving species irrespective of the type of food they eat. Cormorants and Australian Pelicans feed exclusively on animals, grebes eat some vegetation although they are predominantly carnivorous, and diving ducks and Eurasian Coots consume mostly vegetation. However, Musk Ducks also eat large animals, including Gilgies *Cherax quinquecarinatus*.

Table 4: Feeding guilds of waterbirds at Lake Toolibin (data from Reader's Digest 1976; Serventy and Whittell 1976; N.P.I.A.W. 1985).

Guild	Species
Dabblers - mixed diet	Black Swan, Freckled Duck, Australian Shelduck, Pacific Black Duck, Grey Teal, Chestnut Teal, Australasian Shoveler, Pink-eared Duck, Hardhead
Divers - animals	Great Crested Grebe, Hoary-headed Grebe, Australasian Grebe, Australian Pelican[a], Great Cormorant, Pied Cormorant, Little Black Cormorant, Little Pied Cormorant
Divers - vegetation	Blue-billed Duck[b], Musk Duck[b], Eurasian Coot
Large waders - animals	Pacific Heron, White-faced Heron, Great Egret, Rufous Night Heron, Yellow-billed Spoonbill
Small waders - invertebrates	Red-kneed Dotterel, Oriental Plover, Red-capped Plover, Black-fronted Plover, Black-winged Stilt, Banded Stilt, Greenshank, Shark-tailed Sandpiper
Shore feeders - animals	Sacred Ibis, Straw-necked Ibis, Silver Gull
Shore feeders - vegetation	Maned Duck, Black-tailed Native-Hen, Purple Swamphen
Aerial feeders - animals	Marsh Harrier, Whiskered Tern

[a]Does not dive for food but shares many habits with other birds in this guild

[b]Diet contains significant proportion of animals

All but two of the non-diving, non-dabbling species forage on mudflats around the lake, at the water's edge or in comparatively shallow water along the shoreline. Although they feed mostly by diving, Eurasian Coots occasionally graze on mudflats.

The remaining two species, the Marsh Harrier and Whiskered Tern, are aerial feeders. Whiskered Terns catch insects above the water and occasionally dive for animal food. Marsh Harriers usually feed on waterbirds but also take a variety of other animals from around the lake.

In summary, waterbirds feed throughout the lake and around its margin, eating principally invertebrates, small vertebrates (fish and frogs), algae, aquatic macrophytes, and vegetation on the mudflats surrounding the lake. Individual species eat a comparatively narrow range of food items.

Breeding

The 22 species recorded breeding between 1981-85 can be divided into four nesting guilds based on the usual location of their nests (Table 5) even though most species sometimes choose other sites. Nine species nest in trees over water, several using only live trees. Two species build nests of sticks under the cover of trees. Two species nest in dense rushes or grass. Four species nest in tree hollows, often some distance from water (Pacific Black Ducks often nest this way instead of on the ground) and five species build open nests that are either floating or made of sticks built up from the bottom of the lake. Live vegetation in the lake is of paramount importance in providing suitable nesting sites for most of the species breeding there.

Most breeding activity at the lake occurs during spring although in many species it extends into summer (Table 3). The Great Cormorant is a winter-breeding species and Black Swans, Australian Shelducks and Pacific Black Ducks have long breeding seasons that begin in early winter and extend into summer. Grey Teal and Pink-eared Ducks have a variable season, breeding at any time of the year, although most activity occurs between September and December. Pink-eared Ducks are more variable than Grey Teal.

The breeding dates recorded between 1981-85 for Blue-billed and Musk Ducks (Table 3) are the result of heavy aberrant rainfall in January 1982 (see Bekle 1983), which resulted in both species breeding. Normally, breeding in both species occurs between August and November although the breeding habits of Musk Ducks are more variable than those of Blue-billed Ducks (Frith 1977).

Table 5: Nesting guilds of waterbirds at Lake Toolibin (data from Readers' Digest 1976; Serventy and Whittell 1976; Frith 1977; N.P.I.A.W. 1985; R.P. Jaensch personal communication[a]).

