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Inland waters of Rottnest Island

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Abstract

Aspects of the limnology of the inland waters of Rottnest Island are presented. Physical features and chemistry of the waters parallel values for other inland saline waters in southern Australia. The fauna is clearly salt-tolerant, many species tolerating salinities above previously recorded levels. Similarity to the fauna of inland coastal saline waters in southern Australian is noted. Twelve species are shared with south east Australia.

Introduction

The inland waters of Rottnest Island were described by Hodgkin (1959) and Edward and Watson (1959) and then comprised six permanent salt lakes, two ephemeral salt lakes, eight variably-saline ephemeral swamps and three freshwater ephemeral pools. Since 1959 a number of changes has occurred to these water bodies. In the early seventies, five ephemeral swamps (Bickley, Bulldozer, Lighthouse, Parakeet and Salmon) were excavated to provide marl for road construction. These swamps now contain permanent water. Road construction formed two ephemeral freshwater pools, one (named Gull Wash Pool) on the eastern shore of Bagdad Lake, the other (named Frog Pool) on the western shore of Herschell Lake. Landscaping on the eastern shore of Garden Lake modified Garden Pool.

There has been little research on these water bodies since 1959. Chemical and physical characteristics of some lakes and swamps were briefly presented by Playford (1977) and Riggert (1977) and salinities in Pink and Negri Lakes in relation to *Daphniopsis pusilla*, a salt-tolerant cladoceran were noted by Bayly and Edward (1969). Two studies, the population dynamics of *D. pusilla* (Edward, Bunn and Tomney) and meromixis in the salt lakes of Rottnest Island (Edward and Bunn) are in preparation.

Apart from these studies, there has been irregular sampling of the chemistry and biota of most of the water bodies as part of a long-term survey and for undergraduate field courses in the Zoology Department, University of W.A. In 1967, Bagdad, Negri and Pink Lakes and Lighthouse Swamp were sampled fortnightly for physical and chemical parameters and biota. These data, presented in this paper, provide an account of the limnology of the inland waters of Rottnest Island.

Methods

Field measurements of salinity below 40‰ were by salinity-temperature bridge (Yeo Kal Model 602). For salinities above 40‰, total dissolved solids were determined gravimetrically and converted using the equation, Salinity = T.D.S. × 0.95 (determined from analyses for five salt lakes 29-iii-1966). The W.A. Government Chemical Laboratories analysed water samples from 1966 to 1968. Phosphate analysis was by the molybdate-ascorbic acid method (Strickland and Parsons 1972).

Temperature was recorded by salinity-temperature bridge or by maximum minimum thermometer and oxygen was measured using the azide modification of the Winkler technique.

Benthic and planktonic faunal collections were made with coarse and fine hand nets (500 μM and 100 μM mesh) and preserved in 70% ethanol. Fortnightly samples in 1967 were standardised by collecting samples over 15 paces. Relative abundance of species was estimated as rare (< 50 specimens), common (<500 speciments) and abundant (> 500 specimens).

Results

The inland waters of Rottnest Island can be grouped into ephemeral freshwater pools, ephemeral and permanent variably-saline swamps and ephemeral saline lakes and permanent high saline lakes.

Ephemeral freshwater pools comprise Garden north, Corio, Gull Wash and Frog but for this study only the last three were investigated. If an upper limit for salinity of 3‰ is accepted for freshwater (Williams 1964) then these pools fall into the freshwater category. The pattern of drying shows considerable variation. Gull Wash and Frog Pools have little bottom sediment and as evaporation proceeds the salinities increase to levels above 3‰ (Table 1). Corio Pool, a small pool with a thick ooze bottom is situated in an area of freshwater seepage and as drying proceeds there is no notable salinity increase. Flora in these pools is mainly filamentous algae, with small patches of *Elodea canadensis* in Corio Pool. The fauna (Table 1), consists of a few freshwater with mainly salt-tolerant freshwater species.

The ephemeral and permanent variably-saline swamps and ephemeral saline lakes comprise the major proportion of water bodies on the Island. The waters showed Na^+ and Cl^- ionic dominance, high pH (Figs. 1 and 2) and extremely low phosphate concentration (0-2.48 μg l^{-1} range for five swamps in November 1982). Originally all ephemeral waters, three swamps (Barkers, Rifferange and Aerodrome) and two lakes (Negri and Sirius) are still in a natural state, however the other swamps, after excavation for marl now contain permanent water. Lighthouse swamp, prior to excavation, was consistently fresh with only freshwater and salt-tolerant freshwater species (Table 1). There were 12 dominant species of fauna in the swamp during the 1967 survey (Fig 1).

