Use of the Leschenault Inlet estuary by waterbirds

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Abstract

Leschenault Inlet estuary is a large, permanent estuary supporting a heterogenous array of habitats, giving the inlet the potential to support significant waterbird populations. Nine waterbird surveys were conducted in the estuary, including its fringing wetland area, and in some closely associated out-lying wetlands. During this 14 month study 23 565 waterbird records comprising 57 species were recorded between 1987 and 1988. The functional uses of the habitats within the estuary and out-lying wetlands were determined by analysing the numbers, species richness and behavioural activity of waterbirds in each habitat type. Analyses of these data, in combination with Birds Australia data-bases, indicate that Leschenault Inlet estuary is an important waterbird location within southern Western Australia and is likely to be a critical integral component of the wetland network used by waterbirds in this region. For example it is a dry season refuge for waterbirds in mid spring and summer and ranks amongst the top wetlands in the south west of the State in terms of species richness, numbers of waterbirds and numbers and richness of waterbird species scheduled under international migratory bird agreements. Locally, the out-lying wetlands appear to be a complementary part of a wider Leschenault wetland system. They support a wide variety of species, including five species not recorded in the estuary, with 71% of all breeding activity recorded. Waterbirds make extensive use of most habitats within the estuary and out-lying wetlands, often using them for different purposes. For example, in the estuary the open water habitats (*e.g.* sandbars and shallow water) support the larger part of the waterbird population and are largely used for feeding. However, the fringing wetland habitats (*e.g.* wet and dry salt marshes and pools) support a greater density and a larger variety of waterbirds. These wetlands are used equally for feeding and roosting and support significant breeding.

Keywords: Avifauna, avifauna habitats, Leschenault Inlet, estuary, south-western Australia.

Introduction

Leschenault Inlet estuary is located 135 km south of Perth, immediately north of Bunbury, Western Australia (Fig 1). The estuary is an elongate lagoonal estuarine system, separated from the Indian Ocean by the dunes of the Leschenault Peninsula. A narrow cut has been excavated at the southern end to allow greater exchange of ocean water. Within the estuary there are several large scale, tidal and subtidal geomorphic/bathymetric units, a poikilosaline range of salinity fields and a heterogeneous array of vegetation types across the system, including various forms of fringing vegetation (Wurm & Semeniuk 2000; Pen *et al.* 2000).

Given the variety of habitat types present, Leschenault Inlet estuary is likely to support a significant number of waterbird species. While the estuary has been included in a number of broad scale, comparative waterbird studies (Jaensch *et al*. 1988; Halse *et al*. 1990, 1992, 1995; Storey *et al.* 1993), the present paper describes the most detailed study of the waterbird usage of Leschenault Inlet estuary conducted to date.

In this study total counts were conducted over the whole estuary including the wetland fringes, which comprised wet and dry salt marsh, pools and bare shoreline. Some closely associated wetlands immediately east and south of the estuary were also included, but analysed separately. Nine surveys were conducted between September 1987 and October 1988, providing two samples per season except spring, which had three. Waterbird species, number, location, habitat type and behaviour were recorded for each observation. This study was originally designed to determine the importance of mosquito breeding areas to waterbirds (Ninox Wildlife consulting 1989). In this study the data have been re-analysed in an attempt to determine the likely ornithological value and functional use of Leschenault Inlet estuary and the small-scale habitats within it.

Methods

Study area

Leschenault Inlet estuary is one of the few large estuaries in southern Western Australia opening to the Indian Ocean (Fig 1). It is located on the south west coast of Western Australia and is the third largest estuary (2600 ha) between Hill River to the north and the Vase-Wonnerup Estuary to the south (Hesp 1984). The estuary is a permanent, microtidal (mean diurnal tide = 0.5 m), wave-dominated estuarine lagoon, with sea and land breezes and winter storms developing wind waves. Atmospheric pressure has a greater effect on water levels than astronomical tides, with summer high pressure systems resulting in low water and winter low pressure systems producing a small general rise in mean sea level (Semeniuk & Meagher 1981). The estuary is annually poikilosaline with a south to north salinity gradient, which is generally unstratified (Wurm & Semeniuk 2000).