Guild	Species
Floating or anchored nest of rushes, aquatic macrophytes or sticks on water	Great Crested Grebe, Hoary-headed Grebe, Australasian Grebe, Black Swan, Eurasian Coot
Nest of sticks in, or under cover of, tree over water	Great Cormorant, Little Black Cormorant, Little Pied Cormorant, Pacific Heron, White-faced Heron, Great Egret, Rufous Night Heron, Yellow-billed Spoonbill, Freckled Duck, Blue-billed Duck, Musk Duck
Nest in tree hollow	Australian Shelduck, Grey Teal, Pink-eared Duck, Maned Duck
Nest on ground in grass or rushes	Pacific Black Duck, Australasian Shoveler

[a] R.P. Jaensch, R.A.O.U.

IMPORTANCE OF LAKE TOOLIBIN

More species were recorded breeding in Lake Toolibin than in any other of the 251 wetlands examined in R.A.O.U. surveys (Jaensch in press). The lake also had the second highest number of species of any inland wetland. Thus Lake Toolibin is undoubtedly one of the most important wetlands in south-western Australia.

It is a particularly important breeding site for Great Egrets, Yellow-billed Spoonbills, Freckled Ducks, Rufous Night Herons and Great Cormorants (nesting recorded in five or fewer surveyed wetlands in the south-west) and a significant one for Little Black and Little Pied Cormorants, Great Crested Grebes and Blue-billed Ducks (nine or fewer surveyed wetlands). The lake is the stronghold of the Freckled Duck in south-western Australia, being the wetland where this species was seen most frequently and in greatest numbers between 1981-1985. Freckled Ducks are gazetted rare under the Wildlife Conservation Act and are generally considered to be declining in numbers (Frith 1977).

Reasons for number of breeding species

An analysis of the characteristics of wetlands of south-western Australia in relation to the number of breeding species they support shows that wetlands with inundated tree or sedge-type vegetation support more breeding species than lakes with completely open water. Furthermore, fresh/brackish lakes tend to have the highest number of breeding species (Halse unpublished data). Provided water is present in spring of most years, the degree of permanence of a wetland has little effect on number of breeding species; neither does depth nor area. Therefore, there appear to be three reasons for the high number of breeding species at Lake Toolibin:

(1) the extensive, dense thickets of *C. obesa* and *Melaleuca* spp. through much of the inundated area

(2) the fresh/brackish water, which is of sufficiently high quality for growth of emergent vegetation (Froend *et al.* 1987) and is potable for very young birds (see Swanson *et al.* 1984).

(3) the occasional drying out of the lake allows persistence of the trees growing in it. No species grow in permanently waterlogged soils (Gill 1970). It may also increase productivity, leading to a greater availability of food for breeding waterbirds (see Briggs and Maher 1985).

Reasons for total number of species

The reasons for Lake Toolibin having the highest recorded number of species of any inland lake other than Lake Wannamal are the same as those given for its high breeding numbers. The extensive area of emergent vegetation provides habitats that are not available in open lakes and thus more species occur (MacArthur 1964). The other lakes that contain more species than Lake Toolibin are coastal and do so because of their location; they are visited by significant numbers of wader species, many of which are migratory and have strong marine affinities so that they rarely move inland.

EFFECT OF INCREASED SALINITY

If nothing is done to modify the hydrology of the catchment of Lake Toolibin it is likely that the water table will continue to rise (Martin 1986), leading to more saline soil in the lake bed and more saline water flowing into the lake from the Arthur River and creek and drain on the western side (Stokes and Sheridan 1986). This will cause death of the emergent vegetation (Martin 1986; Froend *et al.* 1987). That alone will render the lake an unsuitable nesting habitat for Freckled Ducks, most of the large tree-nesting wading birds and those species that nest in dense rushes and reeds (Table 5). A further, more direct effect of increasing salinity is that the water in the lake may no longer be potable for young birds. For the first week or so after hatching the salt glands are undeveloped so that young birds can only drink fresh water. In saline wetlands they rely on the existence of fresh-water seepages around the lake, if these are present, for drinking water (Riggert 1969, pp. 168-182; Swanson *et al.* 1984). The seasonal pattern of salinity and time of breeding are important in this context. The data in Table 3 show that young of most species hatch in spring, and providing water is potable at this time, from the viewpoint of having drinking water it does not matter if salinity levels subsequently rise substantially (although it will affect the vegetation) because older birds can survive on quite saline water (Riggert 1977; Baudinette *et al.* 1982; Mahoney and Jehl 1985).