Lighthouse Swamp is now permanent and saline and the fauna (Table 1) consists of salt-tolerant freshwater species which appear with suitable

Table 1

Fauna of the inland waters of Rottnest Island

Classification Code	Fauna	Range of field salinity at Rottnest ‰	Corio			Gull Wash		Frog		Lighthouse					Salmon				Bickley		
			1·1‰S 18- x -1958	0·7‰S 29-viii-1982	1·4‰S 20- x -1982	2·5‰S 26- ix -1982	6·2‰S 20- x -1982	2·4‰S 2- ix -1978	8·7‰S 20- x -1982	3·1‰S 18- x -1958	1·4‰S 14-vii-1967	6·7‰S 2- ix -1978	10·4‰S 26- ix -1982	14·2‰S 28- xi -1982	4·7‰S 18- x -1958	12·5‰S 2- ix -1978	15·0‰S 26- ix -1982	38·7‰S 28- xi -1982	4·3‰S 18- x -1958	13·0‰S 26- ix -1982	22·9‰S 20- x -1982
Ol	OLIGOCHAETA	1 – 2·2	*	*	*			*			*										
Am	*Litoria moorei*	1 – 2·4	*	*	*						*										
Tu	TURBELLARIA	1 – 2·5				*															
Cl	*Chydorus sphaericus*	1 – 2·5		*																	
Cl	*Ceriodaphnia quadrangula*	1 – 2·5				*															
Cl	*Alona quadrangularis*	1 – 2·5				*															
Cu	*Aedes camptorynchus*	1 – 4·3						*			*										
Os	*Candonocypris novaezelandiae*	1 – 4·3	*	*	*						*										
Cl	*Simocephalus elizabethae*	1 – 4·7	*							*	*				*						
Od	*Anax papuensis*	1 – 4·7									*				*				*		
Hy	*Berosus* sp.	1 – 4·7									*										
Os	*Sarscypridopsis aculeata*	1 – 6·2		*		*		*			*										
Ch	*Chironomus* aff. *alternans*	1 – 8·7		*	*		*	*			*				*						
Cx	*Sigara* sp.	1 – 8·7	*	*	*			*			*										
Co	*Mesocyclops albicans*	1 – 10·7		*	*	*	*	*	*		*		*								
Cx	*Micronecta* sp.	1 – 12·5	*	*	*			*			*		*								
Cl	*Daphnia carinata*	1 – 12·6				*	*	*	*	*	*				*	*			*		
Ch	*Tanytarsus fuscithorax*	1 – 14·8							*	*	*					*					
Cl	*Echinisca capensis*	1 – 14·8						*	*	*	*					*					
Os	*Kennethia cristata*	1 – 14·8								*	*										
Os	*Alboa worooa*	1 – 14·8	*							*	*		*			*			*		
Os	*Mytilocypris ambiguosa*	1 – 14·8		*																	
No	*Paranisops* sp.	1 – 14·8	*																		
Co	*Boeckella triarticulata*	1 – 15·7				*		*	*	*	*		*								
No	*Anisops* sp.	1 – 22·9	*	*	*		*														
Od	*Austrolestes annulosus*	1 – 24·1									*										
St	*Odontomyia* ? sp.	1 – 36·0	*								*		*								
Ch	*Cryptochironomus curtivalva*	1 – 38·7																			
Os	*Diacypris spinosa*	2·4– 44·0						*					*								
Ap	*Austrochiltonia subtenuis*	1 – 45·0									*										
Cl	*Daphniopsis pusilla*	8·7– 59·0											*								
Dy	*Necterosoma penicillatus* (larva)	1 – 70·0	*	*	*	*	*	*	*	*	*		*		*				*		
Os	*Mytilocypris minuta*	2·4– 70·0						*	*				*								
Co	*Microcyclops dengizicus*	8·7– 70·0																			
Mo	*Coxiella striatula*	10·4– 70·0																			
Cu	*Aedes ashworthi*	10·4– 70·0														*					
Os	*Diacypris* aff. *spinosa*	15·9– 81·0																			
Co	*Heterolaophonte wellsi*	15·9– 87·0																			
Ch	*Procladius paludicola*	1 – 98·0							*							*					
Co	*Mesochra baylyi*	10·4–104·0																			
Po	POLYCHAETA	21·6–106·0																			
Co	*Calamoecia clitellata*	12.5–113·0																			
Dy	*Necterosoma penicillatus* (adult)	1 –145·0	*							*	*				*	*					
Is	*Haloniscus searlei*	8·0–173·0																			
Tr	*Symphitoneuria wheeleri*	10·4–173·0																			
Ch	*Tanytarsus barbitarsis*	12·5–173·0																			
Ep	EPHYDRIDAE (larva)	15·0–173·0																			
Ce	*Culicoides waringi*	17·6–173·0																			
Ar	*Artemia* sp.	69·0–173·0																			

Classification code:

Ol, Annelida: Oligochaeta; Am, Vertebrata: Amphibia;

Tu, Platyhelminthes: Turbellaria; Cl, Crustacea: Cladocera;

Cu, Insecta: Diptera: Culicidae; Os, Crustacea: Ostracoda;

Od, Insecta: Odonata; Hy, Insecta: Coleoptera: Hydrophilidae;

Ch, Insecta: Diptera: Chironomidae; Cx, Insecta: Hemiptera: Corixidae;

Co, Crustacea: Copepoda; No, Insecta: Hemiptera: Notonectidae;

St, Insecta: Diptera: Stratiomyidae; Ap, Crustacea: Amphipoda;

Dy, Insecta: Coleoptera: Dytiscidae; Mo, Mollusca: Gastropoda;

Po, Annelida: Polychaeta; Is, Crustacea: Isopoda; Tr, Insecta: Trichoptera: Ep, Insecta: Diptera: Ephydridae; Ce, Insecta: Diptera: Ceratopogonidae; Ar, Crustacea: Anostraca.