Leschenault Inlet estuary has a deeper central basin

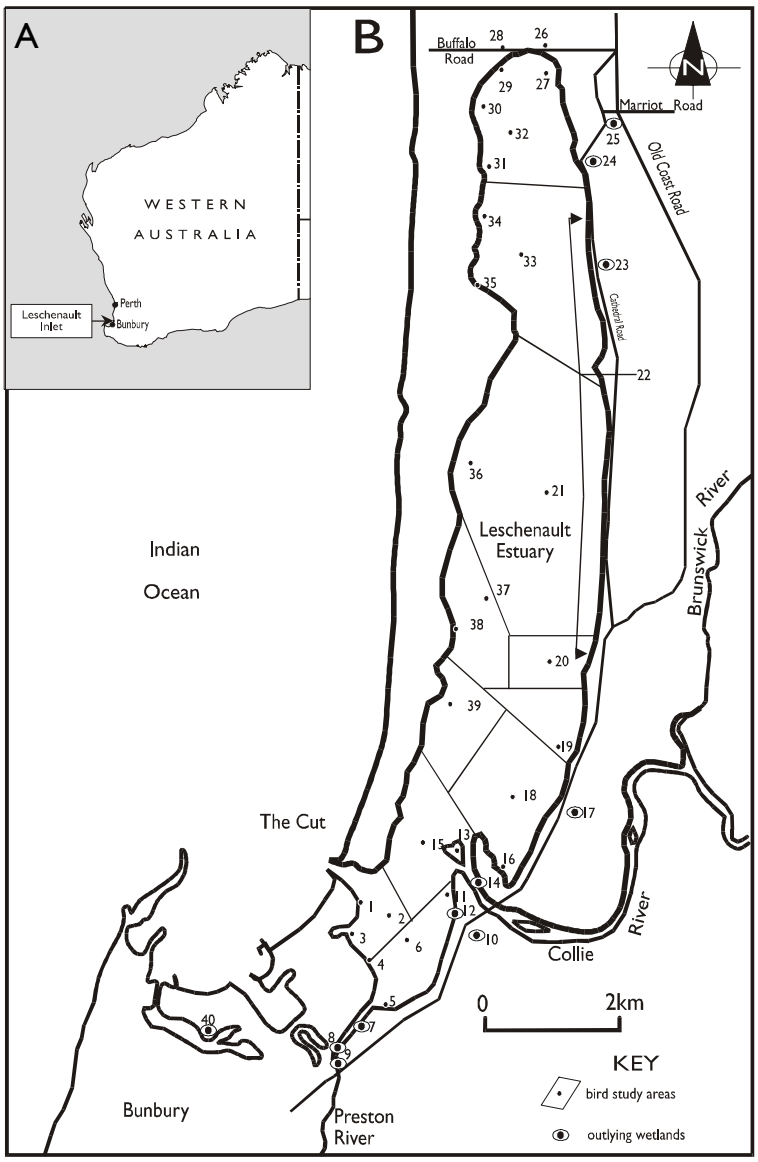

Figure 1. A. Locality of Leschenault Inlet estuary and outlying wetlands. B. Waterbird sampling areas.

(approximately 1 m) with shallower peripheral platforms and ramps. The estuary is composed of subtidal, tidal, and supratidal areas and can be divided into eight bathymetric and geomorphic units (Wurm & Semeniuk 2000). The estuary comprises open water habitats (deep water, shallow water, tidally exposed sandbars and mud flats) and fringing habitats (shoreline, salt marsh, pools, mangroves and paperbark thickets). For the purposes of the present study, these habitats and habitat elements such as perches (posts protruding from the water, rocks, tree branches), man-made drains, car parks, and grassed areas were divided into 13 habitat sub-units plus one miscellaneous category (Table 1). The sub-unit 'other fringing wetland habitat' was used to encompass diverse habitat elements such as fly-ash dumps, car parks, grassed areas, roads, and telephone poles found in the fringing wetlands.

Sampling

Thirty sites were selected to cover the whole Leschenault Inlet estuary area (Fig 1). In addition ten closely associated out-lying wetland areas were included because they were likely to be used by waterbirds using the estuary. Most of these sites were located on the east side of the estuary (sites 10, 12, 17, 23-25), one was on the south side (site 40) and three on the Preston River (sites 7-9). All sites comprised more than one habitat sub-unit. Site 40 was the only location having significant mangrove habitat and the only site for which the mangrove habitat sub-unit was used. Other minor mangrove habitat was included in the other habitat sub-units.

No attempt was made to scale the relative areas of habitat sub-units in individual wetlands since this varied from survey to sur-

Table 1. List of habitat sub-units used in this study.

