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THE SIGNIFICANCE OF MOSQUITO BREEDING AREAS TO THE WATERBIRDS OF LESCHENAULT ESTUARY WESTERN AUSTRALIA

June 1989

THE SIGNIFICANCE OF MOSQUITO BREEDING AREAS TO THE WATERBIRDS OF LESCHENAULT ESTUARY, WESTERN AUSTRALIA

Prepared for: Mosquito Control Review Committee, Waterways Commission

By: Ninox Wildlife Consulting
June 1989

ISBN 0-7309-2629-X
ISSN 0814-6322
Waterways Commission Report Number 14
184 St George's Tce
Perth Western Australia
6000

Cover sketch by
M Bamford

SUMMARY

The Mosquito Eradication Campaign study of 1985 showed that most mosquito breeding took place in tidal saltmarshes surrounding Leschenault Estuary (Wright 1986). As a result the Mosquito Control Review Committee commissioned a study of waterbird usage of the estuary to determine the importance of tidal saltmarshes to waterbirds.

Nine surveys of 40 sites were conducted between September 1987 and October 1988. Data were amassed for 62 species of waterbird and 23,470 individuals; each record was accompanied by information on habitat and activity.

The study has shown that Leschenault Estuary is important to birds and that tidal saltmarshes and other mosquito breeding areas are an integral and necessary part of the estuarine system. This conclusion was reached on the basis that mosquito breeding areas:

- are used by at least 60 of the 62 species of waterbird recorded at the estuary;
- support 38% of all individual waterbirds counted at Leschenault Estuary in an area representing 11% of the estuarine system;
- show a disproportionate usage per unit area by certain waterbird groups (77% of all herons, egrets and ibis; 49% of all ducks and grebes; 41% of all wading birds);
- act as refuges for large numbers of birds during very high tides and stormy weather;
- provide rich intertidal and freshwater feeding areas for a large proportion of the waterbird species using the estuary (37% of all individuals recorded in mosquito breeding areas were observed feeding);
- are virtually the only areas where breeding takes place and which can provide refuge for young waterbirds;
- are used by a large number of migratory wading birds many of which are protected by international conservation agreements.

Fringing wetlands of special significance to waterbirds are defined and recommendations on mosquito control measures compatible with waterbird conservation are given.

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LIST OF PARTICIPANTS

The survey and report described in this document were planned, supervised and synthesised by the principals of Ninox Wildlife Consulting:

J. Henry
W.K. Youngson

The following sub-consultants assisted in the field work, report preparation and database management:

D.G. Watkins	BSc., (Biol)
S.A. McNee	BSc., (Grad.Dip) (Biol)
M.J. Bamford	BSc., (Hons); PhD
M. Bamford	BSc., (Hons) Zool
A.J. Peacey	BA., (Hons) Dip Ed

ACKNOWLEDGMENTS

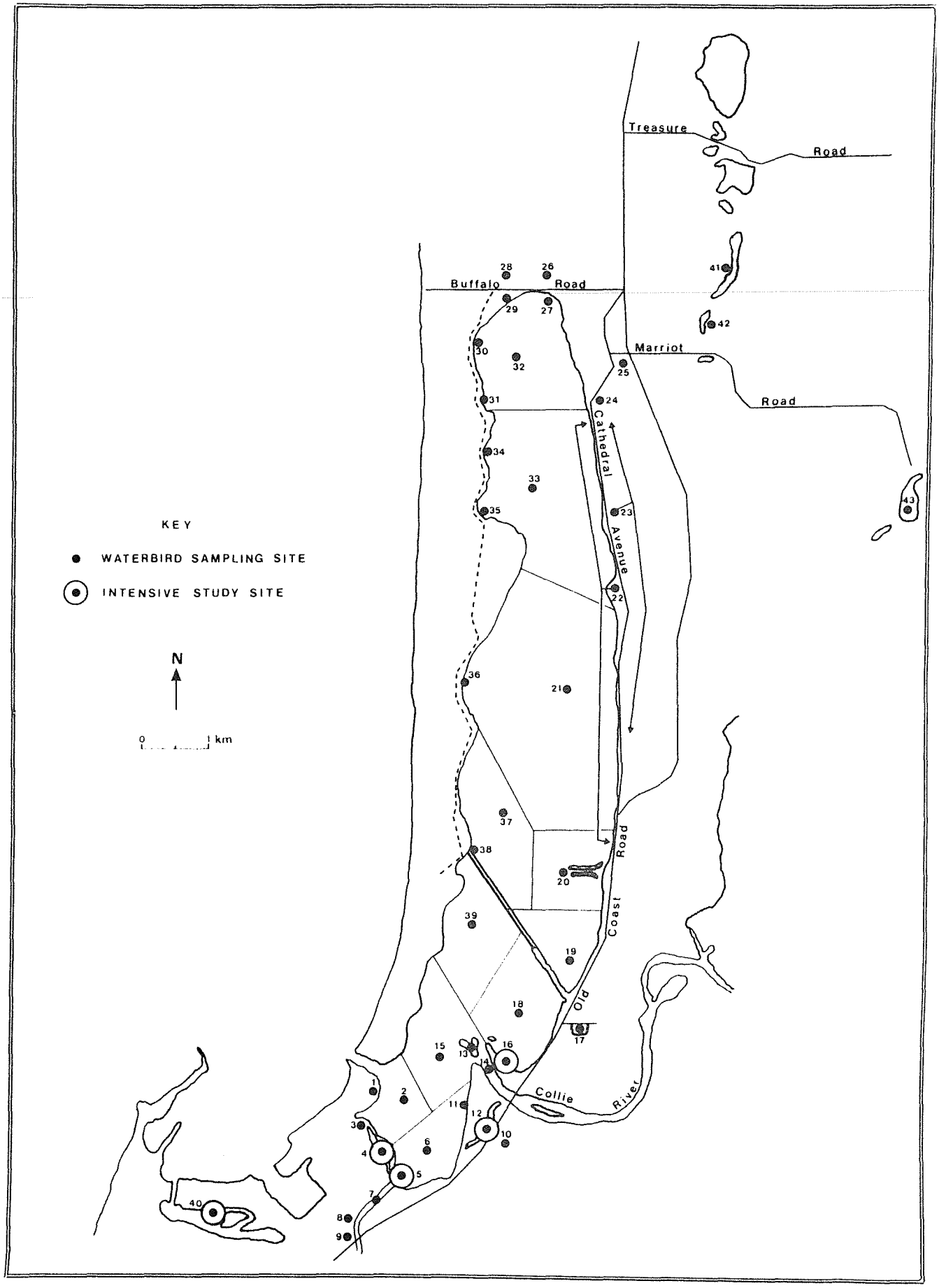
The authors wish to thank all members of the Mosquito Control Review Committee for their continuing assistance and advice throughout this project and their constructive comments on the draft of this report. Special thanks are due to Verity Klemm for her unfailing assistance on day to day matters.

We are grateful to the field survey team whose accurate recording of data, advice and good humour, in what were occasionally trying conditions, made this study run smoothly.

Anthony Peacey designed a custom-built data entry system for this project and his assistance in guiding us through the intricacies of the DBASE III+ data management program is gratefully acknowledged.

Roger Jaensch, W.A. Waterbirds Officer of the Royal Australasian Ornithologists Union reviewed the results of this survey and assisted in placing Leschenault Estuary in a regional and local context.

Figure 1 Waterbird sampling site locations at Leschenault Estuary and associated wetlands.



1.0 INTRODUCTION

The severity of the mosquito nuisance problem in the Mandurah/Bunbury region is well documented and an extra dimension was added in 1984 when eight residents from the Mandurah area and nine from Bunbury were diagnosed as having contracted epidemic polyarthritis, commonly known as Ross River fever. The main vector of this disease in Western Australia appears to be the mosquito *Aedes vigilax*.

Numerous complaints by residents prompted several Local Authority Health Surveyors in the region to contact the Leschenault Inlet Management Authority (LIMA) and Peel Inlet Management Authority (PIMA) who, in turn approached the Waterways Commission for guidance.

In order to maximise expertise and minimise conflict of interest R. Atkins, a Scientific Officer with the Waterways Commission formed an interdepartmental committee to investigate and recommend solutions to the problem of mosquito control measures. The resulting Mosquito Control Review Committee (MCRC) consisted of representatives from the following government departments:

Waterways Commission
Health Department
Environmental Protection Authority
(formerly Department of Conservation and Environment)
Department of Agriculture
Department of Conservation and Land Management
(formerly Department of Fisheries and Wildlife)

One of the first priorities of the MCRC was to quantify the extent of the problem by instigating an extensive field sampling and public assessment programme. Leschenault Estuary, situated near the City of Bunbury, Western Australia was chosen as the first survey area and A. E. Wright, the current Health Department representative on the MCRC was commissioned to supervise the study and produce a report which was to include recommendations on methods of mosquito control. The study was funded by the Mosquito Eradication Campaign and sponsored by the Health Department of Western Australia. During 1985 a year-long survey of the larval breeding and adult biting activities of mosquitoes in the Bunbury region was carried out and a comprehensive report submitted to the MCRC (Wright, 1986).

The study provided much needed data on mosquitoes, but the single most important feature which provided the rationale for the

following waterbird study was that the greater proportion of mosquito breeding in the Bunbury region took place within the tidal saltmarshes around the margin of Leschenault Estuary. Mosquito control measures such as filling, draining, fogging and the application of larvicide would have to be primarily directed at tidal saltmarshes if they were to be effective, and it was immediately apparent to the MCRC that current control techniques had the potential to seriously affect waterbirds.

Tidal saltmarshes include areas of samphire, pools, mudflats and shorelines, all of which are used to a greater or lesser extent by waterbirds and associated passerine species such as the Little Grassbird, White-fronted Chat, Richards Pipit and Australian Magpie-lark. Inter-tidal zones are recognised as rich feeding areas for trans-equatorial migratory shorebirds, many of which are protected by agreements such as the Japan/Australia Treaty and the China/Australia Treaty.

Although there had been some broad scale, unpublished studies of the waterbirds of Leschenault Estuary in the past by the Department of Conservation and Land Management, the Royal Australasian Ornithologists Union and by consultants reporting on specific development areas, none had concentrated specifically on waterbird usage of habitat sub-units and, in particular, the importance of tidal saltmarshes to resident and migratory birds. In recognition of this lack of detailed knowledge, the MCRC commissioned Ninox Wildlife Consulting to carry out a detailed, year-long study of the waterbirds of Leschenault Estuary and a report on their findings.

Survey work commenced in September 1987 and ended in October 1988; the results are presented in this document.

2.0 STUDY OBJECTIVES

The aims of this waterbird study as outlined by the Mosquito Control Review Committee are given below.

2.1 THE ESTUARY

- Provide an overview of annual and seasonal waterbird populations including those of saline and freshwater fringing wetlands;

- define the relative waterbird usage of habitat sub-units throughout the estuarine system;

- assess the local and regional conservation status of the estuary and relate it to other estuarine systems.

2.2 MOSQUITO BREEDING AREAS

- Concentrate on tidal saltmarshes and other mosquito breeding areas to assess their importance to waterbirds in terms of species richness, abundance and the activities which take place within them;

- Define mosquito breeding areas of particular significance to waterbirds;

- Recommend mosquito control strategies compatible with maintaining waterbird species diversity and abundance in the above locations.

3.0 METHODS

3.1 SAMPLING SITE CHOICE

A reconnaissance survey by three field personnel was carried out on August 14-15, 1987. Forty sites were chosen on the estuary itself and a further three sites established at wetlands near Kemerton, some five kilometers east of the study area (Fig. 1). These latter sites represented a means of assessing whether there was a waterbird connection between the estuary and outlying areas in order to further define the local conservation status of the estuary. These wetlands are described in Appendix 2.

In the choice of the 40 estuarine sites the first priority was to gain as much coverage as possible of tidal saltmarshes. Nineteen sites included saline mosquito breeding areas, (Sites 1, 3-5, 7, 11, 12, 14, 16, 26-31 ,34, 35, 36, 38, 40), eight represented freshwater mosquito breeding areas (Sites 8-10, 17, 22, 23, 24, 25) and the remainder (Sites 2, 6, 13, 15, 18- 21, 32, 33, 37 39) covered open water, shallows, tidal flats, sandbars, islands and rivers (Fig. 1). These latter habitats were included to assess tidal saltmarshes in the context of the entire estuary.