Table 1—continued

Barkers				Parakeet		Bulldozer				Rifle Range			Aerodrome			Negri			Sirius		Pink				Bagdad			Govt. House		
8·7°/oo S 18-x-1958	7·7°/oo S 2-ix-1978	11·5‡/oo S 26-ix-1982	14·8°/oo S 20-x-1982	21·6°/oo S 26-ix-1982	34·8°/oo S 28-xi-1982	12·6°/oo S 18-x-1958	15·7°/oo S 2-ix-1978	25·1°/oo S 26-ix-1982	44·0°/oo S 28-xi-1982	8·7°/oo S 2-ix-1978	23·8°/oo S 26-ix-1982	70·0°/oo S 28-xi-1982	8·0°/oo S 18-x-1958	22·0°/oo S 28-viii-1982	68·5°/oo S 28-xi-1982	15·9°/oo S 1-vii-1967	51·3°/oo S 21-xi-1967	33·7°/oo S 20-x-1982	45·0°/oo S 26-ix-1982	69·7°/oo S 20-x-1982	29·0°/oo S 25-viii-1967	145·0°/oo S 11-iii-1968	61·8°/oo S 20-x-1982	104·0°/oo S 28-xi-1982	173·0°/oo S 7-iv-1967	70·0°/oo S 7-ix-1967	98·0°/oo S 28-viii-1982	167·0°/oo S 7-iv-1967	107·0°/oo S 29-vii-1967	134·0°/oo S 28-viii-1982
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salinities and halobiont species (salinity range 10-300+°/oo, Bayly 1972).

The other swamps and lakes reflect the species composition now seen in Lighthouse Swamp with fewer species as the minimum salinities increase (Table 1). In Negri Lake during the 1967 survey there were eight dominant species and their relative abundances are shown in Fig. 2. Permanent saline swamps have the species shown in Lake Negri and the halobiont species *Haloniscus searlei*, *Symphitoneuria wheeleri* and *Culicoides waringi*. In 1958, the flora of some of these waters consisted of freshwater and saline species however, in latter years only the salt-tolerant *Cladophora spp*, *Lamprothamnium papulosum*, *Lepilaena preissi* and *Ruppia tuberosa* (Brock 1981, 1982 pers comm.) were recorded.

The permanent salt lakes have waters with Na^{+} and Cl^{-} ionic dominance, high pH, extremely low phosphate concentrations (0-3.1 $\mu g\ l^{-1}$ range for five lakes in November 1982) and high salinities. Meromixis occurs in Government House, Herschell and Serpentine lakes and details together with mean depths are presented in Edward and Bunn (in prep.) on meromixis in the salt lakes of Rottnest Island.

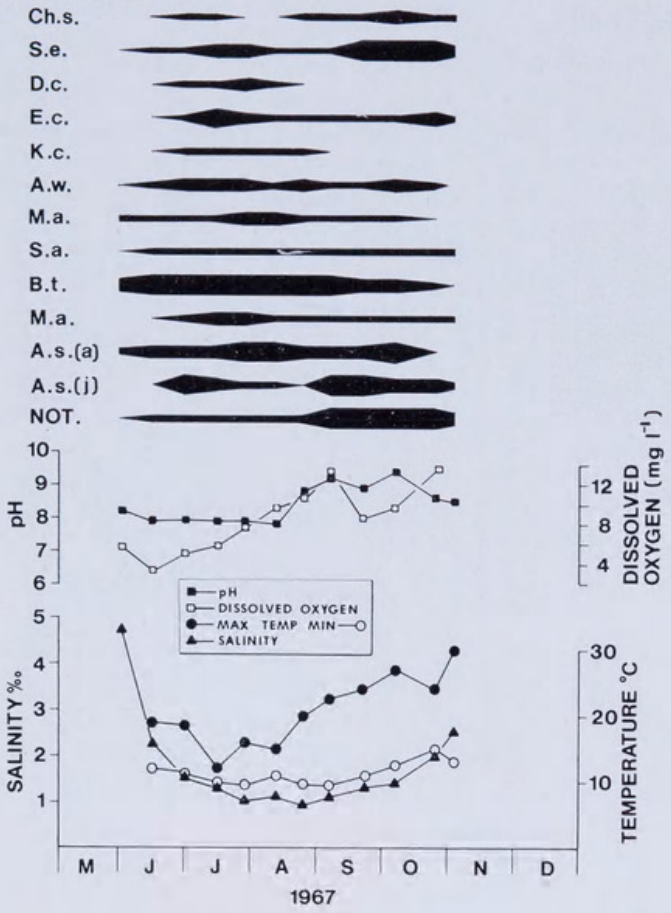

Figure 1.—Seasonal variations in the salinity, temperature, pH, dissolved oxygen and macrofauna of Lighthouse Swamp, Rottnest Island. Horizontal bars indicate presence and relative abundance of species. Abbreviation of species: Ch. s., *Chydorus sphaericus;* S.e., *Simocephalus elizabethae;* D.c., *Daphnia carinata;* E.c. *Echinisca capensis;* K.c., *Kennethia cristata;* A.w., *Alboa worooa;* M.a., *Mytilocypris ambiguosa;* S.a., *Sarscypridopsis aculeata;* B.t., *Boeckella triarticulata;* M.a., *Mesocyclops albicans;* A.s., *Austrochiltonia subtenuis* (a., adults; j., juveniles) NOT., Notonectidae.