Habitat Sub-Units	Description
Fringing Wetland Habitats	
Dry salt marsh	Supratidal samphire vegetated flat
Wet salt marsh	High tidal samphire vegetated flat
Pools (fringing wetland habitat)	Pools within high tidal vegetated flat
Bare shoreline	Mid-tidal flats bare of vegetation
Mangroves	Mangroves on mid to high tidal flats fronting steep dune shores
Drains	Man made drains within the fringing wetland habitat
Perches (fringing wetland habitat)	Perches in paperbark thickets, mangroves, dead trees and fence posts.
'Other' (fringing wetland habitat)	Grassed areas, roads, car parks, telephone poles, fly ash dumps
Open Water Habitats	
Deep water basin	Central basin of estuary and deeper parts of the platforms & ramps
Shallow water	Shallow sub-tidal and low tidal parts of the platforms and ramps
Tidal flats	High tidal flats without vegetation.
Sandbars	Beach ridges, spits, bar and lagoon shores
Perches (open water habitat)	Rocks protruding from the water, fence posts, and other man made objects within the open water habitat
Other (open water habitat)	Miscellaneous

vey depending on tide height. For example, an area of dry salt marsh observed during one survey could be inundated at the next survey, appearing as wet salt marsh or even a large pool. Scaling has therefore been limited to an overview of the estuary. The fringing wetland habitat in the estuary represents approximately 11% of the total estuary area, while the open water habitat represents approximately 89%. This will obviously vary with tides and fresh water inflows.

In this study waterbirds are defined as those bird species that are dependent on wetlands for their survival (Jaensch *et al*. 1988) and comprise various groups including waterfowl, shorebirds, crakes, rails and certain species of raptors and passerines (warblers). Four species of bird (domestic duck sp, Magpie-lark *Grallina cyanoleuca*, White-fronted Chat *Epthianura albifrons* and Richard's Pipit *Anthus novaeseelandiae*), recorded in the Ninox Wildlife Consulting (1989) surveys, were not included in this study because the domestic duck is not a native species and the other three birds are not reliant on these habitats. The nomenclature used in this study is according to Christidis & Boles (1994).

Sampling was conducted simultaneously by three field-staff working co-operatively with one another such that the combined samples could be viewed as a total census of the estuary and out-lying wetlands conducted within one day during day light hours. The dates of the nine surveys are given in Table 2. At a sampling site, the observer selected a vantage point, remaining there until confident that all visible birds had been identified, counted, allocated to habitats and their activity defined. Foot or vehicle transects were conducted between each sample site and spot-checks made along the way to ensure that all birds were recorded. Members of the more cryptic, secretive species, such as crakes and rails, may have been missed because different methods of survey are required to adequately sample these species. Behavioural activities recorded included feeding, roosting (any sort of land-based resting/sleeping), loafing (bird resting on water including directionless drifting), flying overhead, breeding (nesting or small young feeding) and 'other' (miscellaneous including preening and fighting). The functional use of each habitat sub-unit was determined by considering the numbers, species richness and behavioural activity of the waterbirds utilising them. The data from out-lying wetlands were analysed separately from the data from the estuary.

Table 2. Surveys conducted at Leschenault Inlet estuary and out-lying wetlands in 1987 and 1988.

SURVEY	DATE	SEASON
1	3 September 1987	Spring
2	29 October 1987	Spring
3	15 December 1987	Summer
4	4 February 1988	Summer
5	23 March 1988	Autumn
6	11 May 1988	Autumn
7	29 June 1988	Winter
8	4 August 1988	Winter
9	20 October 1988	Spring

To give the conservation values of Leschenault Inlet estuary and the out-lying wetlands a State perspective, the Birds Australia data bank on wetlands (Anon 1999) was consulted, and data collected from 1988 to 1999 was analysed. Over 700 wetlands in southern Western Australia were compared and ranked under the following parameters: total numbers of waterbirds recorded in any one survey, species richness, numbers and richness of species scheduled under international migratory bird agreements and richness of species that breed in the study site. The out-lying wetlands were assessed separately. As most of the out-lying wetlands were not included in the Birds Australia data bank (Anon 1999), unpublished data were used instead to make the State comparisons. Birds Australia and Ninox Wildlife Consulting (1989) data were considered together to determine the State perspective and seasonal use of the estuary and out-lying wetlands.