In general terms, moderate increases in salinity result in reduced species diversity but increased productivity in wetlands (Williams 1969; Bayly and Williams 1973, pp. 28, 211). However, accurate predictions about the effect of increased salinity on food supplies of particular species, and hence their occurrence at the lake, cannot be made without better information about the diets of waterbirds and the biology of algal, macrophyte and invertebrate species likely to inhabit the lake if it were more saline.

Salinity and number of breeding species

Some idea of the number of species that will stop breeding at Lake Toolibin if it becomes more saline can be gained from Figures 5 and

6. These show, for species currently breeding there, the percentage of recorded breeding attempts in the south-west between 1981-85 that occurred in various categories of salinity. The data suggest that only Black Swans, Australian Shelducks, Grey Teal, Australasian Shovelers, Pink-eared Ducks, Eurasian Coots and Little Pied Cormorants could be expected to attempt to breed in similar numbers if Lake Toolibin became truly saline (> 10 ppt TDS in September). It is possible that Great Crested Grebes, Australasian Grebes, Pacific Black Ducks and White-faced Herons would also nest but at least 11 (50 per cent) of the species now breeding at the lake would stop doing so. Seven of the nine species whose breeding at Lake Toolibin makes a significant contribution to their breeding effort in south-western Australia (Great Cormorant, Little Black Cormorant, Great Egret, Rufous Night Heron, Yellow-billed Spoonbill, Freckled Duck, Blue-billed Duck) would cease using the lake for that purpose.

The analysis used in Figures 5 and 6 was not designed to distinguish successful and unsuccessful breeding attempts so they must be interpreted with some caution. Data on breeding in relation to salinity have been collected near Northam by J.R. Masters (personal communication[2]), who recorded whether young were raised. He found that Australasian Grebes, Blue-billed and Musk Ducks breed successfully at salinities up to 3.9 ppt TDS. Australasian Shovelers and Pink-eared Ducks raised young at salinities between 2.9 - 4.3 ppt TDS but did not attempt to breed at salinities below 2 ppt TDS. Australian Shelducks, Grey Teal and Eurasian Coots bred successfully at salinities 'often well above 4.3 ppt TDS.'. Masters found that Pacific Black Duck have a low salinity tolerance, being largely unsuccessful in breeding attempts when salinities were greater than 2.9 ppt TDS.

Comparison of Masters' data and that of the R.A.O.U. (Figs 5 and 6) suggests species may attempt to breed in conditions that are too saline for successful rearing of young. However, they may be raised at apparently high salinities by using fresh-water seepages (Riggert

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[2] J.R. Masters, Glen Avon, Northam