Fortnightly records of temperature, dissolved oxygen, pH and salinity are shown for Pink Lake (Fig. 3) and Bagdad Lake (Fig. 4). The usefulness of fortnightly oxygen analyses can be questioned. Samples were collected between 1200 and 1500 hours when dissolved oxygen concentrations are highest (Fig. 5). The values do indicate when oxygen levels in these high saline waters could be potentially limiting to biota.

The salt lakes have no macrophytes except Pink Lake which has *Ruppia tuberosa* throughout most of winter and spring. Apart from *Botryococcus* sp. recorded by Hodgkin (1959) and Playford (1977) the blue-green algae *Aphanothecae halophytica, Oscillatoria* sp., *Anacystis* sp. and *Spirulina* sp. and the diatom *Navicula* sp. form benthic microbial mats up to 10 cm thick in the deeper lakes. The green alga *Dunaliella salina* is also present (T. Moulton pers comm).

The fauna is restricted to six halobiont species, except for Pink and Bagdad lakes where other species appear with lower winter salinities (Table 1, Figs. 3 and 4).

Table 1 lists the fauna for all of the inland waters with the range of field salinities recorded at Rottnest Island for each species. The sample dates cover the widest range of salinities for each locality. Unidentified species from the initial study by Edward and Watson (1959), now identified, are

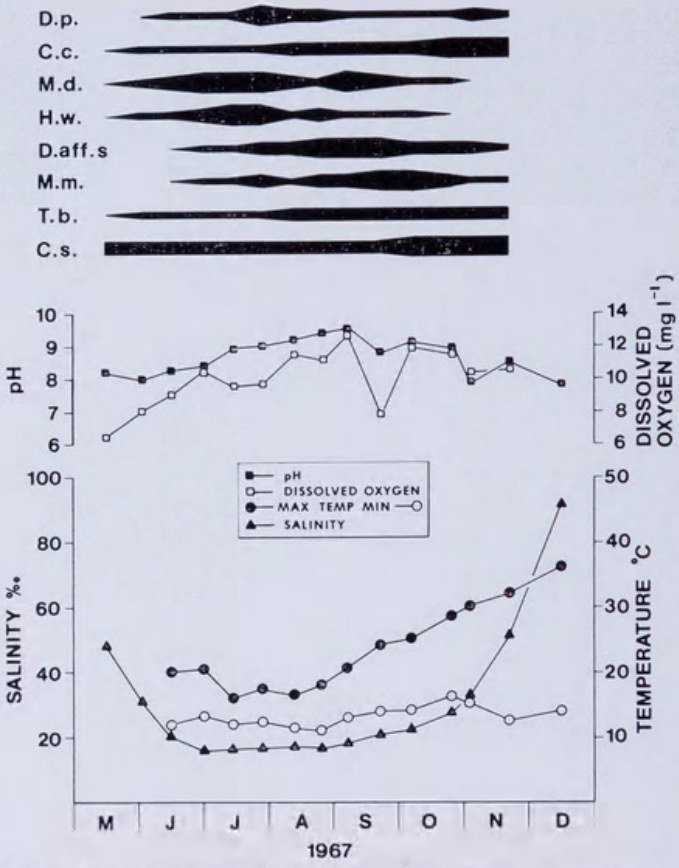

Figure 2.—Seasonal variations in the salinity, temperature, pH, dissolved oxygen and macrofauna of Negri Lake, Rottnest Island. Horizontal bars indicate presence and relative abundance of species. Abbreviation of species: D.p., *Daphniopsis pusilla;* C.c., *Calamoecia clitellata;* M.d., *Microcyclops dengizicus;* H.w., *Heterolaophonte wellsi;* D.aff.s., *Diacypris* aff. *spinosa*; M.m., *Mytilocypris minuta;* T.b., *Tanytarsus barbitarsis;* C.s., *Coxiella striatula.*