Results

Species richness and numbers of waterbirds

During the Ninox Wildlife Consulting (1989) study, 21 040 records of waterbirds comprising 50 species were

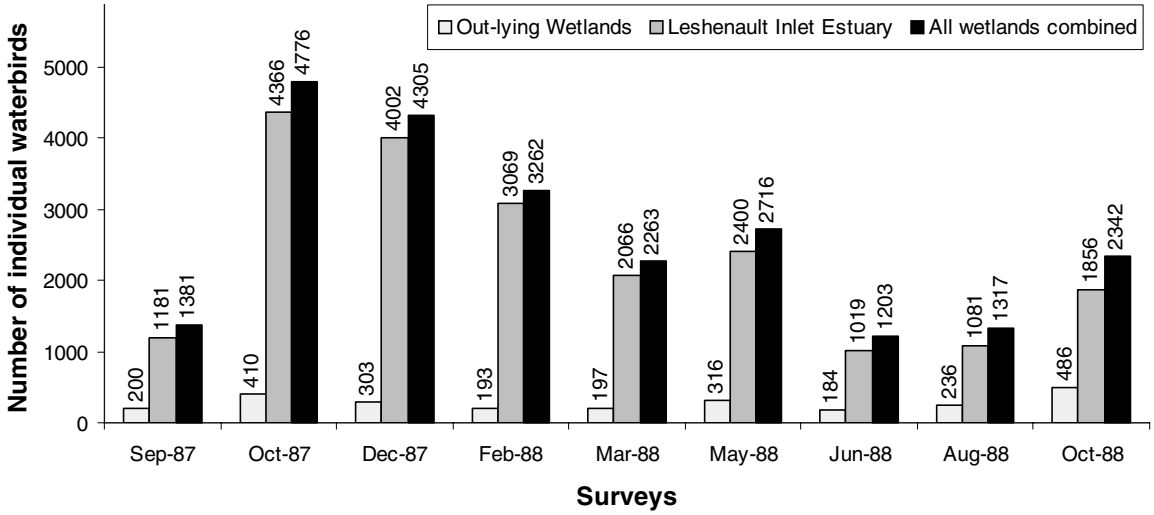

Figure 2. Number of individual waterbirds counted during surveys of the Leschenault Inlet estuary and outlying wetlands.

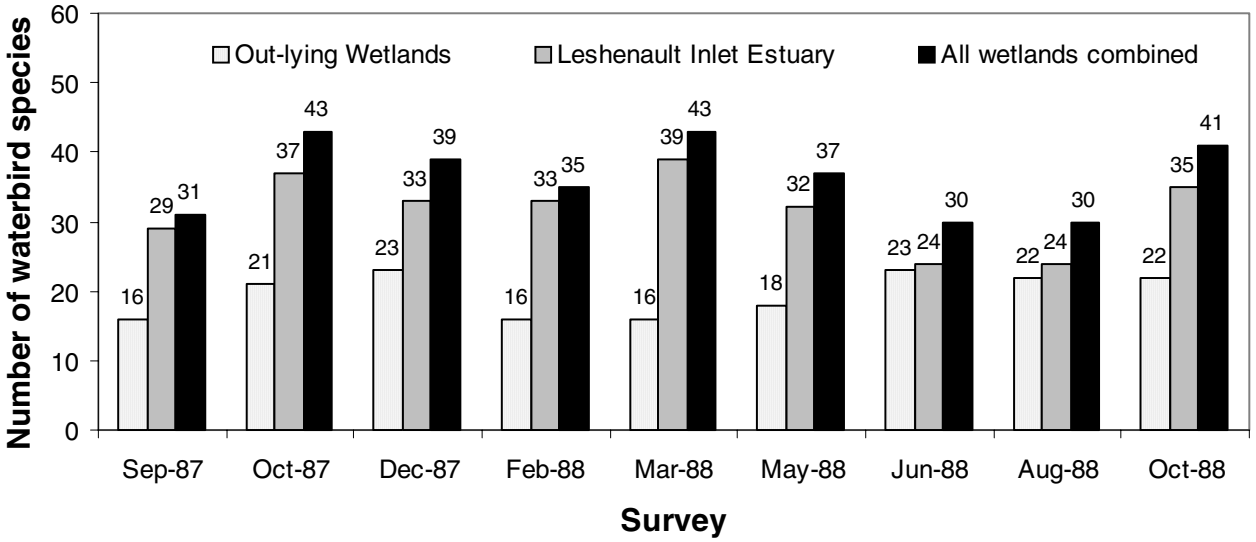

Figure 3. Species richness during surveys of the Leschenault Inlet estuary and outlying wetlands.