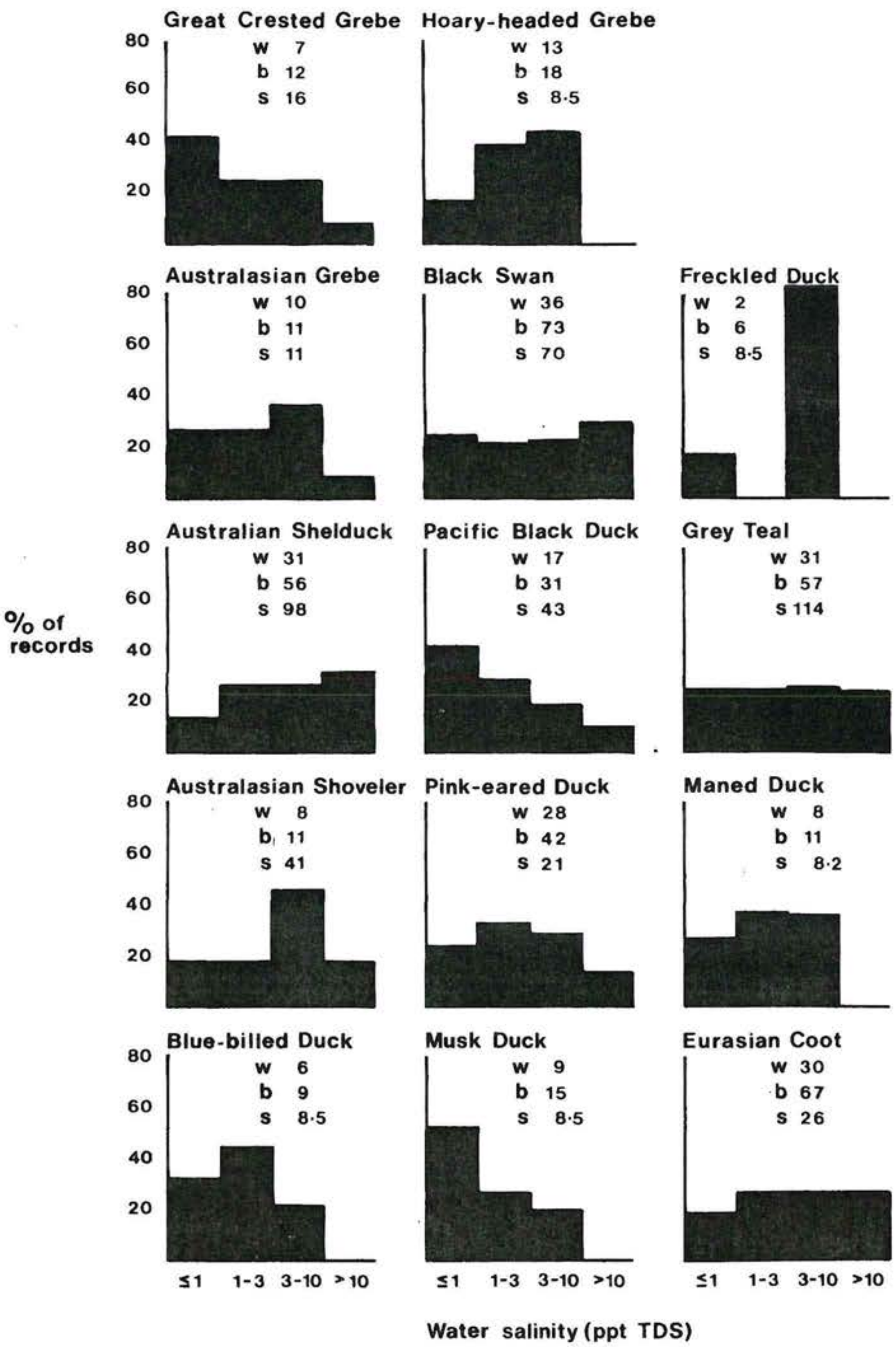

Fig. 5 Breeding attempts in south-western Australia (R.A.O.U. data) in relation to salinity (data supplied by J.A.K. Lane) for waterbirds that breed at Lake Toolibin and have precocial young. w = number of wetlands where breeding was recorded, b = number of breeding attempts (ie wetlands and years, not individual pairs), s = maximum September salinity at which the species attempted to breed.