3.2 FIELD SAMPLING

Sampling was conducted by three field staff working independently of one another. The estuary was visited on nine occasions between September 1987 and October 1988 (Table 1) and the relatively small size of the study area meant that each session could be viewed as a total estuary census. Ease of access, visibility and the number of personnel allocated to the various sectors ensured that over or under-counting of individuals and misidentifications were kept to a minimum.

Table 1 Census periods conducted at Leschenault Estuary in 1987 and 1988.

CENSUS #	DATE	
1	September 3	1987
2	October 29	"
3	December 15	"
4	February 4	1988
5	March 23	"
6	May 11	"
7	June 29	"
8	August 4	"
9	October 20	"

Census periods were not equally spaced; an opportunistic element was introduced to maximise returns during the months when migratory shorebirds were present and after the onset of the main waterbird breeding season.

3.3 DATA COLLECTION

On arrival at a sampling site the observer picked a vantage point and stayed in position until confident that all visible birds had been identified, counted, allocated to habitats and their activity defined. Telescopes and binoculars were used to assist in identification and to minimise disturbance of birds. Foot or vehicle transects were conducted between each station and spot-checks made along the way to ensure that all birds were, as far as possible, recorded. Some of the more cryptic or secretive species such as crakes and rails may have been missed; adequately sampling this group is extremely time-consuming and requires very different methods of survey. During the allocation of

significance categories to the various wetlands, the potential presence of this group was considered to be a factor raising the loading applied to areas which showed low usage by other waterbirds.

The eastern edge of Leschenault Estuary is highly modified with only a very narrow strip of shoreline extending from Ridley Place to Marriot Road. Site 22 (Fig. 1) is a composite site taking in the whole of this area. All records from tidal marshes and other habitats along this strip have been amalgamated, although special mention is made of certain areas in Section 6.1. Similarly the chain of ephemeral freshwater wetlands on farmland east of Cathedral Avenue (Site 23) has also been grouped. Exceptions have been made for more permanent freshwater wetlands such as Marriot Road Swamp (Site 25) and Laporte Swamp (Site 17). These are distinct enough to warrant separate treatment.

No attempt was made to scale the relative areas of habitat sub-units in individual wetlands since this varied from survey to survey depending on tide height. Areas of samphire on one survey could be a large pool on the next. Scaling has therefore been limited to an overview of the estuary i.e. fringing wetlands represent 11% of the total area while the open water of the estuary and its attendant habitat sub-units represents 89%.

3.4 DATA LOGGING

Field data sheets were designed for this study and were tailored to its specialised requirements. An example of a field data sheet is given in Appendix 1. To fulfill one of the main objects of the survey i.e. establishing the importance of tidal saltmarshes to waterbirds, it was necessary to make a distinction between the main body of the estuary and areas subject to periodic inundation. In reality such a division does not exist since the estuary and its surrounds are used by waterbirds as a dynamic, interdependent continuum. Similarly, the effects of mosquito control measures do not cease beyond fringing formations.

However, some workable criterion had to be established and it was decided that any area which had the capacity to retain pools of water over a period of several days following high tides or heavy rain was a potential mosquito breeding site (see Wright, 1986). In effect, it was assumed that all locations above exposed tidal mudflats were fringing wetlands and all areas below the upper limits of exposed tidal mudflats were associated with the estuary.

This distinction ultimately proved workable since mosquito larvae were found in tyre-ruts just above the limits of tidal mudflats, a high tide covered Cathedral Avenue on one occasion and mosquito larvae and birds were observed in some previously questionable locations. Tidal saltmarshes, including those transitional with dry land, were therefore well surveyed.

Data sheets were logged in the field to prevent transcription errors and categories were kept simple to reduce ambiguities. An example showing the habitat types surveyed and the activity codes used is given in Appendix 1.

During data analysis, however, it was apparent that the habitat categories "Bare Other" and "Other" tended to overlap, with no element dominating such that a separate category was warranted. As a result records from these two units have been combined to produce a single unit (Other) containing diverse habitat elements such as fly-ash dumps, carparks, grassed areas, roads, telephone poles, logs and rocks on the shoreline etc.

Activity codes are self explanatory except that for this study "loafing", which arbitrarily refers to birds resting on either water or land, has been applied to aquatic activity exclusively. This was done to cover non-specific aquatic behaviour such as directionless drifting. Roosting applies to land-based activity only, whether it took place on trees, shorelines or very shallow water.

3.5 DATABASE MANAGEMENT

Each waterbird species was given a Bird Atlas code number (Blakers *et al.*, 1984) and, using a custom-designed DBASE III+ data entry system, transferred with all accessory information to computer hard disk files. The flexibility of the DBASE III+ program allowed data retrieval in almost any combination or permutation of species, habitat and/or activity.

3.6 REPORT STRUCTURE

This report is divided into two main parts. Section 4.0 is an assessment of the Leschenault system as a whole and covers all habitat sub-units including mosquito breeding areas. In effect, this part of the report gives a broad overview of Leschenault Estuary and defines its current conservation status.

Sections 5.0 - 7.0 take a sub-sample of the main database i.e. mosquito breeding areas and define the importance of habitats such as tidal saltmarshes and freshwater swamps to waterbirds.

It is important to recognise that such a division is artificial since there is a free flow of birds from open water to vegetated wetlands and that the effects of mosquito control measures cannot be confined to the latter areas.

PART 1

LESCHENAULT ESTUARY - AN OVERVIEW

Table 2 Total number of waterbirds recorded during each of nine surveys of Leschenault Estuary between September 1987 and October 1988. Bold figures represent highest individual waterbird counts for the study.

SURVEY MONTHS BIRD SPECIES	SEP.	OCT.	DEC.	FEB.	MAR.	MAY	JUN.	AUG.	OCT.
PODICIPEDIDAE									
Hoary-headed Grebe						7			
Australasian Grebe	6	4	3				38	1	2
Unidentified Grebe					1				
PELECANIDAE									
Australian Pelican	66	55	77	82	47	31	119	60	95
ANHINGIDAE									
Darter	12	33	15	12	19	53	29	28	30
PHALACROCORACIDAE									
Great Cormorant		8	20	19	17	20	28	18	13
Pied Cormorant	4	8	18	112	3		100	5	10
Little Black Cormorant	14	64	46	119	72	181	66	64	25
Little Pied Cormorant	167	344	491	427	450	459	286	308	327
Unidentified Cormorant								6	
ARDEIDAE									
Pacific Heron			1						
White-faced Heron	30	53	47	39	25	88	23	16	19
Great Egret	15	59	73	49	25	16	21	19	26
Little Egret		3	2	1	5	1	10	4	5
Rufous Night Heron		21	43	10					6
PLATALEIDAE									
Sacred Ibis	6	6	1	4	1	17	2	16	18
Straw-necked Ibis	14		1		4	25	1	33	
Yellow-billed Spoonbill	19	42			1	1	21	11	
ANATIDAE									
Black Swan	230	217	237	414	200	484	69	201	315
Australian Shelduck	64	132	368	126		23	48	106	64
Pacific Black Duck	75	240	229	82	106	177	72	59	70
Grey Teal	101	106	134	277	399	241	27	63	66
Australasian Shoveler	2						3		
Maned Duck		2			46	21	2	2	23
Musk Duck				16	47	112	53	2	
Domestic Hybrid	1								

SURVEY MONTHS	SEP.	OCT.	DEC.	FEB.	MAR.	MAY	JUN.	AUG.	OCT.
BIRD SPECIES- Cont.									
PANDIONIDAE									
Osprey				1	1	2	2	1	1
ACCIPITRIDAE									
Marsh Harrier					1	2			
RALLIDAE									
Buff-banded Rail		3							1
Spotless Crake							1		
Dusky Moorhen		2	1		2				
Purple Swamphen	2				1	1		1	1
Eurasian Coot						1			3
HAEMATOPODIDAE									
Pied Oystercatcher	3	11	8	5	5	2	2	2	
CHARADRIIDAE									
Grey Plover	3	89	117	72	121	133			79
Lesser Golden Plover		1		8	5				2
Banded Lapwing		3							
Large Sand Plover	3	7	17	8	11	2			5
Red-capped Plover	31	247	168	65	24	8	2	14	17
Black-fronted Plover		1	2			11	1		
RECURVIROSTRIDAE									
Black-winged Stilt	118	55	43	72	115	176			49
Banded Stilt					16				2
Red-necked Avocet	84	228	7		7				
SCOLOPACIDAE									
Ruddy Turnstone		4							7
Eastern Curlew		2			3	1			
Whimbrel			2						1
Grey-tailed Tattler			3		1				
Common Sandpiper	1	5	3	3	2	1		2	46
Greenshank	19	89	40	31	43	6			20
Bar-tailed Godwit		121	152	105	6	24		5	27
Red Knot		26		1	61				
Great Knot		74	99	99	25				12
Sharp-tailed Sandpiper		6	25	246	10				80
Red-necked Stint	96	1904	1089	118	16				311
Curlew Sandpiper	14	167	211	48	4	2			70
Unidentified Shorebird	5	8		6					
LARIDAE									
Silver Gull	164	283	473	533	237	320	114	227	412
Caspian Tern	2	5	18	21	25	18	5	1	10
Fairy Tern							29	1	24

SURVEY MONTHS	SEP.	OCT.	DEC.	FEB.	MAR.	MAY	JUN.	AUG.	OCT.
BIRD SPECIES- Cont.									
Crested Tern	3	37	17	35	40	46	4	22	35
Unidentified Tern	20						1	3	
MOTACILLIDAE									
Richard's Pipit	16		3				3	1	2
SYLVIIDAE									
Little Grassbird	12	9	4	8	14	3	25	25	13
EPHTHIANURIDAE									
White-fronted Chat	25	4	10	2	1	11	7	12	
GRALLINIDAE									
Australian Magpie-lark	13				1		14		
SURVEY TOTAL	1460	4788	4318	3270	2266	2727	1228	1339	2344

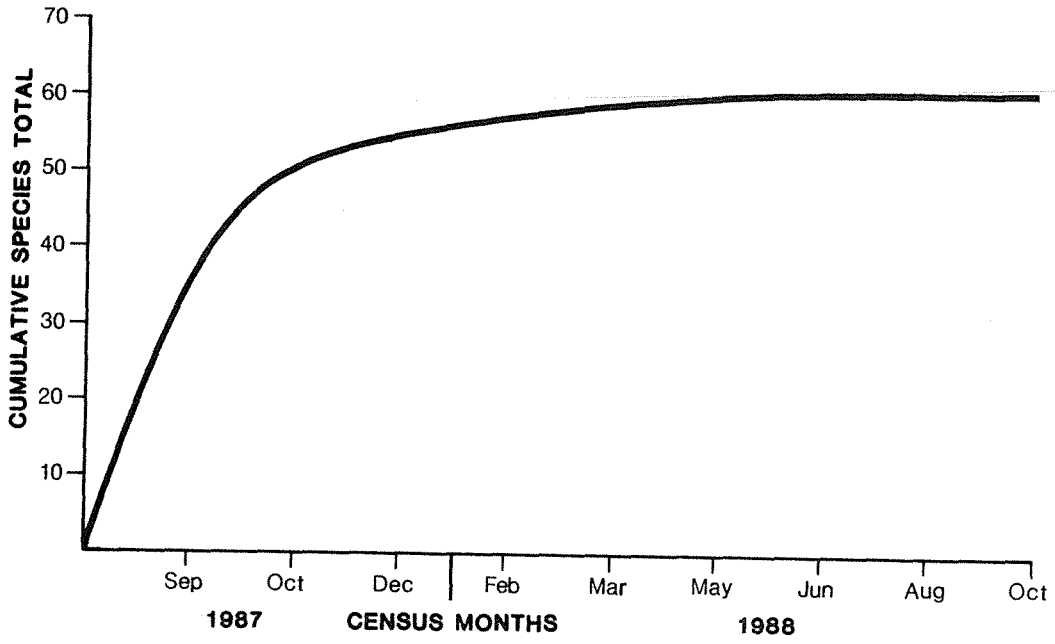
4.1 THE ESTUARY - AN OVERVIEW

Species Richness and Abundance - fifty-eight species of waterbirds were recorded during the survey of Leschenault Estuary and its fringing tidal saltmarshes and swamps. A further four species of bird, Australian Magpie-lark, White-fronted Chat, Little Grassbird and Richard's Pipit were included since these birds are strongly associated with samphire flats and water. A total of 23,740 individual birds were counted (Table 2).