collected on the Leschenault Inlet estuary. During the nine samples taken over this 14 month study, the estuary was populated by 1 019-4 366 waterbirds comprising 24-39 species. Greatest numbers of waterbirds occurred on the estuary in mid-spring (when numbers for October 1987 and 1988 are averaged) and early summer, generally decreasing towards winter (Fig 2). Species richness was generally high throughout the year, but lowest during winter (Fig 3). An additional 2 525 waterbird records (10.7% from a total of 23 565 for the estuary and outlying wetlands) and seven species (12.2% from a total of 57) were contributed by sampling the closely associated outlying wetlands (sites 7-10, 12, 17, 23-25, 40). These areas were populated by 200-486 waterbirds comprising 16-23 species. Greatest numbers of waterbirds on these wetlands occurred in mid spring (mean for October 1987 and 1988), generally decreasing in numbers in mid summer through to winter (Fig 2). Few or no waterbirds occurred on many out-lying wetlands during summer and autumn. However, sites 7, 9 and 40 supported waterbirds throughout the year. Site 17 had waterbirds as late as February. Species richness was generally moderate throughout the year, but highest in mid to late spring and winter and lowest in late summer and autumn (Fig 3). A list of the species recorded in the estuary and out-lying wetlands is given in the Appendix.

Habitat use

In the Leschenault Inlet estuary the open water habitats (described in Table 1) together had 14 021 waterbird records (67% of the total waterbirds recorded in the estuary) comprising 43 species (86% of all species recorded in the estuary). The sub-units in the open water habitat were largely used for feeding (36.5% of behavioral activity re-

Table 3. Habitat sub-units of the Leschenault Inlet estuary ranked by abundance of waterbirds. Major behavioural activities in each sub-unit are also presented in order of prominence.

Habitat Sub-units in Estuary	Number of birds & % Abundance	Major Activity
*Deep water basin	3730 (17.7%)	Feed, Loaf
*Tidal flats	3161 (15.0%)	Roost, Feed
*Shallow water	2700 (12.8%)	Feed, Loaf
*Sandbars	2580 (12.2%)	Roost, Feed
Bare shoreline	2116 (10.0%)	Roost, Feed
Wet salt marsh	1905 (9.1%)	Feed, Roost
*Perches (open water habitat)	1449 (6.9%)	Roost
Pools (fringing habitat)	1413 (6.7%)	Feed, Loaf
Perches (fringing habitat)	743 (3.5%)	Roost
Dry salt marsh	499 (2.4%)	Roost
Other (fringing habitat)	337 (1.6%)	Roost, Fly
*Other (open water habitat)	401 (1.9%)	Other
Drains	6 (0.03%)	Feed, Other
Mangroves	n/a	n/a

* = open water habitat sub-units. n/a = not applicable to the estuary.

Table 4. Habitat sub-units of Leschenault Inlet estuary ranked by richness of waterbird species.

Habitat Sub-units in Estuary	Species Richness & % Total Species
Wet salt marsh	39 (78%)
Pools	33 (66%)
Bare shoreline	32 (64%)
*Deep water basin	29 (58%)
*Shallow water	29 (58%)
*Sandbars	27 (54%)
*Tidal flats	26 (52%)
Dry salt marsh	22 (44%)
Other (fringing habitat)	22 (44%)
Perches (fringing habitat)	16 (32%)
*Perches (open water habitat)	14 (28%)
*Other (open water habitat)	14 (28%)
Drains	2 (4%)
Mangroves	n/a

* = open water habitat sub-units. . n/a = not applicable to the estuary.

corded in the estuary). They were also used for roosting (18.3%), which mainly took place on the sandbars, on perches within the open water and to a lesser extent on the tidal flats. Loafing (7.8%) mainly took place in the deep water basin and shallow water (Table 3). In contrast, the fringing wetlands together supported 7 019 waterbirds (33% of total waterbirds recorded) comprising 46 species (92% of all species recorded). Since the fringing wetlands only comprise approximately 11% of the estuary, these facts reveal a disproportionately high use of this small wetland area (24 birds ha^{-1}) compared to the rest of the estuary (6 birds ha^{-1}). The fringing wetland sub-units were mainly used for roosting (16.8% of behavioural activity recorded in the estuary) and feeding (12.3%). Bare shoreline, perches and wet and dry salt marsh were favoured for roosting and bare shoreline, wet salt marsh and pools were favoured for feeding (Table 3). Most habitats throughout the estuary supported a range of species; most notably the wet salt marsh supported 78% of all species recorded in the estuary (Table 4).