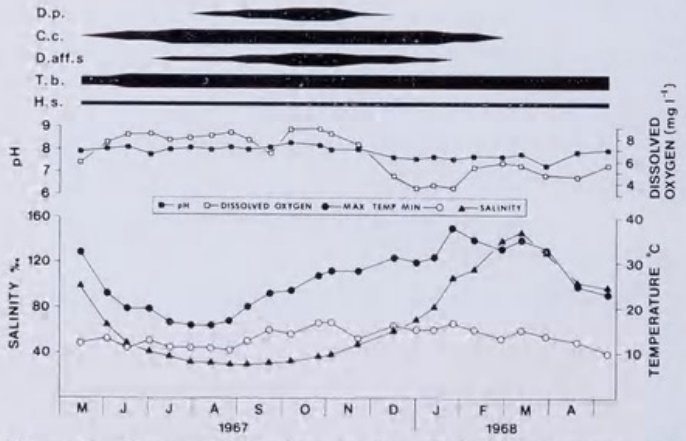

Figure 3.—Seasonal variations in the salinity, temperature, pH, dissolved oxygen and macrofauna of Pink Lake, Rottnest Island. Horizontal bars indicate presence and relative abundance of species. Abbreviation of species: D.p., *Daphniopsis pusilla*; C.c., *Calamoecia clitellata*; D.aff.s., *Diacypris* aff. *spinosa*; T.b., *Tanytarsus barbitarsis*; H.s., *Haloniscus searlei.*

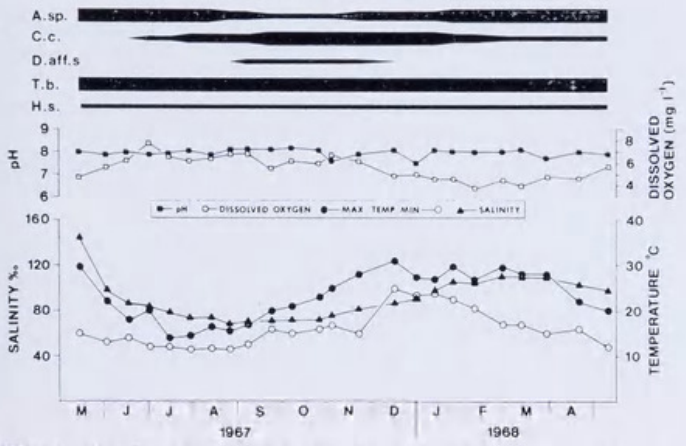

Figure 4.—Seasonal variations in the salinity, temperature, pH, dissolved oxygen and macrofauna of Bagdad Lake, Rottnest Island. Horizontal bars indicate presence and relative abundance of species. Abbreviation of species: A.sp., *Artemia* sp.; C.c., *Calamoecia clitellata*; D.aff.s., *Diacypris* aff. *spinosa*; T.b., *Tanytarsus barbitarsis*; H.s., *Haloniscus searlei*.

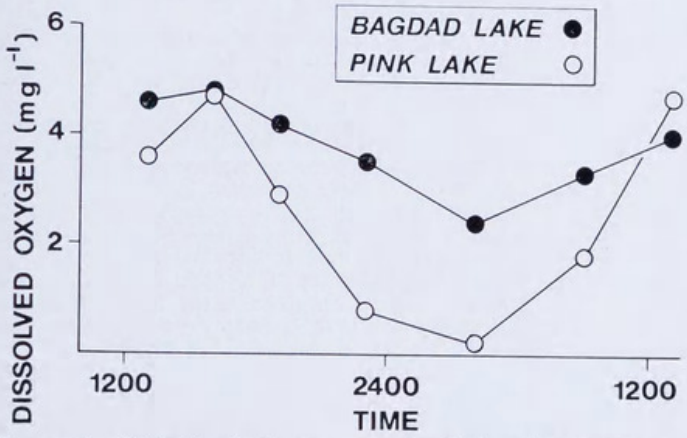

Figure 5.—Diel dissolved oxygen in Bagdad and Pink Lakes, Rottnest Island. (25.i.1968).

included. Garden, Herschell and Serpentine Lakes are not listed as they contain the same species as Government House lake. In addition there are single records for a number of species; chironomids, *Corynoneura scutellata* and *Polypedilum nubifer* (Lighthouse Swamp, 22-ix-1967, 1.3‰S), *Dicrotendipes conjunctus* Corio pool, 10-x-1959, 1.8‰S); cyclopoid copepods, *Halicyclops* sp. (Salmon Swamp, 3-ix-1978, 12.5‰S) and *Neocyclops* sp. (Pink Lake, 25-i-1968, 106‰S); cladoceran *Biapertura rigidicaudis* and rotifer *Brachiomus* sp. (both shallow pool, south side of Serpentine Lake, coll. I.A.E. Bayly, 11-viii-1973); isopod *Alloniscus nicobaricus* (Serpentine Lake, 25-vii-1982, 126‰S); conchostracans *Limnetis* sp. and *Limnadia* sp. (small shallow freshwater area, east end of airstrip, coll. I. A. E. Bayly, 11-viii-1973).

The data in Table 1 were used to explore the relationship between salinity and number of species in the inland waters of Rottnest Island. Excluding 1958 data which are incomplete and samples from freshwater pools, the number of species in each sample decreases with increasing salinity according to the relationship; number of species = 23.16 — 3.34 (ln salinity in ‰). [n = 37, p (β = 0) 0.005; r^2 = 0.51].