Accumulation of Species - in Fig. 2 the successive gain of new waterbird species after each census period has been graphed, and typically shows a steep rise for the first two surveys. Thereafter the accumulation of new species is a gradual process with no new species recorded in the final three census periods. The graph shows that the survey of the estuary has been comprehensive and that species equilibrium (Southwood 1976) for the 1987-1988 sampling period at least, has been reached. Extending the survey over a period of years would almost certainly result in several more species being added, but as these are likely to be uncommon birds or vagrants with marginal relevance to the aims of this study, the list of species given in Table 2 can be regarded as "complete" or more than adequate for the task in hand. It is worthy of note that nine Royal Australasian Ornithologists Union (RAOU) waterbird surveys

conducted at the northern and southern sections of Leschenault Estuary prior to and during this survey did not add any species, further breeding species or higher numbers of individuals than the results of this current MCRC waterbird survey.

Figure 2 Graph showing successive gain of waterbird species after each census period at Leschenault Estuary during 1987 and 1988.



4.2 SEASONALITY

Species Richness - the number of species recorded during each census period is shown in Fig. 3a and it is apparent that there was very little variation in seasonal species complement throughout the survey although certain waterbird groups numerically dominated at different times (Table 2). The difference between the months with the highest totals (October 1987/88, March 1987) and the lowest (August 1988) is 13 species and mainly reflects the absence of migratory shorebirds in winter.

The March 1988 survey was unusual in that the number of species rose to the October 1987 level (45) with the appearance of nine

species not recorded in the previous survey (Table 2). It was expected that there would be a gradual drop in species from the peak months of October and December as shorebirds departed for the northern hemisphere. This was not the case since four species of shorebird not recorded in February were present in March. One of these, the Banded Stilt had not been recorded in any other census. It is probable that birds such as the Banded Stilt and Red-necked Avocet represented birds in passage using Leschenault Estuary as a staging area. The remaining five species were uncommonly recorded birds (Table 2) and almost certainly represent vagaries of sampling or prevailing tidal conditions.

Abundance of Individuals - seasonal changes in the number of individual birds show a much clearer pattern and are given in Fig. 3b. Bird numbers were low in September 1987, peaked in October and gradually tailed off until March 1988. Fifty percent of the total species list for Leschenault Estuary showed their greatest abundance in the October 1987-March 1988 period with migratory shorebirds contributing the largest number of species (21) for any waterbird group. Most of the remaining species represented birds using the estuary as a drought refuge as inland lakes and swamps dried out. Significant among this latter group were the Yellow-billed Spoonbill, Australian Shelduck, Pacific Black Duck, Grey Teal and Maned Duck. Peak abundance figures for individual waterbird species are highlighted in Table 2.

In Fig. 3b an interesting pattern emerges for the May 1988 census when a secondary peak of abundance was evident. Ten species of waterbird reached their greatest numbers in this period (Table 2). Some of these, for example the Hoary-headed Grebe, White-faced Heron, Black Swan and Musk Duck are evidently a second wave of birds adapted to deeper water. The longer drying-out time for deeper inland lakes and swamps appears to have extended the period prior to them being forced to seek drought refuge at Leschenault Estuary. Other species which peaked in May 1988 are the Darter, Little Black Cormorant and Silver Gull. Several species of fish enter estuaries as juveniles around this period and almost certainly provide an abundant food supply for the large numbers of the above birds which were recorded in May (Loneragan *et al.*,1987, Hodgkin,1978).

June 1988 represented the period when waterbird abundance was at its lowest with all but three species of migratory shorebirds having left for the northern hemisphere and many other waterbirds dispersing to inland areas after the commencement of winter rains. Eight species (Table 2) reached their greatest numbers during this period. Relevant examples of these are the Australasian Grebe, Australian Pelican, Great Cormorant and Little Egret. Figs. 4a-e graph the seasonal fluctuations of selected waterbirds throughout the survey period.

Figure 3a Number of waterbird species recorded during each census period at Leschenault Estuary in 1987 and 1988.

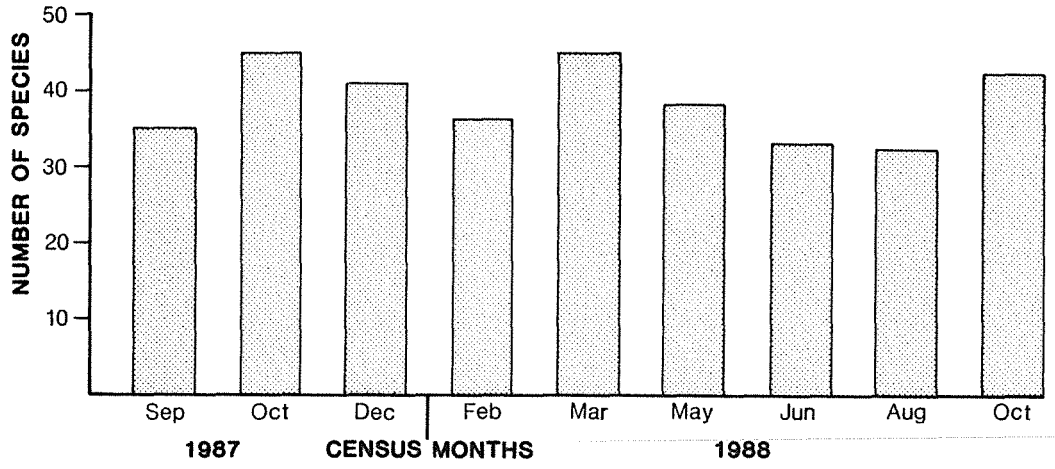


Figure 3b Number of individual waterbirds recorded during each census period at Leschenault Estuary in 1987 and 1988.

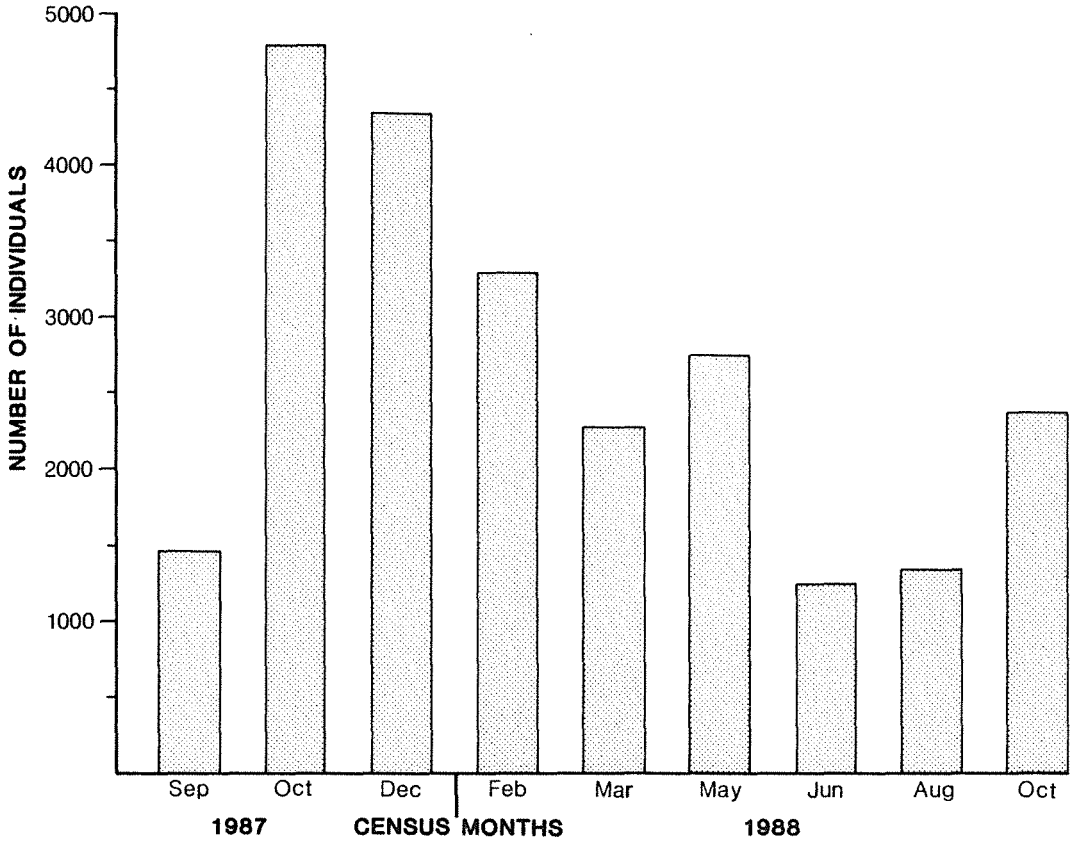


Figure 4a Seasonal fluctuations of the Australian Pelican, Darter and Great Cormorant expressed as a percentage of their individual census total.

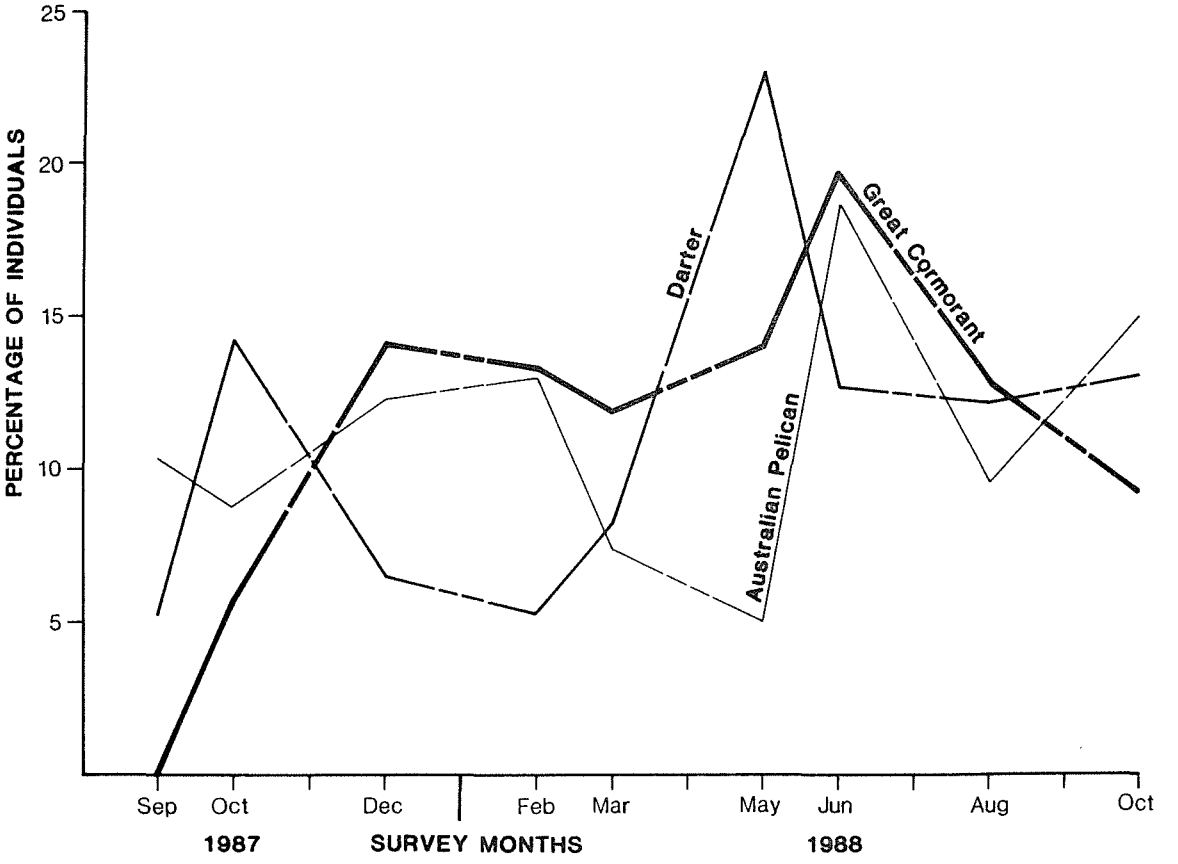


Figure 4b Seasonal fluctuations of the White-faced Heron, Great Egret and Little Egret expressed as a percentage of their individual census total.