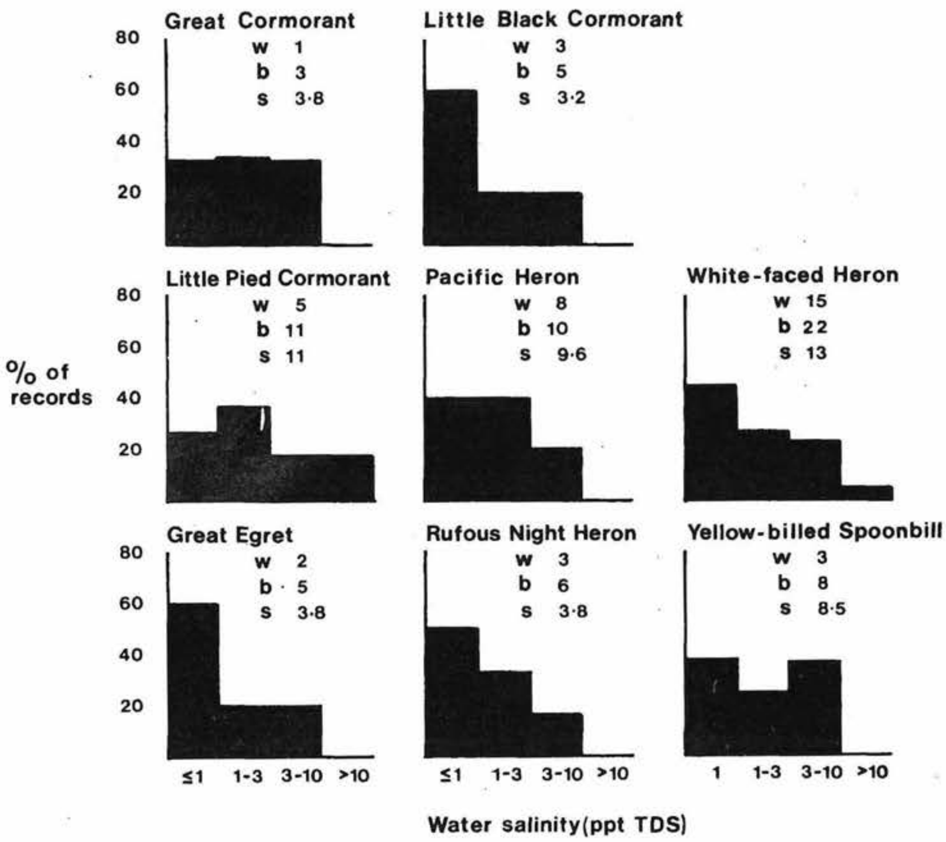

Fig. 6 Breeding attempts in south-western Australia (R.A.O.U. data) in relation to salinity (data supplied by J.A.K. Lane) for waterbirds that breed at Lake Toolibin and have altricial young. See Fig. 5 for abbreviations.

1977). More research is required to ascertain how frequently this occurs and how frequently young die through dehydration because water is too saline. Masters' data, Riggert (1969) and Swanson *et al.* (1984) all suggest that even the more salt-tolerant species cannot raise young at salinities greater than 5–10 ppt TDS without access to fresh-water in the first few days after hatching. Less tolerant species like Pacific Black Duck probably only raise young in water with a salinity less than 3 ppt, although almost 10 per cent of recorded breeding attempts have been at salinities greater than 10 ppt TDS (Fig. 5).

Salinity and total number of species

Very young ducklings cannot drink salt-water because their salt glands are not functional and they cannot excrete the salt load incurred (Riggert 1969). However, this is not a problem for adult birds and many areas that are unsuitable habitat for breeding because of the salt content of the water support large numbers of adults. Lavery (1972) found adult Grey Teal in Queensland fed in coastal, salt-water habitats after the breeding season although most immature birds remained at fresh-water lakes. Grey Teal do not appear to have as great an ability to excrete salt as some other Australian waterfowl. Lavery (1972) found the adult Grey Teal drank some salt-water but also flew inland to fresh-water lakes to drink. Australian Shelducks behave similarly (Riggert 1969, 1977) but adult Black Swans are reported to be able to drink salt-water constantly (Lavery 1972; Hughes 1976).

If Lake Toolibin became saline there would probably be only a small decline in the total number of species and adult individuals occasionally using the lake but a dramatic drop in the number of resident species because birds would move elsewhere to breed. The situation would be similar to that in the nearby, saline Lake Taarblin, for which 31 species were recorded between 1981-85 but only eight were resident.

DISCUSSION

Lake Toolibin supports the largest number of breeding species of waterbird of any wetland in south-western Australia. Significant numbers of individuals are found there throughout the year, except for those occasions when the lake dries out. The three factors that appear to result in Lake Toolibin being such favourable waterbird habitat are:

(1) extensive living thickets and woodlands of *C. obesa* and *Melaleuca* spp.