In the out-lying wetlands, the open water habitats had 23% of the 2 525 waterbirds recorded in these wetlands, comprising 22 species (54% out of 41). These sub-units were used mainly for a mixture of feeding, roosting and to a lesser extent, loafing (Table 5). By contrast 77% of the waterbirds recorded were found in fringing wetland habitat sub-units, mainly the pools, perches and 'other' sub-units (Table 5). These comprised 36 species (88% of species recorded). These habitats were used mainly for feeding and roosting. Notably the pools in the fringing wetland habitat alone supported 61% of species. They were used mainly for feeding with some loafing (Tables 5, 6). A significant amount of breeding activity was noted in the perches and to a lesser extent the pools (Table 5).

Species protected by international migratory bird agreements

The Federal Government of Australia is committed to the protection of a number of migratory waterbirds through the Japan-Australia Migratory Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA). In the Leschenault Inlet estuary 6 385 waterbirds comprising 17 species scheduled under international migratory bird agreements were recorded. The out-lying wetlands supported nine of these species. While the out-lying wetlands did not contribute any additional species under migratory bird agreements they contributed 289 (4.3% from a total of 6 674) additional waterbird records for these species.

In the Leschenault Inlet estuary the tidal flats appear to be particularly important to these species, as there were more than double the number of waterbirds present in this habitat sub-unit compared to other sub-units. The tidal flats, wet salt marsh, bare shoreline, shallow water and sandbar sub-units support 88% of these species (Table 7). The wet salt marsh sub-unit is also highly significant because it supports 100% of these species recorded in the Leschenault Inlet estuary (Table 8).

In the out-lying wetlands the tidal flats, wet salt marsh and shallows were also important, but not the bare shoreline and sandbars. Perches and other elements in the fringing habitat were important. Together the five sub-

Table 5. Habitat sub-units of the out-lying wetlands ranked by abundance of waterbirds. Major behavioural activities in each sub-unit are also presented in order of prominence.

Habitat Sub-Units in Out-lying wetlands	Number of Birds & % Abundance	Major Activity Types
Pools (fringing habitat)	654 (25.9%)	Feed, Loaf
Other (fringing habitat)	442 (17.5%)	Roost, Feed
Perches (fringing habitat)	438 (17.3%)	Roost, Breed
Wet salt marsh	225 (8.9%)	Roost, Feed
*Shallow water	213 (8.4%)	Feed, Loaf
*Tidal flats	134 (5.3%)	Feed, Roost
*Sandbars	88 (3.5%)	Roost
*Perches (open water habitat)	78 (3.1%)	Roost
Bare shoreline	71 (2.8%)	Roost
Mangroves	68 (2.7%)	Feed
*Deep water basin	48 (1.9%)	Loaf, Feed
Dry salt marsh	40 (1.6%)	Roost
Drains	16 (0.6%)	Roost
*Other (open water habitat)	10 (0.4%)	Roost, Fly

* = open water habitat sub-units.

Table 6. Habitat sub-units of the out-lying wetlands ranked by richness of waterbird species.

Habitat Sub-units in Out-lying Wetlands	Species Richness & % Total Species	
Pools	25	(61.0%)
Other (fringing habitat)	21	(51.2%)
Wet salt marsh	16	(39.0%)
Bare shoreline	15	(36.6%)
Perches (fringing habitat)	13	(31.7%)
Mangroves	12	(29.3%)
*Shallow water	11	(26.8%)
*Deep water basin	8	(19.5%)
*Tidal flats	8	(19.5%)
Drains	7	(17.1%)
*Sandbars	6	(14.6%)
*Perches (open water habitat)	5	(12.2%)
Dry salt marsh	4	(9.8%)
*Other (open water habitat)	2	(4.9%)

* = open water habitat sub-units.

Table 7. Habitat sub-units of Leschenault Inlet estuary ranked by the abundance of waterbirds protected by international migratory bird agreements.