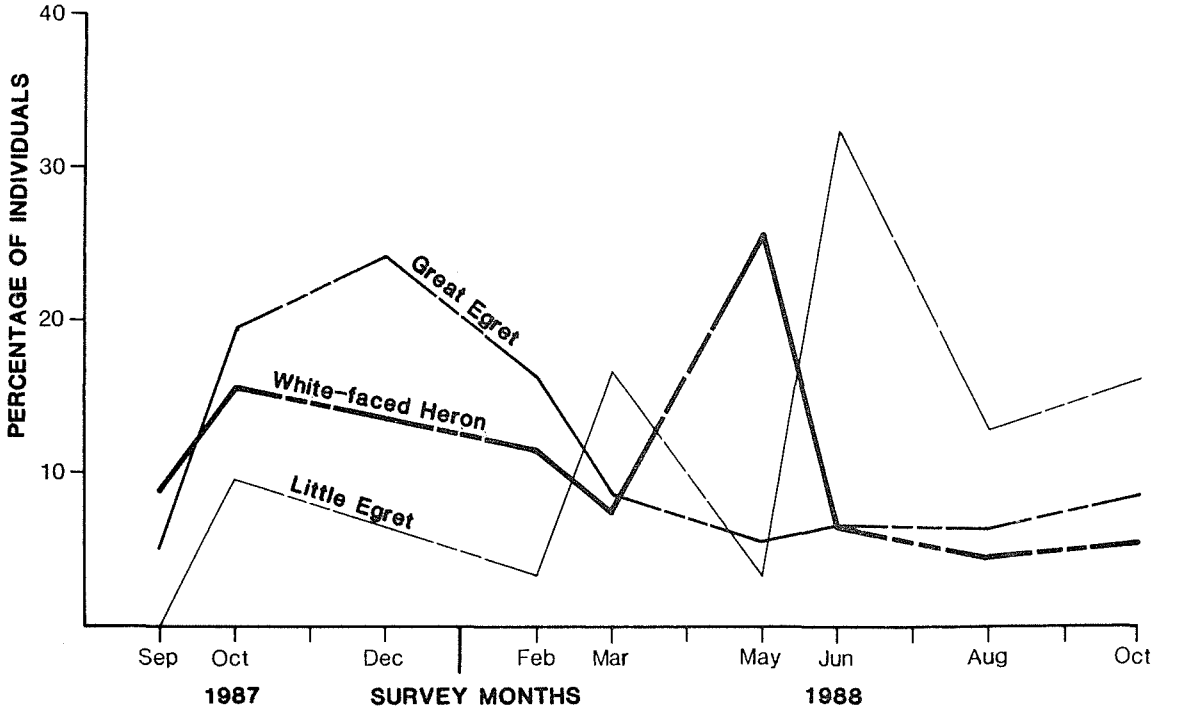


Figure 4c Seasonal fluctuations of the Black Swan, Australian Shelduck and the Pacific Black Duck expressed as a percentage of their individual census total.

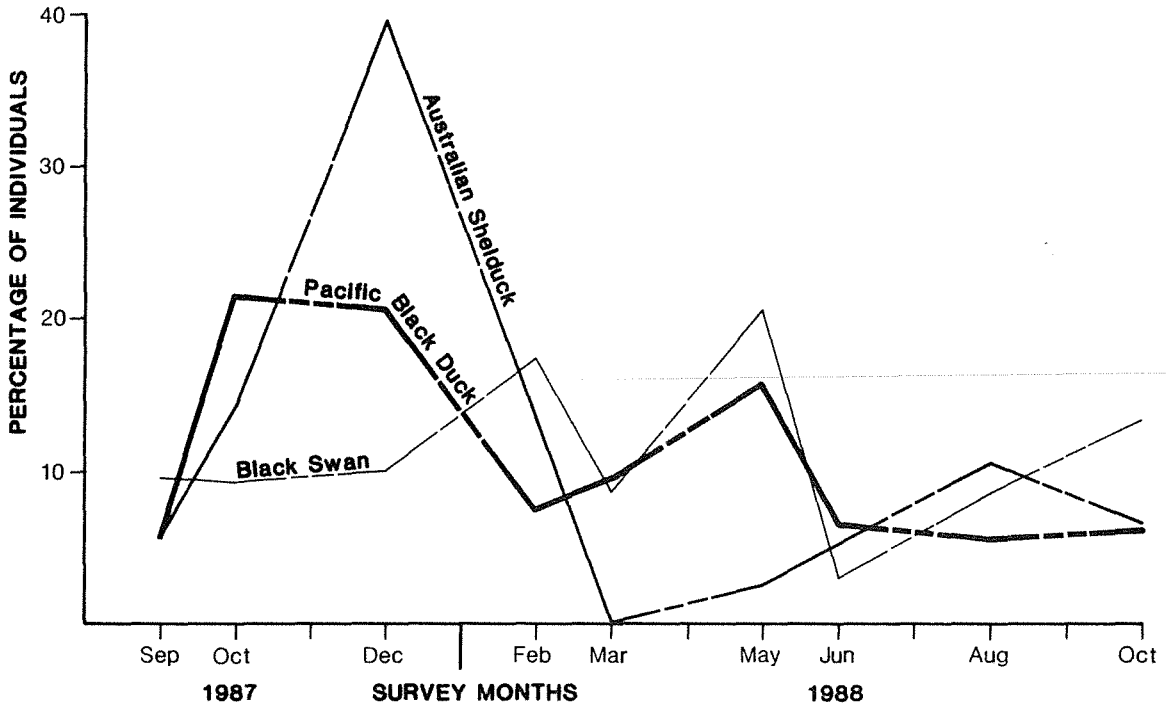


Figure 4d Seasonal fluctuations of the Grey Teal, Maned Duck and Musk Duck expressed as a percentage of their individual census totals.

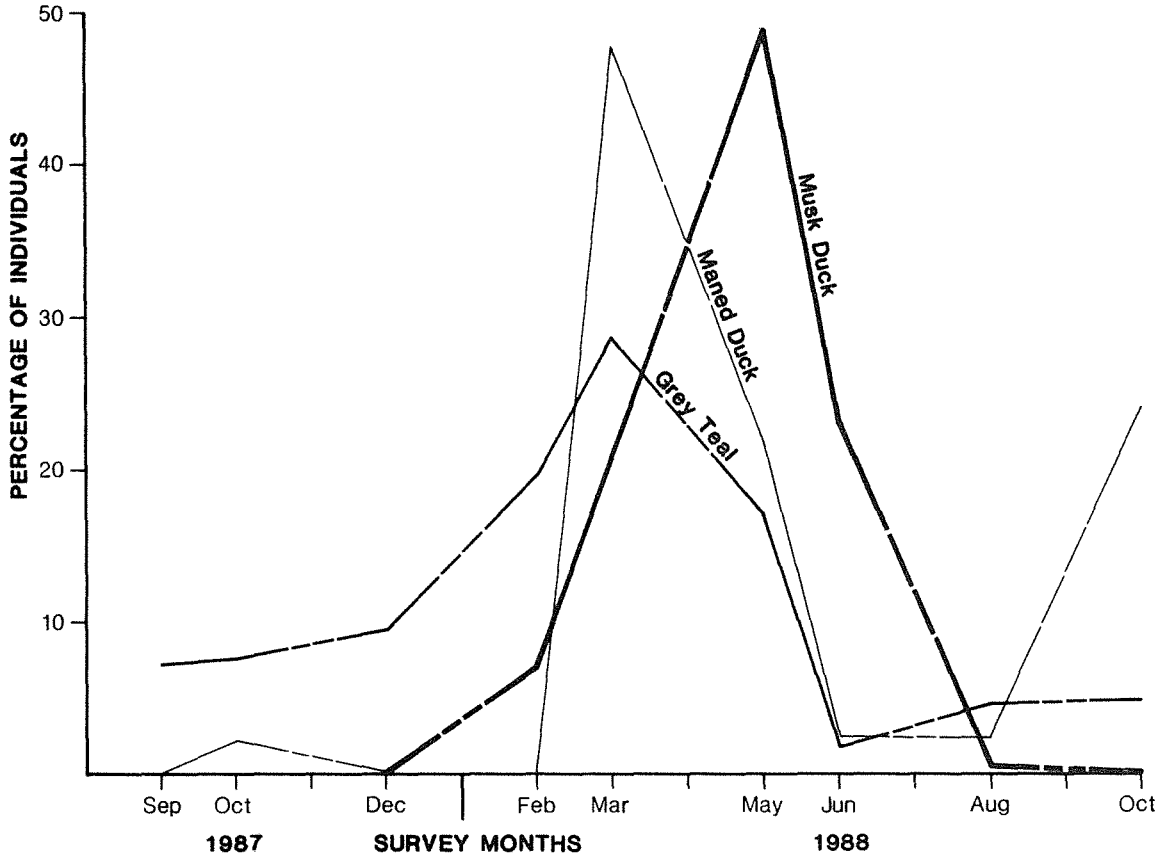
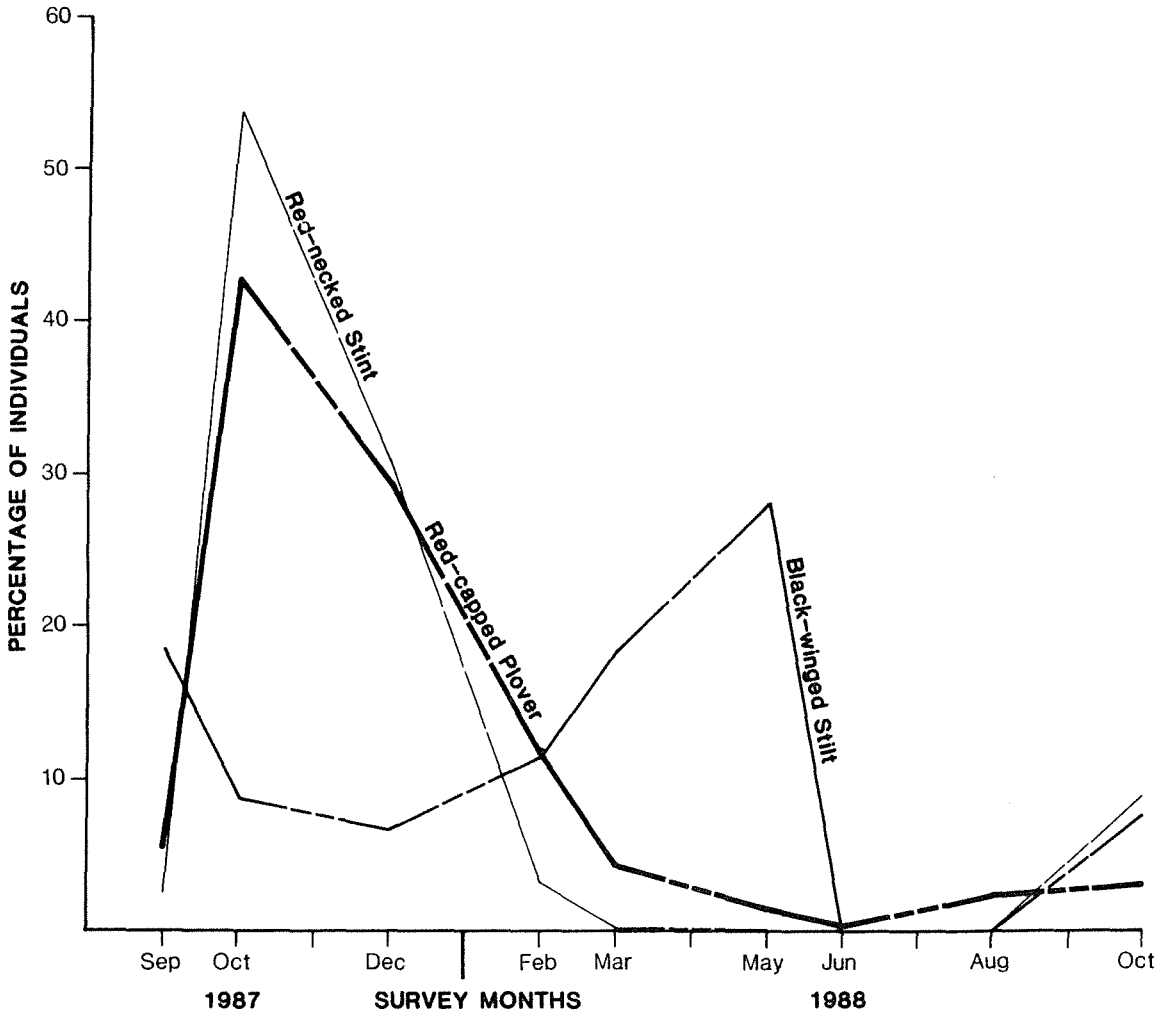


Figure 4e Seasonal fluctuations of the Red-capped Plover, Black-winged Stilt and Red-necked Stint expressed as a percentage of their individual census totals.