(2) comparatively fresh water

(3) occasional drying out of the lake.

As a result of secondary salinity in the catchment area, the level of salinity in the lake is likely to continue to rise (Martin 1986; Stokes and Sheridan 1986) causing all the emergent vegetation to die (Martin 1986; Froend *et al.* 1987). This will lead to Lake Toolibin becoming a typical saline wheatbelt lake. Although only slightly reduced numbers of waterbird species and similar numbers of individuals may continue to use it, few will be resident and the number of breeding species will certainly be restricted to 11 or fewer.

Species particularly affected

The species that will be most affected if the lake becomes saline is the Freckled Duck. Lake Toolibin supports the largest population of this species in south-western Australia (Jaensch in press) and is the most important breeding area. Freckled Duck have specific breeding requirements, using fresh/brackish-water lakes with dense tree vegetation. Loss of this habitat results in Freckled Duck abandoning an area (Frith 1977). Besides Lake Toolibin, there are only four wetlands in south-western Australia where Freckled Duck are known to breed - Benger Swamp, Lake Wannamal, Crackers Swamp and Kwobrup Swamp. Of these, Lake Wannamal is becoming saline and a substantial proportion of the trees in it are now dead. It probably continues to be used because there are substantial areas of fresh-water seepage where trees and 'rushes' still grow (R.P. Jaensch personal communication[3]). Kwobrup Swamp is also becoming saline. Crackers Swamp is fresh but fills only sporadically so that breeding there is erratic. With appropriate management, however, Benger Swamp should remain suitable for Freckled Ducks.

Lake Toolibin is the only wetland in south-western Australia where Great Cormorants were recorded breeding in R.A.O.U. surveys between 1981-1985, although they also bred in Booragoon Swamp in Perth. Between 1977-81 they were recorded breeding in at least three wetlands (Blakers *et al.* 1984) and they are not uncommon in wetlands of the south-west. Nevertheless, the disappearance of the Lake Toolibin breeding colony would represent a significant ornithological loss.

The Great Egret breeds in only six wetlands in south-western Australia. It was recorded breeding in Lake Toolibin, Lake Chandala and Australind Egret Swamp during R.A.O.U. surveys and also breeds at Esperance, Ludlow and Wokalup. Only Lake Chandala and the Esperance site are likely to remain in their present condition; Australind Egret Swamp and the Wokalup site are close to heavy industry and their futures as breeding areas are uncertain (J.A.K. Lane personal communication[4]). Seepage of groundwater from nearby mining operations has caused the seasonal Ludlow wetland to become permanently flooded. The vegetation may die because of water-logging, which will result in loss of the breeding colony there. Thus the disappearance of the Lake Toolibin colony would be a significant loss.

Yellow-billed Spoonbills and Rufous Night Herons are in a similar situation. The spoonbills were recorded breeding regularly in Lakes Toolibin and Chandala; in addition breeding attempts were recorded at Lake Eganu and Crackers Swamp. They also breed near Mandurah and at

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[3]R.P. Jaensch, R.A.O.U.

[4]J.A.K. Lane, Department of Conservation and Land Management.

Ludlow. If Lake Toolibin became more saline they would cease using it regularly for breeding, resulting in Lake Chandala, Mandurah and probably Crackers Swamp having the only breeding colonies.

Table 6: Number of breeding species in wetlands surveyed by the R.A.O.U. in south-western Australia between 1981-1985 (N = 251). Percentages are shown in parentheses.

No. of breeding species	No. of wetlands
0	111 (44.2)
1-4	87 (34.7)
5-10	42 (16.7)
11-20	10 (4.0)
≧21	1[a] (0.4)

[a] Lake Toolibin

Rufous Night Herons were recorded breeding regularly at Lake Toolibin, Lake Chandala and Australind Egret Swamp. They also breed near Esperance. Breeding attempts have also been recorded at Lake Taarblin (Jaensch in press). Only the breeding colonies at Lake Chandala and Esperance are secure.