Discussion

The inland waters of Rottnest Island range in salinity from freshwater (< 1‰) to high saline (> 100‰), however only one small water body, Corio Pool, is consistently freshwater. Physical and chemical aspects of the saline waters require little comment: high pH and Na^+ and Cl^- ionic dominance parallels the values for other saline waters in Western Australia (Williams and Buckney 1976, Geddes *et al.* 1981, Halse 1981) and south east Australia (Williams 1981). The waters show extremely low phosphate concentrations and are characterised by changing salinities and temperatures. Fauna utilizing the waters must be tolerant of these changes and this is attested by the high number of freshwater salt-tolerant and halobiont species.

Some comment can be made about the fauna in relation to known biology and field salinities. Although Cladocera are a predominantly freshwater group some species adapt to higher salinities. For *Chydorus sphaericus*, *Ceriodaphnia quadrangula*, *Simocephalus elizabethae* and *Daphnia carinata* the salinities tolerated on Rottnest Island are the highest recorded. In eastern Australia they are only known from freshwater (Timms 1981). *Echinisca capensis* tolerated salinities up to 14.8‰ and was occasionally found with the halobiont cladoceran *Daphniopsis pusilla*. The range of salinities recorded for *D. pusilla* is similar to that known for the species throughout southern Australia (De Deckker and Geddes 1980, Geddes *et al.* 1981, Williams 1981) with a maximum salinity of 71‰ recorded by Halse (1981).

The Ostracoda *Kennethia cristata* and *Alboa worooa* are freshwater species (De Deckker pers comm, De Deckker 1981a) however on Rottnest Island salinities of 14.8‰ are tolerated. *Sarscypridopsis aculeata* a cosmopolitan species is recorded from salinities up to 21.3‰ (De Deckker 1981b). *Mytilocypris ambiguosa* a freshwater species tolerated salinities of 14.8‰. and *M. minuta* is known from similar salinities (Geddes *et al.* 1981, Halse 1981) on mainland Western Australia. *Diacypris spinosa* is reported by De Deckker (1981c) from a similar salinity range, 4-52‰ and *D.* aff. *spinosa*, which is close to *D. spinosa* (De Deckker pers comm) is a halobiont species.

Copepoda include the freshwater salt-tolerant *Mesocyclops albicans* and *Boeckella triarticulata*, a common and widely-distributed Australasian species occurring in salinities up to 22‰ in highly alkaline lakes in eastern Australia (Bayly 1969, Bayly 1979). *Microcyclops dengizicus*, *Heterolaophonte wellsi*, *Mesochra baylyi* and *Calamoecia clitellata* are all halobiont species.

The amphipod, *Austrochiltonia subtenuis* is a widespread southern Australian species (Williams 1962). Halse (1981) has recorded the species from a Western Australian mainland lake at a salinity of 71‰.

Two species of Isopoda occurred in the salt lakes. *Haloniscus searlei* is a common halobiont in southern Australia and is reported from salinities of 30-110‰ by Williams (1981). On Rottnest Island the species occupied all permanent saline waters with a salinity range of 8-173‰. *Alloniscus nicobaricus* was collected from Serpentine Lake at a

salinity of 126‰ and is the first record for this species from high saline inland waters.

The Anostraca was represented by the cosmopolitan *Artemia*, recorded by Hodgkin (1959) as *A. salina*. Because of confusion in the taxonomy it is best referred to as *Artemia* sp. (Geddes 1981). The species was confined to the permanent salt lakes, which is contrary to the statement by Geddes (1981) that *Artemia* is not found in any natural salt lake in Australia. The explanation lies in the previous use of part of Government House Lake for salt production and eggs must have been introduced with the salt-cleaning machinery. The single species of *Artemia* on Rottnest Island contrasts with the ten species of Anostraca recorded from saline lakes on the Western Australian mainland by Geddes *et al.* (1981).

The mollusc, *Coxiella striatula* occupies shallow littoral areas over a range of salinity consistent with ranges for other species of *Coxiella* in southern Australia (Bayly and Williams 1973, De Deckker and Geddes 1980, Halse 1981).

Among the Insecta, *Necterosoma penicillatus* adults were collected from all waters, however, the larvae, were restricted to waters with salinities less than 70‰. The species is common in salt lakes in southern Australia (Watts 1978) and the salinity range at Rottnest Island is considerably wider than those recorded by Bayly and Williams (1966) and Halse (1981). All chironomid larvae, apart from *Chironomus* aff. *alternans* have been recorded by Halse (1981) from saline waters on the mainland of Western Australia. *Tanytarsus barbitarsis* is a halobiont species occurring over southern Australia (Glover 1973, Williams 1981). The range of salinity tolerated by each species on Rottnest Island is the widest recorded. Larvae of *Culicoides waringi* have been collected from coastal salt marshes in southern Australia (Dyce and Murray 1967). On Rottnest Island, larvae were common in the salt lakes and inhabited detritus in littoral and deep areas, including the benthic microbial mats.