Numbers for August and October 1988 were also low but there was a general trend upwards towards the summer 1987 peak reflecting the arrival once again of migratory shorebirds to the estuary. It is of interest to note the difference in the abundance figures for October 1987 and October 1988. A total of 4788 individuals were recorded in the former period and only 2344 in the latter. Approximately 59% of the species in Table 2 were recorded in greater numbers in 1987 than in 1988 with the small flock sizes of migratory shorebirds mainly accounting for this discrepancy. It may be relevant that the October 1988 census period coincided with the highest tide experienced during the survey; this and the attendant strong winds may have forced birds away from the estuary.

One of the major difficulties with a survey such as this is that in the time available only a small proportion of the full range of tidal and weather conditions can be sampled. Conditions change rapidly and it is evident from opportunistic visits to the estuary that the relatively low numbers of birds seen during unusual conditions can be quickly reversed after the survey when large numbers of birds move into newly created feeding and refuge areas.

4.3 NUMBER OF BREEDING SPECIES

Sixteen species of waterbird were recorded breeding at Leschenault Estuary (Table 3). Breeding was concentrated between August and October.

Table 3 Waterbird species recorded breeding during the 1987-88 census periods.

CENSUS PERIOD	SEP	OCT	DEC	FEB	MAR	MAY	JUN	AUG	OCT
WATERBIRD SPECIES									
Australasian Grebe		X							
Little Pied Cormorant	X							X	X
Little Black Cormorant									X
White-faced Heron									X
Great Egret			X						X
Sacred Ibis									X
Yellow-billed Spoonbill							X	X	
Black Swan	X		X					X	X
Australian Shelduck	X						X	X	X
Pacific Black Duck							X	X	X
Grey Teal	X		X					X	X
Maned Duck									X
Buff-banded Rail		X							
Dusky Moorhen		X							
Black-winged Stilt	X								X
White-fronted Chat								X	
TOTAL	5	3	3	0	0	0	3	7	11

4.4 REGIONAL SIGNIFICANCE OF LESCHENAULT ESTUARY

The estuary has been compared with RAOU data for over 500

wetlands in the south-west of Western Australia; these wetlands, both tidal and freshwater, are located from Kalbarri to Esperance. The RAOU approach is to consider estuarine environments and fringing freshwater wetlands as separate entities but within these constraints comparisons are still possible. They also exclude Passerine species such as the White-fronted Chat which, using the RAOU definition reduces the total number of waterbird species for the estuary to 58, rather than the 62 included in the analyses. We have retained such species because, waterbird or not, they are an integral part of the wetland environment and give a more accurate measure of the potential effects of mosquito control techniques.

Number of Species - Swan-Canning Estuary is known to support 87 species of waterbird; Peel-Harvey Estuary, Vasse-Wonnerup Estuary, Forrestdale and Thomsons Lake each have from 60-80 species. Comprehensive data are not available for Oyster Harbour, but this location and its associated wetlands are suspected to support 50-60 species. Using number of species as a conservation criterion, Leschenault Estuary, although not in the top five wetlands of the region, is clearly in the top ten.

Given that many of these high ranking wetlands have been surveyed much more regularly and intensively than Leschenault it is probable that its rank could be elevated to the top five (perhaps at the expense of Thomsons Lake) if more survey work was conducted there by the RAOU (R.Jaensch, pers. comm.). However, the study area is unlikely to exceed the importance of higher ranked sites since these are particularly rich in waterbird habitats and some are considerably larger than Leschenault Estuary.

Number of Breeding Species - as described earlier, the RAOU views fringing freshwater swamps and the estuary as separate entities. Using this criterion nine breeding species were recorded at the estuary rather than the 16 species recorded overall during this study.

Toolibin Lake and Chandala Swamp each support more than 20 breeding species and at least 20 other wetlands have ten or more. Leschenault Estuary is therefore not particularly outstanding for waterbird breeding although it can be regarded as of moderate significance.

Number of Individuals - the most commonly used statistic for comparing the relative number of individuals in a wetland is the maximum count in any one survey. For Leschenault Estuary this was

4784 birds in October, 1987.

RAOU data shows that the highest count in one wetland survey was 41,000 at Peel-Harvey Estuary, only a portion of which was surveyed. Conservation and Land Management (CALM) give a figure of 100,000 birds for the total estuary (unpublished data). Culham Inlet, Vasse-Wonnerup Estuary and Dumbleyung Lake have been known to support 30-40,000 birds at various times. At least 30 other wetlands in south-western Australia each support more than 5000 birds on occasions.

Consequently, the maximum count of 4784 birds for Leschenault Estuary is not an outstanding result although it has some significance when placed in the context of the 500+ wetlands which have been studied by the RAOU.

Species of Conservation Significance - the following species which were recorded at Leschenault Estuary during this survey may be considered "rare" in the region, although not gazetted as such in Western Australia: Little Egret; Eastern Curlew; Whimbrel. These three species occur in slightly higher numbers at other wetlands, particularly Peel Inlet. The eastern Curlew is internationally recognised as having a relatively small, declining population.

Important Species - Leschenault Estuary may be considered important for several species of waterbird. The following birds have been counted in higher numbers at very few wetlands besides Leschenault:

Little Egret (up to 21 at Peel Inlet - 10 at Leschenault);

Grey Plover (up to 600 at Peel Inlet - 133 at Leschenault);

Bar-tailed Godwit (up to 500+ at Peel Inlet - 152 at Leschenault);

Great Knot (up to 850 at Peel Inlet - 99 at Leschenault).

Precise regional counts of the Large Sand Plover, Common Sandpiper and Darter have not been ascertained as yet by the RAOU but the highest counts at Leschenault appear to be at least as high as those from any other wetland in the region, except possibly Peel Inlet (R. Jaensch, pers. comm.).

The freshwater swamps associated with Leschenault Estuary, notably Laporte Swamp (Site 17, Fig. 1) and Marriot Road Swamp

(Site 25) are important as they support several colonial-breeding species of waterbird. These are: Little Pied Cormorant, Little Black Cormorant, Great Egret, Sacred Ibis and Yellow-billed Spoonbill. Of these, the Great Egret (14 other breeding sites) and Yellow-billed Spoonbill (22+ other sites) are probably the most restricted in terms of breeding localities.

4.5 LOCAL SIGNIFICANCE OF LESCHENAULT ESTUARY

The area under review is defined as Capel to Waroona and includes several sub-coastal wetlands. In this local context Leschenault Estuary is an important wetland for waterbirds because it is the only estuary and therefore the principal habitat for large numbers of shorebirds such as the Red-necked Stint and primarily estuarine species such as the Great Knot.

The only local wetland studies by the RAOU, which is of comparable all-round importance, is Benger Swamp where 53 species of waterbird have been recorded, 12 of which breed there. It is superior to the tidal section of Leschenault Estuary as a breeding area in that its diversity, and probably its number of nesting pairs, is higher. This is understandable in view of the large available area of flooded, relatively undisturbed, tall vegetation at Benger.

Many of the swamps near Bunbury have not been studied in detail by the RAOU and it is therefore difficult to make accurate comparisons. However, they are most unlikely to displace Leschenault in significance. During this study, for example, a series of wetlands at Kemerton immediately north-east of Leschenault were surveyed (Appendix 2). Although supporting several species in numbers more abundant than at Leschenault they can in no way compare with the estuary. All of these swamps were, in fact, dry for a large part of the year. A breeding colony of Darters at Darter Swamp was the most significant feature of these wetlands. It is highly probable that this species commutes between Darter Swamp and Leschenault Estuary in the breeding season. Aspects of the Kemerton wetlands are explored more fully in Appendix 2.

4.6 CONCLUSIONS

Leschenault is less significant than the other estuaries of the lower west coast (Vasse-Wonnerup, Peel-Harvey, Swan-Canning) in terms of the number of species recorded, number of individuals

in one survey and number of species for which it may be judged important. Its smaller size is the controlling factor. Like most estuaries, its tidal waters do not support a high diversity of breeding species. Nevertheless, it has an important local role to play as a feeding ground for a wide and diverse range of waterbirds. It is no doubt a crucial feeding area for the Great Egrets which breed at Laporte Swamp and the several other colonial species which breed at Marriot and Darter Swamp. As a permanent wetland it is a significant drought refuge for ducks, swans and other groups of waterbirds.

Leschenault Estuary also plays a significant, though not spectacular, role in supporting the migration of trans-equatorial shorebirds and is used by several uncommon or rarer species. Eighteen birds protected by the Japan/Australia, China/Australia Migratory Bird Agreements occur there.

Leschenault Estuary, while not internationally important under the current classificatory guidelines, is therefore still of international interest and should be carefully protected and well-managed as such. Furthermore, it is evident that given opportunities for further surveys, the local and regional importance of the estuary could be enhanced given that there are reports that significant waterbird usage of certain habitats not recorded during the surveys, have been noted outside these periods (G. Pearson, pers. comm.).

PART 2

WATERBIRD UTILISATION OF MOSQUITO BREEDING AREAS

Table 4 Number of waterbirds recorded in the habitat sub-units of mosquito breeding areas at Leschenault Estuary in 1987 and 1988.

SW = Wet Samphire; SD = Dry Samphire; PO = Pools; DR = Drains; BS = Bare Shorelines; MG = Mangroves; PE = Perches; Ot = Other. Bold figures = Highest Individual Count.

HABITAT BIRD SPECIES	SW	SD	PO	DR	BS	MG	PE	OT
PODICIPEDIDAE								
Australasian Grebe			14					
PELECANIDAE								
Australian Pelican	**84**	15	4		44		3	
ANHINGIDAE								
Darter	3	4	4		37	2	**81**	3
PHALACROCORACIDAE								
Great Cormorant	1		2		3		8	**9**
Pied Cormorant					11		**74**	2
Little Black Cormorant			13	1	26		**48**	9
Little Pied Cormorant	3	24	91	5	65		**728**	22
ARDEIDAE								
White-faced Heron	**85**	69	36	2	29		14	43
Great Egret	43	9	39	2	9	1	**59**	39
Little Egret	**12**	3	2		4			2
Rufous Night Heron						2	38	**40**
PLATALEIDAE								
Sacred Ibis	**20**	15	9	1			18	4
Straw-necked Ibis	**17**	14	1					13
Yellow-billed Spoonbill	4	2	15		**48**		24	1
ANATIDAE								
Black Swan	60	16	**166**		46			1
Australian Shelduck	71	22	107		**118**			51
Pacific Black Duck	49	34	**213**	2	56	4	12	166
Grey Teal	194	15	**549**	8	64	5	24	24
Australasian Shoveler			4					1
Maned Duck			27		2			67
Domestic Hybrid					1			
PANDIONIDAE								
Osprey	2		1				3	

HABITAT BIRD SPECIES	SW	SD	PO	DR	BS	MG	PE	OT
ACCIPITRIDAE								
Marsh Harrier	3							
RALLIDAE								
Buff-banded Rail			3	1				
Spotless Crake	1							
Dusky Moorhen			2		3			
Purple Swamphen	1		2		1			2
Eurasian Coot			4					
HAEMATOPODIDAE								
Pied Oystercatcher			1		11			2
CHARADRIIDAE								
Grey Plover	290	1	9		48	2		4
Lesser Golden Plover	15							
Banded Lapwing								3
Large Sand Plover	18	3			3			
Red-capped Plover	28	8	6		177			19
Black-fronted Plover	1		7		4	3		
RECURVIROSTRIDAE								
Black-winged Stilt	239	27	221	2	34	11		16
Banded Stilt	2		16					
Red-necked Avocet			15					21
SCOLOPACIDAE								
Ruddy Turnstone	7	3						
Eastern Curlew	2		4					
Whimbrel	1			2				
Grey-tailed Tattler	1				1			
Common Sandpiper	3	1	1		48		1	4
Greenshank	53	4	31	3	54	9		3
Bar-tailed Godwit	39		18		7			
Red Knot	15		1		47			
Great Knot	37		2		32			
Sharp-tailed Sandpiper	221		1		10			30
Red-necked Stint	241	200	14		608			40
Curlew Sandpiper	72		1		72			
Unidentified Shorebird					6			
LARIDAE								
Silver Gull	107		397		415	19	23	135
Caspian Tern	5		2		25			2
Fairy Tern					26			
Crested Tern	30		5		2		20	
Unidentified Tern	1				1			

HABITAT BIRD SPECIES	SW	SD	PO	DR	BS	MG	PE	OT
MOTACILLIDAE								
Richard's Pipit	6	17			1			1
SYLVIIDAE								
Little Grassbird	50	50				7	3	
EPHTHIANURIDAE								
White-fronted Chat	33	32					2	5
GRALLINIDAE								
Australian Magpie-lark	1				4			23
SURVEY TOTAL	2171	588	2060	29	2200	68	1183	807

5.1 OVERALL SPECIES RICHNESS

Of the 62 species of waterbird identified at Leschenault Estuary, 58 (94%) were recorded in mosquito breeding areas. Eighteen species were found only in the habitat sub-units present in these fringing wetlands and were mainly birds adapted to the dense vegetation, sheltered pools and bare shorelines found there. By comparison, the estuarine habitats, typified by open water, mudflats and sandbars, supported 48 species of waterbird or 71% of the total species count. Four species were unique to these estuarine sub-units. Figure 5a shows a comparison of habitat sub-unit utilisation in both fringing wetlands and the open water of the estuary.