Thus, increased salinity in Lake Toolibin would have pronounced effects on the population dynamics of several species. As a group large wading birds, which generally nest in trees over water, would be particularly affected. Besides Great Egrets, Yellow-billed Spoonbills and Rufous Night Herons, both Pacific and White-faced Herons nest at the lake. Probably all would cease breeding there.

General effect on waterbird populations

Conservation of individual species is not the only yardstick to use in assessing the importance of preserving a habitat. Loss of Lake Toolibin as a fresh-water breeding habitat would, as has already been described, have a marked effect on the population sizes of several species in the south-west. It would also have an effect on overall number of waterbirds. As Garstone (1973) and Goodsell *et al.* (1978) have stressed, and Table 6 shows, Lake Toolibin is a very important breeding area. Large numbers of ducks breed there most years, which contributes to overall population sizes of these game species. Because none of the game species is rare, there is frequently insufficient attention paid to the preservation of suitable breeding habitat for them.

There is an aesthetic appeal in the presence of large numbers of waterbirds of all kinds in the south-west which is being increasingly recognized by the community at large. Therefore, the breeding habitat of common, non-game species also should be protected to ensure an abundance of birds in the region and to prevent currently common species becoming rare. It is much easier to conserve and manage animals when they are abundant and population sizes are large enough to accommodate natural fluctuations in numbers than when they are rare. Then a drop in number that is part of a natural population cycle can lead to extinction.

Hence, all that is possible should be done to maintain Lake Toolibin as a densely vegetated fresh-water lake. This will ensure the continued existence of a sizeable population of Freckled Ducks and breeding colonies of Great Cormorants and several species of large wading birds that breed in few wetlands in south-western Australia. It will also provide substantial recruitment to populations of many common waterbird species, including ducks. Only through the existence of high quality breeding grounds where large numbers of birds nest, like Lake Toolibin, will population sizes of waterbird species remain at their present level in south-western Australia.

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REFERENCES

Baudinette, R.V., Norman, F.I. and Roberts, J. (1982). Salt gland secretion in saline-acclimated Chestnut Teal, and its relevance to release programs. *Australian Journal of Zoology* 30 : 407-415.

Bayly, I.A.E. and Williams, W.D. (1973). *Inland waters and their ecology*. Longman, Melbourne.

Bekle, H. (1983). Effect of unseasonal rains in January 1982 on waterfowl in south-western Australia. II. Records of late breeding from inland localities. *Western Australian Naturalist* 15 : 126-130.

Blakers, M., Davies, S.J.J.F. and Reilly, P.N. (1984). *The atlas of Australian birds*. Melbourne University Press, Melbourne.

Briggs, S.V. and Maher, M.T. (1985). Limnological studies of waterfowl habitat in south-western New South Wales. II. Aquatic macrophyte productivity. *Australian Journal of Marine and Freshwater Research* 36 : 707-715.

Briggs, S.V., Maher, M.T. and Palmer, R.P. (1985). Bias in food habits of Australian waterfowl. *Australian Wildlife Research* 12 : 507-514.

Brock, M.A. and Lane, J.A.K. (1983). The aquatic macrophyte flora of saline wetlands in Western Australia in relation to salinity and permanence. *Hydrobiologia* 105 : 63-76.

Burvill, G.H. (1950). The salt problem in the wheatbelt. *Journal of Agriculture, Western Australia* 27 : 174 - 180.

Congdon, R.A. and McComb, A.J. (1976). The nutrients and plants of Lake Joondalup, a mildly eutrophic lake experiencing large seasonal changes in volume. *Journal of the Royal Society of Western Australia* 59 : 14-23.

Frith, H.J. (1977). *Waterfowl in Australia*. Reed, Sydney.

Froend, R.H. (1983). Impact of increased flooding and salinity on the tree vegetation of Lake Toolibin. Unpublished Honours thesis, University of Western Australia.

Froend, R.H., Heddle, E.M., Bell, D.T. and McComb, A.J. (1987). Effects of salinity and waterlogging on the vegetation of Lake Toolibin, Western Australia. *Australian Journal of Ecology* (in press).

Garstone, R. (1973). *Birds of the Great Southern*. Blair, Perth.