Habitat Sub-units in Estuary	Number of Birds & % Abundance	
*Tidal flats	1999	(31.3%)
Wet salt marsh	993	(15.5%)
Bare shoreline	961	(15.0%)
*Shallows	838	(13.1%)
*Sandbars	815	(12.8%)
Dry salt marsh	221	(3.5%)
Pools	109	(1.7%)
Other (fringing habitat)	85	(1.3%)
*Deep water basin	31	(0.5%)
Perches (fringing habitat)	8	(0.1%)
*Perches (open water habitat)	4	(0.06%)
*Other (open water habitat)	1	(0.01%)
Drains	0	
Mangroves	n/a	

* = open water habitat sub-units. n/a = not applicable

Table 8. Habitat sub-units of the Leschenault Inlet estuary ranked by the richness of waterbird species protected by international migratory bird agreements.

Habitat Sub-units in Estuary	Species Richness & % Total Species	
Wet salt marsh	17	(100%)
Bare shoreline	13	(76%)
Pools (fringing habitat)	12	(70.5%)
*Tidal flats	12	(70.5%)
*Sandbars	10	(58.8%)
*Shallows	10	(58.8%)
Dry salt marsh	7	(41.1%)
*Deep water basin	5	(29.4%)
Perches (fringing habitat)	2	(11.8%)
*Perches (open water habitat)	2	(11.8%)
*Other (open water habitat)	2	(11.8%)
Other (fringing habitat)	4	(23.5%)
Drains	0	
Mangroves	n/a	

* = open water habitat sub-units. n/a = not applicable

Table 9. Habitat sub-units of the out-lying wetlands ranked by the abundance of waterbirds protected by international migratory bird agreements.

Habitat Sub-units in Out-lying Wetlands	Number of Birds & % Abundance	
Wet salt marsh	70	(24.2%)
Perches (fringing habitat)	52	(18.0%)
*Tidal flats	48	(16.6%)
*Shallows	44	(15.2%)
Other (fringing habitat)	37	(12.8%)
Pools	17	(5.9%)
Mangroves	12	(4.1%)
Drains	4	(1.4%)
Bare shoreline	3	(1.0%)
*Sandbars	2	(0.7%)
*Other (open water habitat)	0	
Dry salt marsh	0	
*Deep water basin	0	
*Perches (open water habitat)	0	

* = open water habitat sub-units.

Table 10. Habitat sub-units of the out-lying wetlands ranked by the richness of waterbird species protected by international migratory bird agreements.

Habitat Sub-units in Out-lying Wetlands	Species Richness & % Total Species	
Wet salt marsh	5	(55.5%)
*Tidal flats	5	(55.5%)
Pools (fringing habitat)	3	(33.3%)
Mangroves	3	(33.3%)
*Shallows	3	(33.3%)
Other (fringing habitat)	3	(33.3%)
Bare shoreline	2	(22.2%)
Drains	2	(22.2%)
*Sandbars	2	(22.2%)
Perches (fringing habitat)	1	(11.0%)
Dry salt marsh	0	
*Deep water basin	0	
*Perches (open water habitat)	0	
*Other (open water habitat)	0	

* = open water habitat sub-units.

units having the most waterbirds supported 86.8% of all the waterbirds recorded (Table 9). The wet salt marsh notably supported 55% of species scheduled under international migratory bird agreements, in the out-lying wetlands (Table 10).

Breeding species

In the Leschenault Inlet estuary, 124 waterbird records involved evidence of breeding (29% from a total of 432 breeding records in the estuary and out-lying wetlands combined) involving six species (37.5% from a total of 16 breeding species). These observations mainly involved recently hatched young feeding. The out-lying wetlands contributed 308 additional records of breeding behaviour (71%) providing 10 extra species (62.5%). Species displaying breeding behaviour are noted in the Appendix.

As there were few breeding observations made in the Leschenault Inlet estuary compared to the out-lying wetlands, the analysis of habitat use by breeding birds is assessed using the combined data from the estuary and out-lying wetlands. In the estuary and out-lying wetlands evidence of breeding was found from June to December, but was not evident in the mid summer to late autumn surveys. Ninety percent of all breeding activity occurred in the August to October surveys. Breeding activity occurred mainly at Marriot Road Swamp site 25 (55%), site 32 (13%), La Porte Swamp site 17 (7.2%), site 22 (5.5%) and site 12 (4.9%). Notably site 12 has been destroyed in the course of development.

In the estuary and out-lying wetlands breeding activity occurred predominantly in the fringing wetland habitat, which contained 85% of all waterbirds exhibiting evidence of breeding. In particular the perches in the fringing wetlands had 49% of the breeding records (Table 11). The fringing wetland habitat also supported 100% of the species exhibiting breeding behaviour. In particular the pools and perches in the fringing wetland habitat supported 50% and 44% of species displaying breeding activity respectively. By contrast the open water habitat only supported 12.5% of species exhibiting breeding behaviour or evidence of breeding. These observations largely comprised young feeding (Table 12).