5.2 OVERALL ABUNDANCE

Thirty-eight percent of all waterbirds (9106 individuals) were recorded in fringing wetlands and when compared to the open water of the estuary these mosquito breeding areas support a high number of individuals per unit area. Fringing wetlands have been estimated at 349 ha. compared to a figure of 2754 ha. for the open water of the estuary itself. (G. Pearson pers. comm.). Combining all 9 surveys and standardising waterbird results to a density per unit area gives 29 birds per 10 ha. for mosquito breeding areas and 6 birds per 10 ha. for estuarine habitats. Figure 5b shows the distribution of individuals through fringing wetlands and the open water of the estuary.

Figure 5a Number of waterbird species recorded in each habitat sub-unit surveyed at Leschenault Estuary in 1987 and 1988.

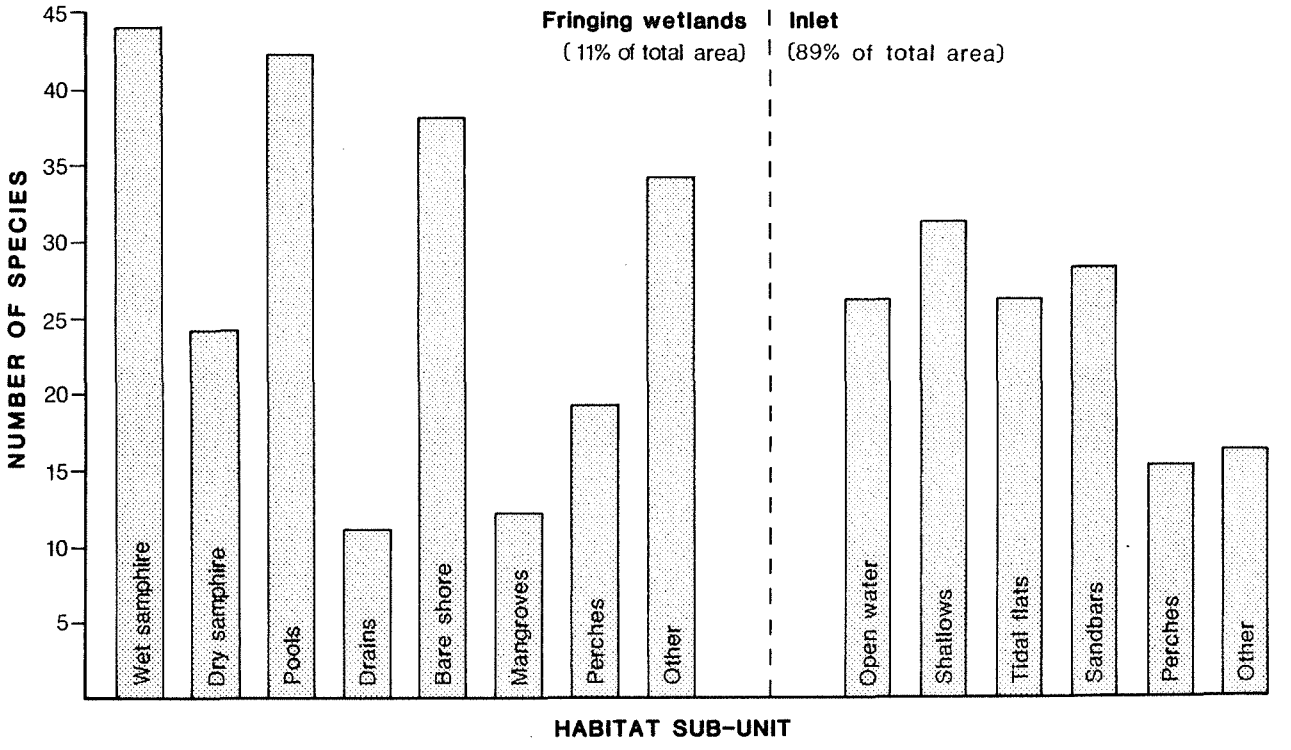
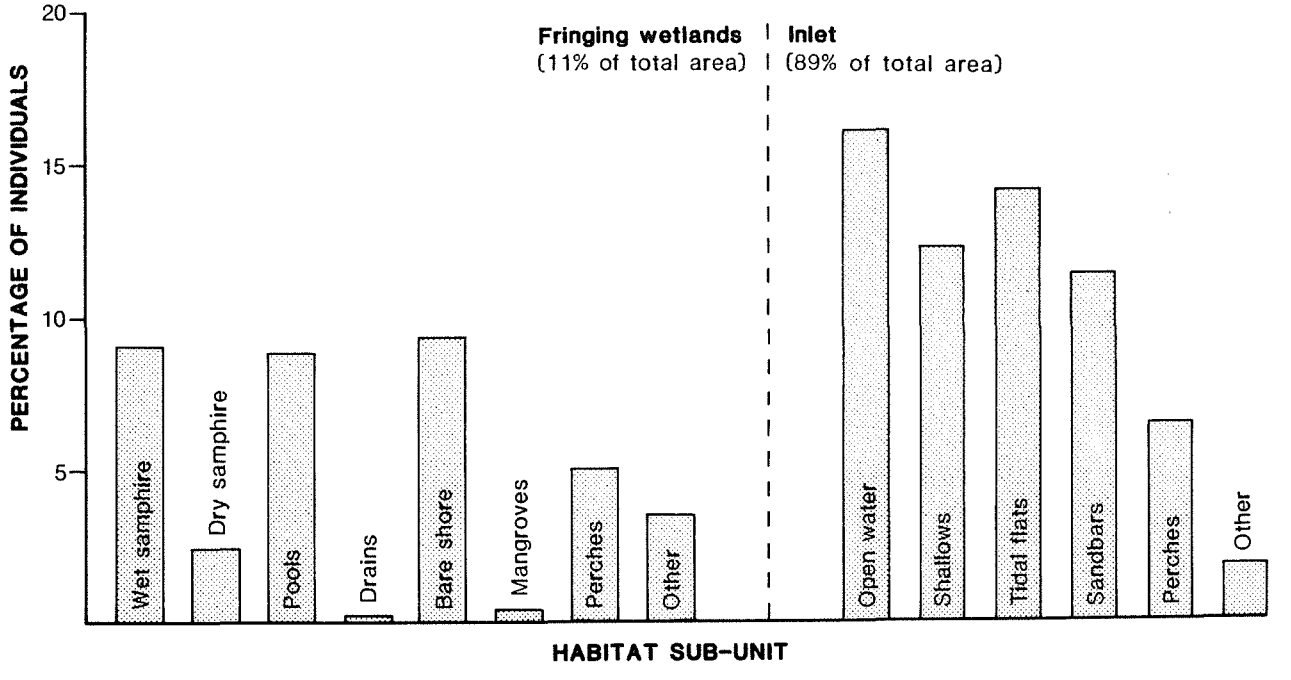


Figure 5b Percentage of total number of individuals recorded in each habitat sub-unit surveyed at Leschenault Estuary in 1987 and 1988.



5.3 WATERBIRD GROUPINGS

In order to further define the significance of mosquito breeding areas to waterbirds and to accentuate the disproportionate usage by some waterbirds, the 9106 individuals recorded in fringing wetlands have been divided into six groups roughly approximating feeding habits and/or Families. The number of individuals within each group has been expressed as a percentage of the total recorded for that group throughout the estuary. These have been ranked and are presented below. For example, 999 individuals of the Heron/Egret/Ibis group were counted in all habitats of the estuary including locations such as open water, sandbars and mudflats. Mosquito breeding areas supported 788 individuals or 79% of the total number recorded.

Heron, Egret, Ibis group	79%
Duck, Grebe group	49%
Wading bird group	41%
Gull, Tern group	38%
Pelican, Darter, Cormorant group	27%
Black Swan	12%

Despite the relatively small amount of fringing wetland in comparison to estuarine habitat it is immediately apparent from the above figures that mosquito breeding areas are important to waterbirds. Standardising bird densities to unit area of habitat accentuates this feature.

5.4 SEASONALITY AND TIDAL INFLUENCES

In general, seasonal fluctuations of bird numbers in fringing wetlands reflect those for the estuary as a whole with abundance peaking in mid-summer (see Fig. 3b). A minor fringing wetland peak also occurs in autumn with ducks and swans appearing in larger numbers. However, attempts to clarify whether mosquito breeding areas and the estuary sub-units were used differently at the same time of the year (i.e. which area was more important to birds) were not successful since tidal influences tended to mask preferences. For example, high tides massively reduce the area of exposed mudflats and sandbars on the estuary resulting in an influx of birds into saltmarshes and other mosquito breeding areas. Conversely, low tides expose rich feeding areas within the estuary and allow tidal mosquito breeding areas to dry out, thus significantly reducing the number of birds using them.

The very high tide and strong winds on October 20, 1988 resulted

in no birds being recorded on mudflats or sandbars of the estuary while 1419 were observed on the wet samphire and pools within fringing wetlands. Conversely, during the extremely low tide of December 15, 1987 only 98 birds were seen in samphire and pools while 2281 were recorded on mudflats and sandbars.

5.5 SPECIES RICHNESS AND ABUNDANCE IN HABITAT SUB-UNITS

Figure 6a shows the number of species found in the habitat sub-units making up mosquito breeding areas. Flooded samphire, pools within samphire and bare shorelines show the greatest variety of species. Bare shorelines have numerous wheel-ruts and depressions where some mosquito breeding takes place and may therefore be subject to control measures.

The habitat category "OTHER" is a non-specific unit of diverse habitats such as fly-ash dumps, car parks, roads, pasture etc. and because of its variety many species were recorded there. Mosquito breeding in such locations is minimal. Few species were recorded in drains or mangroves partly because they are small in area and do not provide sufficient resources for large bird populations.

Figure 6a Number of waterbird species recorded in the habitat sub-units of mosquito breeding areas.