The fauna is clearly adapted to changes in salinity with many freshwater salt-tolerant species, particularly *Daphnia carinata, Echinisca capensis, Kennethia cristata, Alboa worooa, Cryptochironomus curtivalva, Procladius paludicola* and *Necterosoma penicillatus*, tolerating high salinities. For halobiont species the lowest salinity tolerated is important allowing some species to colonise and persist in waters in association with freshwater salt-tolerant species.

Comparing species from Rottnest Island with those recorded from saline waters in south east Australia (De Deckker and Geddes 1980, Williams 1981) and mainland Western Australia (Geddes *et al.* 1981, Halse 1981) further confirms the view of Geddes *et al.* (1981) that similarities exist between the faunas of saline waters in south west and south east Australia. Of 43 species recorded from Rottnest Island with salinity tolerances between 4.3 and 173‰, 12 species, *Simocephalus elizabethae, Daphnia carinata, Daphniopsis pusilla, Boeckella triarticulata, Calamoecia clitellata, Mesochra baylyi, Mytilocypris ambiguosa, Tanytarsus barbitarsis, Haloniscus searlei, Austrochiltonia subtenuis, Culicoides waringi* and *Necterosoma penicillatus* are shared with south east Australia. Overall, the fauna is similar to other coastal saline water fauna in Western Australia (Halse 1981) and southern Australia (Bayly 1970, De Deckker and Geddes 1980) and lacks the richness of species in the Anostraca, Copepoda and Ostracoda recorded for saline waters in inland Western Australia (Geddes *et al.* 1981).

Previous studies on the fauna of saline waters (Bayly and Williams 1966, De Deckker and Geddes 1980, Williams 1981) noted a relationship between the number of species and salinity. For inland saline waters of Rottnest Island there is a significant negative correlation between species diversity and salinity.

References

Bayly, I. A. E. (1969).—The occurrence of calanoid copepods in athalassic saline waters in relation to salinity and anionic proportions. *Verh. Int. Ver. Limnol.*, **17**: 449-455.

Bayly, I. A. E. (1970).—Further studies on some saline lakes of southeast Australia. *Aust. J. Mar. Freshwat. Res.*, **21**: 117-129.

Bayly, I. A. E. (1972).—Salinity tolerance and osmotic behaviour of animals in athalassic saline and marine hypersaline waters. *Ann. Rev. Ecol. Systematics*, **3**: 233-268.

Bayly, I. A. E. (1979.—Further contributions to a knowledge of the centropagid genera *Boeckella, Hemiboeckella* and *Calamoecia* (athalassic calanoid copepods) *Aust. J. Mar. Freshwat. Res.*, **30**: 103-127.

Bayly, I. A. E. and Edward, D. H. (1969).—*Daphniopsis pusilla* Serventy: a salt-tolerant cladoceran from Australia. *Aust. J. Sci.*, **32**: 21-22.

Bayly, I. A. E. and Williams, W. D. (1966).—Chemical and biological studies on some saline lakes of southeast Australia. *Aust. J. Mar. Freshwat. Res.*, **17**: 177-228.

Bayly, I. A. E. and Williams, W. D. (1973).—*Inland Waters and their Ecology*. Longman, Melbourne.

Brock, M. A. (1981).—The ecology of halophytes in the southeast of South Australia. *Hydrobiologia*, **81**: 23-32.

De Deckker, P. (1981a).—Taxonomy and ecological notes of some ostracods from Australian inland waters. *Trans. R. Soc. S. Aust.*, **105** (3): 91-138.

De Deckker, P. (1981b).—Ostracods of athalassic saline waters. *Hydrobiologia*, **81**: 131-144.

De Deckker, P. (1981c).—Taxonomic notes on some Australian ostracods with description of new species. *Zoologica Scripta*, **10**: 37-55.

De Deckker, P. and Geddes, M. C. (1980).—Seasonal fauna of ephemeral saline lakes near the Coorong Lagoon, South Australia. *Aust. J. Mar. Freshwat. Res.*, **31**: 677-699.

Dyce, A. L. and Murray, M. D. (1967).—Autogeny in *Culicoides waringi* and *Culicoides mackerrasi* (Diptera: Ceratopogonidae) from Australia with notes on breeding places and behaviour. *J. Aust. ent. Soc.*, **6**: 119-126.

Edward, D. H. and Watson, J. A. L. (1959).—Fresh water and brackish water swamps of Rottnest Island. *Jour. R. Soc. W.Aust.*, **42**(3): 85-86.

Geddes, M. C. (1981).—The brine shrimps *Artemia* and *Parartemia*: Comparative physiology and distribution in Australia. *Hydrobiologia*, **81**: 169-179.

Geddes, M. C., De Deckker, P., Williams, W. D., Morton, D. W. and Topping, M. (1981).—On the chemistry and biota of some saline lakes in Western Australia. *Hydrobiologia*, **82**: 201-222.

Glover, B. (1973).—The Tanytarsini (Diptera: Chironomidae) of Australia. *Aust. J. Zool. Suppl. Ser.*, No. **23**: 403-478.

Halse, S. A. (1981).—Fauna assemblages of some saline lakes near Marchagee, Western Australia. *Aust. J. Mar. Freshwat. Res.*, **32**: 133-142.