Gill, C.J. (1970). The flooding tolerance of woody species - a review. *Forestry Abstracts* 31 : 671-688.

Gentilli, J. and Bekle, H. (1983). Modelling a climatically pulsating population : Grey Teal in south-western Australia. *Journal of Biogeography* 10 : 75-96.

Goodsell, J., Garstone, R. and Lambert, P. (1978). Guidelines to the management of the fauna of Lake Toolibin Nature Reserve and other nearby Nature Reserves. *In* Northern Arthur River Wetlands Rehabilitation Committee - progress report. Unpublished report to Minister of Fisheries and Wildlife.

Hughes, M.R. (1976). The effects of salt-water adaptation on the Australian Black Swan *Cygnus atratus* (Latham). *Comparative Biochemistry and Physiology* 55 : 271-277.

Jaensch, R.P. (in press). R.A.O.U. waterbird usage studies in south-western Australia: wetland nature reserves of the South-west and Eucla Land Division. Department of Conservation and Land Management, Perth.

Lavery, H.J. (1972). Studies of waterfowl (Anatidae) in north Queensland. 9. Grey Teal *Anas gibberifrons gracilis* Buller at salt-water habitat. *Queensland Journal of Agriculture and Animal Science* 29 : 223-235.

MacArthur, R.H. (1964). Environmental factors affecting bird species diversity. *American Naturalist* 98 : 387-394.

Mahoney, S.A. and Jehl, J.R. (1985). Avoidance of salt-loading by a diving bird at a hypersaline and alkaline lake : Eared Grebe. *Condor* 87 : 389-397.

Martin, M.W. (1986). Hydrogeology of Lake Toolibin. Hydrogeology Report 2684. Geological Survey of Western Australia, Perth.

Mattiske, E.M. (1978). Vegetation studies of Lake Toolibin and surroundings. *In* Northern Arthur River Wetlands Rehabilitation Committee - progress report. Unpublished report to Minister of Fisheries and Wildlife.

Mattiske, E.M. (1982). Progress report - Lake Toolibin study. February, 1982. Unpublished report to Department of Fisheries and Wildlife.

Mulcahy, M.J. (1978). Salinization in the south-west of Western Australia. *Search* 9 : 269-272.

N.A.R.W.R.C. (1978). Northern Arthur River Wetlands Rehabilitation Committee - progress report. Unpublished report to Minister of Fisheries and Wildlife.

N.P.I.A.W. (1985). *The waterbirds of Australia. The National Photographic Index of Australian Wildlife.* Angus & Robertson, Sydney.

Readers' Digest (1976). *Complete book of Australian birds.* Readers' Digest, Sydney.

Riggert, T.L. (1969). The biology of the Mountain Duck

Tadorna tadornoides on Rottnest Island. Unpublished Ph.D. thesis, University of Western Australia.

Riggert, T.L. (1977). The biology of the Mountain Duck on Rottnest Island, Western Australia. *Wildlife Monographs* 52: 1-67.

Serventy, D.L. and Whittell, H.M. (1976). *Birds of Western Australia*. University of Western Australia Press, Perth.

Stokes, R.A. and Sheridan, R.J. (1986). Hydrology of Lake Toolibin. Report No. WH2. Water Authority of Western Australia, Perth.

Swanson, G.A., Adomaitis, V.A., Lee, F.B., Serie, J.R. and Shoesmith, J.A. (1984). Limnological conditions influencing duckling use of saline lakes in south-central Dakota. *Journal of Wildlife Management* 48 : 340-349.

Watson, A.N. (1978). The clearing history of the Toolibin area and some of its effects. *In* Northern Arthur River Wetlands Rehabilitation Committee - progress report. Unpublished report to Minister of Fisheries and Wildlife.

Williams, W.D. (1969). Eutrophication of lakes. *Proceedings of the Royal Society of Victoria* 83 : 17-26.

Williams, W.D. and Buckney, R.T. (1976). Chemical composition of some inland surface waters in south, western and northern Australia. *Australian Journal of Marine and Freshwater Research* 27 : 379-397.

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