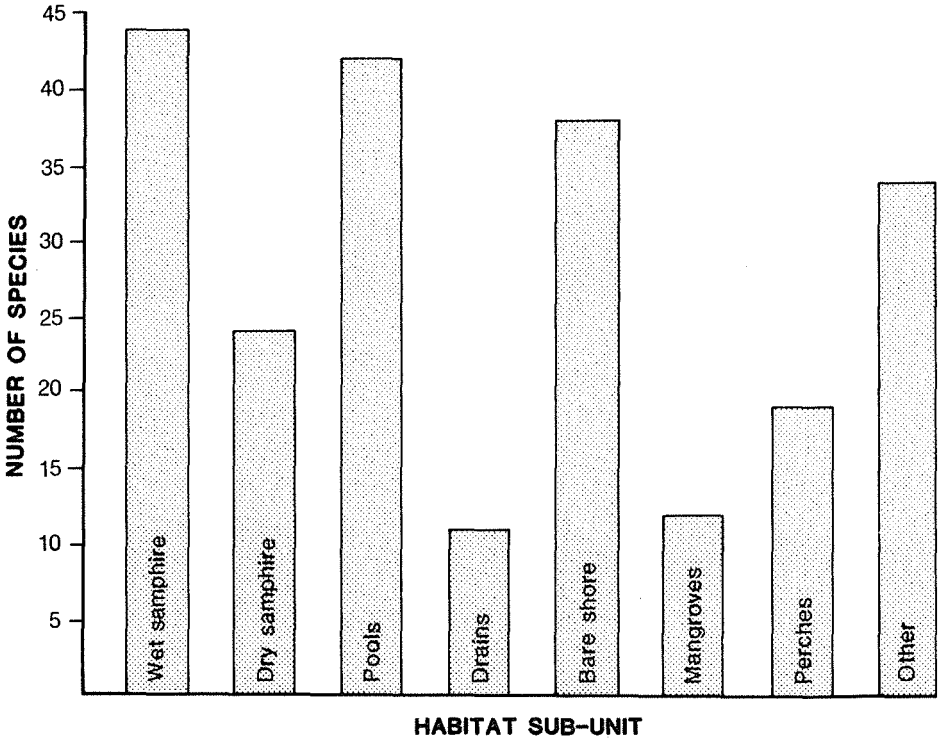
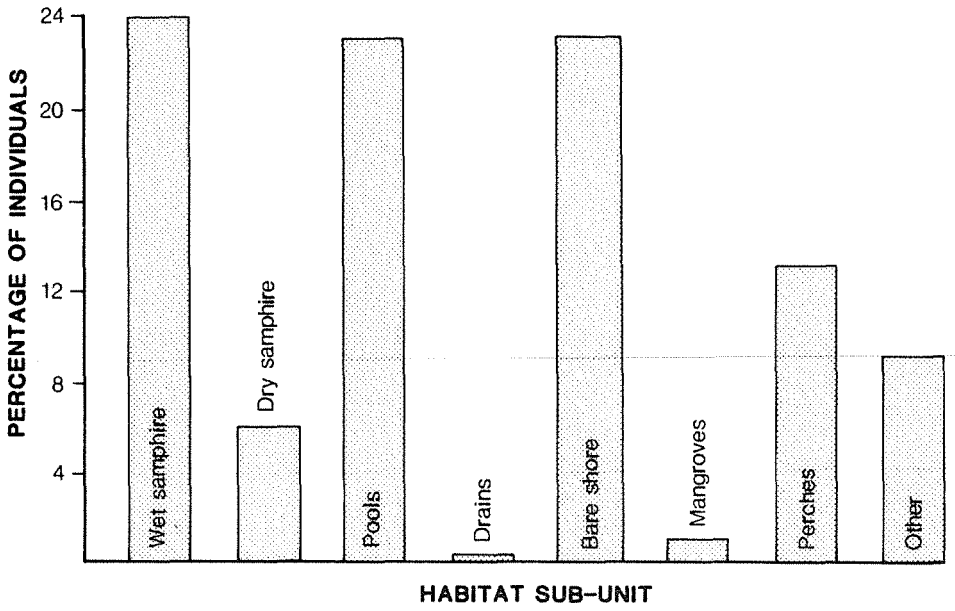


Figure 6b Waterbird utilisation of habitat sub-units within mosquito breeding areas, expressed as a percentage of the number of individuals.



The proportion of individual birds found in the habitat sub-units of mosquito breeding areas is shown in Figure 6b. Once again the three main mosquito breeding areas, flooded samphire, pools and bare shorelines, show the greatest usage. These three habitats supported 71% of all waterbirds recorded in fringing wetlands and over a quarter of all birds observed throughout the estuary.

5.6 ACTIVITY IN HABITAT SUB-UNITS

The major waterbird activities in each of the habitat sub-units shown in Figures 6a, b are listed below along with the percentage of the total number of birds carrying out these activities:

Wet samphire	-	Feeding	46%	Roosting	46%
Dry samphire	-	"	17%	"	69%
Pools	-	"	62%	Loafing	26%
Drains	-	"	34%	Roosting	48%
Bare shore	-	"	32%	"	67%
Mangroves	-	"	75%	"	12%
Perches	-	Roosting	82%	Breeding	18%
Other	-	Feeding	32%	Roosting	46%

The survey has shown that the major activities taking place in mosquito breeding areas are feeding, roosting or loafing with one or the other taking precedence depending on how much surface water is available. Pools within samphire retain their water for the longest period and are therefore prime mosquito breeding areas. In terms of the number of birds using them (Section 5.5) and the amount of feeding which takes place within their confines, they are significant to waterbirds. Wet samphire, another prime mosquito breeding area, is also important to waterbirds.

Breeding - all 16 species listed in Table 3 were recorded breeding in fringing wetlands. Most activity was observed in pools and consisted mainly of ducklings feeding. Freshwater swamps followed, with nesting activity taking place in locations such as Laporte and Marriot Road Swamp. Some breeding was evident in wet samphire and the remainder was observed in diverse locations such as fly-ash dumps and pasture.

6.0 CONCLUSIONS

This study has shown that Leschenault Estuary is important to waterbirds and that its fringing wetlands, where mosquito breeding takes place, are an integral and necessary part of the system. Further loss or degradation of fringing wetlands, particularly certain locations, (see following sections) will adversely affect waterbird populations on the estuary. Tidal saltmarshes stand out as productive waterbird locations with their wet samphire areas, small pools and associated shorelines contributing most to maintaining waterbird populations.

Mosquito breeding areas are considered to be a necessary part of the system in that they:

- are used by at least 60 of the 62 species of waterbird recorded at the estuary;

- support 38% of all individual waterbirds counted at Leschenault Leschenault in an area representing 11% of the total area;

- show a disproportionate usage per unit area by certain waterbird groups (77% of all herons, egrets and ibis; 49% of all ducks and grebes; 41% of all shorebirds);

- act as refuges for large numbers of birds during very high tides and stormy weather;

- provide rich intertidal and freshwater feeding areas for a large proportion of the waterbird species using the estuary (37% of all individuals recorded in mosquito breeding areas were observed feeding);

- are virtually the only areas where breeding takes place and which can provide refuge for young waterbirds;

- are used by a large number of migratory shorebirds many of which are protected by international conservation agreements.

6.1 AREAS OF CONSERVATION SIGNIFICANCE

Prior to dealing with waterbird sampling sites individually, it is important to take an overview of the conservation significance of larger sectors of the estuary. On this basis, with reference to Figure 1, all fringing wetlands along the extreme northern limits and western shoreline of the estuary are of conservation significance because of their low disturbance and productivity.

The Preston River mouth is of extremely high significance since 72% of all shorebirds recorded throughout the estuary were observed in this area.

Laporte Swamp (Site 17) and Marriot Road Swamp (Site 25) require special attention in that they support breeding colonies of Great Egrets, Yellow-billed Spoonbills, Little Pied Cormorants, Little Black Cormorants and Sacred Ibis.

If for no other reason than that the lower inlet supports a relict population of the mangrove *Avicennia marina*, this site is of special significance. Construction of a rowing course at the eastern end of the bay and a premature series of drainage ditches through samphire at its north-western limits during this study, appear to have strongly influenced results. Data from this site are therefore unreliable. Observations carried out prior to the survey, however, indicate that it is used by large numbers of waterbirds and should therefore be protected.

Site 22 (Fig. 1) is described in Section 3.3 as a large, composite sampling area established to cover the highly disturbed eastern shoreline of the estuary. In general, this shoreline is unproductive in species because of a lack of diversity of habitat. However, within Site 22 there is a dense, relatively undisturbed area of sedgeland, samphire marsh and *Melaleuca rhaphiophylla* low, closed forest situated on the portion of the

shoreline projecting into the estuary (Fig. 1). CALM data shows that this location is richer than our surveys suggest and may well support secretive birds such as Crakes and Rails. In the following section, Site 22 is broadly assessed as being of intermediate significance. The portion described above should therefore be excised from our mosquito control measure assessment and viewed as high significance. This area, and several other small, unsurveyed patches on the eastern shoreline, may appear to be of low significance during periods of low tidal amplitude but act as rich feeding, breeding and refuge areas when flooded. At this time they also support high levels of mosquito breeding which necessitates them being treated by either larvicide or physical control. If physical control is deemed necessary for the portion of Site 22 described above, great care will have to be taken to protect the Paperbark forest from saline intrusions.

6.2 ASSESSMENT OF INDIVIDUAL WATERBIRD CENSUS SITES

The previous section gives a broad outline of the conservation significance of groups of wetlands fringing Leschenault Estuary. The following assessment takes a site by site approach in order to fine-tune mosquito control measures and ensure that sites of known high conservation value are treated individually by applying techniques which will maintain their current status as far as possible.

It should be stressed, however, that sites designated as low significance do make some contribution to the Leschenault system and that the cumulative effect of control measures such as earth fills can impinge on high significance sites, or the estuary as a whole.

In order to assess each site, including its potential which may not have been established during the survey, a series of criteria have been developed and are based on:

1. actual quantitative field data;

2. physical aspects which control diversity;

3. subjective or qualitative judgments.

Eight criteria were chosen; some self-explanatory and others requiring clarification. Each criterion was given a series of parameters upon which points were scored for each site.

Species Richness - (1-5 species = 1 point; 6-10 = 2; 11-15 = 3; 16-20 = 4; 21-25 = 5; 25+ = 6).

Number of Individuals - (1-100 individuals = 1 point; 101-200 = 2; 201-300 = 3; 301-400 = 4; 401-500 = 5; 500+ = 6).

Significant Species - the number of species per site protected by international treaties such as the Japan/Australia Agreement was taken as a convenient measure of site significance (1-3 species = 1 point; 4-6 = 2; 7-12 = 3; 13-15 = 4).

Breeding Potential - this category is composed of actual results and, to a degree, informed judgment. Investigating breeding is time-consuming and beyond the scope of this study (Low potential = 1; Intermediate = 2; High = 3; Very High = 4).

Habitat Quality - highly disturbed sites, in human terms, are not necessarily unattractive to waterbirds, Preston River Mouth being a typical example. Judgments have been made on bird usage and the potential of semi-pristine sites over a longer survey period (Low quality = 1 point; Moderate = 2; High = 3; Very high = 4).

Habitat Representation - some sites at Leschenault Estuary are dominated by a particular vegetation type, reeds for example. Such areas may represent the largest expanse of this sub-unit and have the capacity to support specialised or cryptic birds which may have been overlooked during the survey. Allowance has been made for this on a scale of 1-4 points.

Diversity of Habitats - diversity of habitats in an area generally equates with high waterbird productivity. Points have been apportioned on a scale of 1-3.

Site Area - each site differed in area such that direct comparisons could not be made between one location and another. Large areas, Site 22 for example, appear to be fairly significant only because of their size. Compared to small productive sites they are actually of marginal significance and introduce a misleading error factor. To compensate for this anomaly, one to four points were subtracted from such locations depending on their size (see note in Section 6.1).

Totalling the points accumulated for each site (Appendix 3) gave a functional measure of its significance and a method of establishing relevant mosquito control techniques tailored to individual locations. An approach such as this has a high degree of subjectivity and should not be considered as a final statement

on a wetland since many attributes are interdependent and in some cases synergistic. In certain locations the primary aim should be to minimise all mosquito control measures. While this may not appeal to the general public in the vicinity of important wetlands it is highly probable that the adverse effects of mosquito control on waterbirds are not fully realised. A public education programme may assist in accomplishing a trade-off between a certain level of mosquito nuisance and the maintenance of a highly visible and attractive fauna.

Table 5 Waterbird conservation significance of wetlands fringing Leschenault Estuary. Rankings based on aggregate scores for eight waterbird habitat attributes applied to larval breeding areas. (NA = Not applicable - no larval sampling; * = High priority mosquito control area.)