Hodgkin, E. P. (1959).—The salt lakes of Rottnest Island. *Jour. R. Soc. W. Aust.*, **42**: 84-85.

Playford, P. E. (1977).—Geology and groundwater potential. In: Geology and hydrology of Rottnest Island, P. E. Playford and R. E. J. Leech (eds.), *Geol. Surv. W.A. Rep.* **6**: 1-53.

Riggert, T. L. (1977).—The biology of the mountain duck on Rottnest Island, Western Australia. *Wildlife Monographs* No. 52.

Strickland, J. D. H. and Parsons, T. R. (1972).—A practical handbook of seawater analysis. *Bull Fish. Res. Bd. Can.*, **167** (2nd ed.) 310 pp.

Timms, B. V. (1981).—Animal communities in three Victorian lakes of differing salinity. *Hydrobiologia*, **81**: 181-193.

Watts, C. H. S. (1978).—A revision of the Australian Dytiscidae (Coleoptera) *Aust. J. Zool. Suppl. Ser.*, No. **57**: 1-166.

Williams, W. D. (1962).—The Australian freshwater amphipods, I. The genus *Austrochiltonia* (Crustacea: Amphipoda: Hyalellidae) *Aust. J. Mar. Freshwat. Res.*, **13**: 198-216.

Williams, W. D. (1964).—A contribution to lake typology in Victoria, Australia. *Verh. Int. Ver. Limnol.*, **15**: 158-168.

Williams, W. D. (1981).—The limnology of saline lakes in Western Victoria. *Hydrobiologia*, **82**: 233-259.

Williams, W. D. and Buckney, R. T. (1976).—Chemical composition of some inland surface waters in South, Western and northern Australia. *Aust. J. Mar. Freshwat. Res.*, **27**: 379-397.

The birds of Rottnest Island

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Abstract

The literature on the birds of Rottnest Island is reviewed and presented in a Table which lists the species of bird which have been seen on, around or over the island. Each species has been classed as resident (N=28), breeding migrant (N=6), non-breeding migrant (N=21) and vagrant (N=54) and listed under the habitats in which it has been recorded. In addition 4 species which formerly occurred on the island are also listed.

The importance of Rottnest Island as a conservation reserve is pointed out and the need for a long-term management plan for the island is stressed.

Introduction and literature review

In reviewing the literature, it is convenient to regard publications relating to the birds of Rottnest Island as coming from two periods: before the Biological Field Station was opened, and after. Before this event it was difficult for biologists to spend long periods on the island and publications reflect both this and the fact that ornithology in Australia was at the stage of producing inventories. Information on the birds appeared as: annotated species lists based on one visit (Lawson 1905, Kilpatrick 1932); annotated species lists based on more than one visit and incorporating observations of people other than the author (Alexander 1921, Glauert 1929, Serventy 1938, 1948); notes adding to existing birds lists (Conigrave 1909, Storr and Dunnet 1955, McCrum and Slater 1955, Storr 1957, Ford 1957, 1958); comments on breeding (Robinson 1935, Serventy 1947, Reid 1949, 1950, Serventy 1950). None provided detailed analyses of any of the birds, although Serventy (1950) gave an account of three breeding seasons of the Fairy Tern *Sterna nereis* based on a few visits each season (2 in 1947; 4 in 1949; 1 in 1950).

The early phase of the Field Station was reviewed by Hodgkin and Sheard (1959) and included a bird list for each habitat on the island (Serventy and Storr 1959). Since then the literature has been dominated by biologists operating from the Field Station, resulting in more detailed publications (Storr 1964a, 1964b, 1965a, 1965b, 1976; Holsworth 1965; Riggert 1969, 1977; Williams 1971, 1979; Williams and Main 1976, 1977). Notes which add to distribution lists are still published (Storr and Ford 1962, McMillan 1963, Smith and Saunders 1980), as are notes about breeding (Abbott 1977, Abbott *et al.* 1978), feeding (Farmer 1961) and longevity (Robin 1966).

Of these publications, Storr's papers (1964b, 1965a, 1965b) are the most comprehensive. Based on data collected during 275 days on the island from January 1953, together with previous literature and data from his colleagues, he presented detailed information on the status and habitat preferences of each species.

Since this work appeared there have been several studies of single species. Holsworth (1965) gathered data over three years on the breeding and juvenile dispersal of the Osprey *Pandion haliaetus*. During the period 1961-1963, three pairs bred each season, producing a total of 15 young of which 10 were banded. The three band returns showed that the immature birds disperse widely from the island.

Between October 1964 and December 1974 a study of the breeding biology and population dynamics of the Mountain Duck *Tadorna tadornoides* was carried out on the island (Riggert 1969, 1977). In addition, the possible effects on this population of shooting pressure on the mainland during the annual duck-hunting season was investigated. During the study 1690 ducks were banded, and of these, 1012 were marked with "A-frame" bill tags to enable individuals to be recognized from a distance. Counts of broods and of the population on the island were made at monthly intervals while band recoveries gave estimates of dispersal and mortality. Riggert found that