RANK	SCORE	WATERBIRD SITE	MOSQUITO SITE/S	CATEGORY
1	26	4	115	VERY HIGH SIGNIFICANCE
1	26	5*	113	"
2	24	25	NA	"
2	24	3	115	"
3	23	31	17-20	"
4	22	40*	121,122, 124	"
5	21	17	NA	"
6	20	29	9-11	HIGH SIGNIFICANCE
7	19	10	103	"
7	19	30	12-16	"
7	19	34	21,22	"
7	19	36	NA	"
7	19	38	28	"
8	18	35	23-27	INTERMEDIATE SIGNIFICANCE
9	17	27	8	"
10	15	16*	50-64	"
11	14	12*	101,102	"
11	14	22	31,32,35, 36,39,40	"
12	11	7	NA	LOW SIGNIFICANCE
12	11	9	110	"
13	10	1*	116	"
13	10	8	111	"
13	10	11*	104	"
13	10	23	33,34, 37,38	"
13	10	26	NA	"
14	9	24	NA	"
15	7	28	NA	"

Individual attribute scores are given in Appendix 3.

7.0 RECOMMENDED CONTROL OPTIONS

Various control techniques have already been recommended by Wright (1986) for the numerous mosquito breeding areas in the vicinity of Leschenault Estuary. The following section reviews these strategies in the light of data from the intensive waterbird surveys. The primary aim of this review is to conserve valuable waterbird habitat while acknowledging that mosquito control in certain sites is seen to be necessary by the MCRC, Local Government Authorities and Public Health department. The advantages and disadvantages of the various methods for dealing with the mosquito problem are discussed in the "Interim Strategy for Mosquito Control in the Peel Inlet and Leschenault Estuary Regions" (Government of Western Australia, 1989).

Four categories of wetland have been defined in Table 4, based on their waterbird conservation significance. Preferred control options for each wetland group are listed below and codes showing their significance are marked on Figure 1.

VERY HIGH SIGNIFICANCE

1. Selected and precise aerial application of ABATE on large wetlands (high or moderate priority control) until the granular formulation of Bti is available.

2. No control measures in moderate control priority locations distant from residential areas if it is found that there is minimal migration of mosquitoes.

3. Backpack spraying of liquid Bti in small wetlands with localised breeding sites.

4. Filling of all wheel-ruts, minor depressions and limiting or prohibiting vehicular access.

HIGH SIGNIFICANCE

1. Accurate aerial application of ABATE on large wetlands (high or moderate priority control) until the granular formulation of Bti is available.

2. No control measures in moderate control priority locations distant from residential areas if it is found that there is minimal migration of mosquitoes.

3. Backpack spraying of liquid Bti in small wetlands with localised breeding sites.

4. Filling of all wheel-ruts, minor depressions and limiting or prohibiting vehicular access.

5. Minimal channels (runnels) dug by hand in high priority control areas as a last resort.

INTERMEDIATE SIGNIFICANCE

1. Aerial application of ABATE on large wetlands (high or moderate priority control) until the granular formulation of Bti is available.

2. No control measures in moderate control priority locations distant from residential areas if it is found that there is minimal migration of mosquitoes.

3. Filling of all wheel-ruts and manageable larger depressions.

4. Shallow machine-dug spinner drains with lateral feeders if required.

5. Perimeter channels if warranted.

6. Creation of artificial lakes in areas earmarked for development.

The portion of Site 22 described in Section 6.1 should be treated as a high significance wetland.

LOW SIGNIFICANCE

1. Control measures as suited to each site with the objective being to retain as much wetland as possible in locations distant from residential areas.

8.0 REFERENCES

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Loneragan, N.R., Potter, I.C. and Lenanton, R.C.J. (1987). The fish and fishery of the Swan Estuary. In: *The Swan River Estuary, ecology and management.* (Ed. John, J. Curtin University Environmental Studies Group) Report No.1 1987.

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Appendix 1 An example of a field data sheet.

STUDY: ______________________

DATE: ______ 19 ____

TIME: ______ to ______ hrs

OBS: ______

SAMPLE SITE NO: ______

DESCRIPTION: ______________________

WATER LEVEL: __·__ m

MOSQUITO INDEX (0-3)

LARVAE: ____

ADULT: ____

SPECIES		FRINGING WETLANDS																INLET												TOTAL	REMARKS
		SAMPHIRE WET		SAMPHIRE DRY		POOLS		BARE AREAS SHORE		BARE AREAS OTHER		MAN-GROVES		PERCH		OTHER		OPEN WATER		SHALL-OWS		TIDAL FLATS		SAND BARS		PERCH		OTHER			
	Code	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac	Nos	Ac		

ACTIVITY CODES – F = Feeding, R = Roosting, L = Loafing, A = Flying over, O = Other.
B = Breeding

APPENDIX 2 ASSESSMENT OF THE KEMERTON WETLANDS.

1.0 INTRODUCTION

The Kemerton wetlands are located some 3 kilometers north-east of Leschenault Estuary (Figure 1) and are a complex chain of freshwater swamps and damp depressions with a rich and diverse waterbird population. Some wetlands are situated in cleared land and others in native vegetation.

The area has attracted attention in recent years as a large industrial complex, which has the capacity to impinge on the fauna and vegetation of the wetlands, is in the planning stage. Several studies of the wildlife of the area have been carried out in the past; principal among these are Bamford *et al.* (1983) and Ninox Wildlife Consulting (1985). In the latter report the authors consider that the wildlife of the Kemerton area:

> "is representative of the Southern Coastal Plain since it supports elements of the small suite of species which distinguishes this area from the adjacent, western Darling Range. It has value as a waterbird refuge because wetlands are a rapidly diminishing resource on the Swan Coastal Plain."

The Mosquito Control Review Committee commissioned a study of the waterbirds of selected locations in the Kemerton wetlands in order to assess whether mosquito control techniques used on Leschenault Estuary could perhaps have some effect on birds which potentially move between both areas.

Three sampling sites were chosen at Kemerton. Site 41 (Darter Swamp) is a fairly large, narrow swamp located in farmland but surrounded by dense fringing vegetation in which a number of waterbirds, particularly Darters, regularly breed. Site 42 is a small reedy swamp just south of site 41 (Figure 1) and is effectively a continuation of Darter Swamp. Site 43 lies well to the south-east of the two other sites and is an artificial, ephemeral wetland. These sites were chosen partly because they represented specific types and partly because they had been sampled earlier by the authors during the survey quoted above.

All sampling techniques used at Kemerton are identical to those applied at Leschenault Estuary. The wetlands were surveyed during the same periods as the main estuary sampling. Methods and timing are described in Section 2.0 (this report).

2.0 RESULTS

Table 1 Total number of waterbirds recorded during each of nine surveys of the Kemerton wetlands between September 1987 and October 1988.

SURVEY MONTHS	SEP.	OCT.	DEC.	FEB.	MAR.	MAY	JUN.	AUG.	OCT.
BIRD SPECIES									
PODICEPEDIDAE									
Hoary-headed Grebe		1	2						1
Australasian Grebe	3						1	4	
Unidentified Grebe								1	
ANHINGIDAE									
Darter	4	15	8					1	6
PHALACROCORACIDAE									
Great Cormorant	4	30							
Little Pied Cormorant	1	2	7						
ARDEIDAE									
Pacific Heron		1							
White-faced Heron	2		1				1		
Great Egret			2						
Rufous Night Heron			11						
PLATALEIDAE									
Sacred Ibis		2	16						
Yellow-billed Spoonbill		2							
ANATIDAE									
Black Swan		4						1	2
Australian Shelduck	6		2					18	
Pacific Black Duck	4	12	14				22	9	6
Grey Teal	6	2	12				4	8	7
Australasian Shoveler	2								
Hardhead	5								
Maned Duck	5	3					1	2	5
Blue-billed Duck	2							2	
Musk Duck	4	1	2				1		3
ACCIPITRIDAE									
Marsh Harrier		1							1
RALLIDAE									
Dusky Moorhen	1		2				1		
Purple Swamphen	4	2		2		6	3		1
Eurasian Coot	4	2					18	10	10
CHARADRIIDAE									
Black-fronted Plover			1						
SYLVIIDAE									
Clamorous Reed-Warbler		1	2						
TOTAL	57	81	82	2	0	6	52	56	42

Since this is not a study of individual wetlands at Kemerton, but more an exploration of its links with Leschenault Estuary, all data from the three sites have been combined. Site specific data are available if required.

Twenty-seven species of waterbird and 378 individuals were recorded using the wetlands with the greatest number of species and individuals concentrated at Darter Swamp. Three species were unique to Kemerton: Hardhead, Blue-billed Duck, Clamorous Reed-warbler. These birds reflect the freshwater conditions and dense reeds of the wetlands.

Waterbird populations were high in October and November 1987 when the wetlands were used as a summer drought refuge, but from February to May 1988 all the sites had dried out and were unable to support waterbird populations except for the Purple Swamphen which appears to be resident in the dense reedbeds of some swamps. Breeding was recorded between August and November and was concentrated on Darter Swamp. Eight species were involved in this activity:

Darter	-	17
Great Cormorant	-	1
Sacred Ibis	-	2
Black Swan	-	5
Australian Shelduck	-	16
Maned Duck	-	2
Musk Duck	-	1

The Darter and Great Cormorant form breeding colonies at Darter Swamp.

3.0 DISCUSSION AND CONCLUSIONS

Without banding or otherwise marking birds it is difficult to make a conclusive statement as to whether waterbirds travel between the Kemerton wetlands and Leschenault Estuary. However, three factors strongly suggest that this is the case:

- Darters and Great Cormorants breed colonially in the wetlands and feed their young mainly on small fish. Leschenault Estuary is the only estuarine fish nursery close to Kemerton where large concentrations of suitable sized fish occur;

- groups of the above species were seen coming from and heading in the general direction of Kemerton;

- the amount of clearing and general disturbance around Leschenault Estuary suggests that a portion of breeding waterbirds are required to travel further afield to find suitable nesting sites. Kemerton almost certainly absorbs some of the overflow from the estuary;

- from February to May the Kemerton wetlands are either dry or very shallow. The estuary probably acts as a refuge for some of the Kemerton birds at this time.

On the balance of probabilities, there is a strong link between the Kemerton wetlands and Leschenault Estuary and if this is the case, mosquito control measures, particularly physical methods, at the estuary could have an effect on Kemerton, especially on those species which breed there but travel to the estuary to gather food for their young. Species such as the Darter and Great Cormorant are unlikely to be affected as much as some other species since most of their feeding takes place well away from mosquito breeding areas. Others such as the several species of ducks which concentrate in fringing wetlands are more likely to be susceptible to both physical and chemical control. The system of high to low significance wetlands developed for this report should greatly assist in reducing adverse affects because high significance wetlands subject to minimal or no control measures are also the locations where the bulk of all waterbird feeding activity at the estuary takes place.

Appendix 3 Specific attribute scores for mosquito breeding areas censused for waterbirds at Leschenault Estuary.

SR = Species Richness; NI = Number of Individuals; SS = Significant Species; BP = Breeding Potential; HQ = Habitat Quality; HR = Habitat Representation; DH = Diversity of Habitats; * = points subtracted for large area.

SITE	SR	NI	SS	BP	HQ	HR	DH	TOTAL
1	3	1	1	1	2	1	1	10
3	6	6	3	1	2	3	3	24
4	6	6	4	1	3	3	3	26
5	6	6	4	1	3	3	3	26
7	3	2	1	1	1	1	2	11
8	2	2	1	1	1	1	2	10
9	3	2	1	1	1	1	2	11
10	4	3	2	1	2	3	4	19
11	3	1	1	1	2	1	1	10
12	4	2	1	2	2	2	1	14
16	5	3	2	2	1	1	1	15
17	2	3	1	4	3	4	4	21
22*	4	6	2	2	2	1	1	14
23*	2	3	1	3	2	1	2	10
24	2	2	0	2	1	1	1	9
25	3	5	1	4	3	4	4	24
26	1	1	0	2	2	2	2	10
27*	2	1	1	4	3	4	4	17
28	2	1	0	1	1	1	1	7
29*	3	4	1	4	3	4	3	20
30	3	2	1	3	3	4	3	19
31*	5	6	1	3	3	4	3	23
34	4	1	1	3	3	4	3	19
35	4	3	2	2	3	2	2	18
36	2	2	1	3	3	4	4	19
38	3	4	1	3	3	2	3	19
40*	5	3	2	4	3	4	4	22