A State perspective of Leschenault Inlet estuary

The Birds Australia data bank (Anon 1999) containing the results of broad-scale waterbird surveys of over 700 wetlands in southern Western Australia was consulted. These wetlands, both tidal and freshwater, are located from Kalbarri to Esperance. According to these data, Leschenault Inlet estuary ranked highly for its importance to waterbirds under many parameters. The estuary ranks in the top 5% of wetlands of importance to waterbirds in terms of species richness, richness of species scheduled under international migratory bird agreements and median numbers of waterbirds. The estuary also ranks in the top 10% of wetlands in terms of numbers of waterbirds scheduled on international migratory bird agreements and in the top 15% for maximum numbers of waterbirds counted in any one survey. It is also ranked in the top 1% of wetlands of importance for

numbers of Caspian Tern (*Sterna caspia*) and in the top 5% of wetlands of importance for numbers of Australian Pelican (*Pelecanus conspicillatus*), Little Pied Cormorant (*Phalacrocorax melanoleucos*), Darter (*Anhinga melanogaster),* Australian Shelduck (*Tadorna tadornoides*), Common Greenshank (*Tringa nebularia*), Red-necked Stint (*Calidris ruficollis*), Pied Oystercatcher *(Haematopus longirostris*), Crested Tern (*Sterna bergii*) and Silver Gull (*Larus novaehollandiae*). Site 12, in the out-lying wetlands, was ranked in the top 5% of wetlands of importance to the Australian Wood Duck (*Chenonetta jubata*) before it was destroyed by development.

Some of the out-lying wetlands were not included in the Birds Australia data bank. When data on these wetlands (Ninox Wildlife Consulting 1989) were compared with data from Birds Australia, Marriot Road Swamp (site 25) ranked in the top 5% of wetlands of importance to waterbirds in terms of richness of breeding species.

Discussion

Functional use of habitats within the Leschenault Inlet estuary area.

The habitat usage and behavioural activity data presented here were collected for all seasons within a 14-month period. Sampling was conducted during the day only. A three to four year data collection, including data gathered in both wet and dry years, and data gathered at night, would be preferable. This would help deduce how waterbirds use the estuary and out-lying wetlands under different annual conditions and in the evening. However, as this type of habitat and activity data are rarely gathered, the data analysed in the present study still provide a valuable insight into the relative uses of wetland habitat by waterbirds.

Based on this 14-month study of habitat usage in the wider Leschenault Inlet estuary area, it was determined that waterbirds made extensive use of most habitats within the estuary and out-lying wetlands, but often used them for different purposes. In the estuary the majority of waterbirds, comprising a large variety of species, use the open water habitats. These habitats are largely used for feeding and to a lesser extent for roosting or loafing. By contrast only one third of waterbirds use the fringing wetlands. However, they concentrate into a much higher density over this small wetland area, suggesting that some of these habitat sub-units provide important resources for waterbirds. Notably a huge variety of species (92% of all species counted) use the fringing wetlands, which are used equally for roosting and feeding.

In the out-lying wetlands the preferences for habitats appears to be reversed. The majority of waterbirds and the majority of species use the fringing wetland habitat sub-units. These habitats are used mainly for feeding and roosting and to a lesser extent for breeding. However, as there is less open water habitat in the out-lying wetlands, this apparent reversal in preference would not be as pronounced as the results of the surveys suggest.

Table 11. Habitat sub-units of the Leschenault Inlet estuary and out-lying wetlands ranked by the abundance of waterbirds exhibiting evidence of breeding.

Habitat Sub-units	Number of Birds & % Abundance	
Perches (fringing habitat)	213	(49.3%)
Pools (fringing habitat)	92	(21.3%)
*Deep water basin	48	(11.1%)
Wet salt marsh	36	(8.3%)
'Other' (fringing habitat)	18	(4.2%)
*Shallow water	17	(3.9%)
Dry salt marsh	7	(1.6%)
*Perches (open water habitat)	1	(0.2%)

* = open water habitat sub-units.

Table 12. Habitat sub-units of the Leschenault Inlet estuary and out-lying wetlands ranked by the richness of species exhibiting evidence of breeding.

Habitat Sub-units	Species Richness & % Total Species	
Pools (fringing habitat)	8	(50.0%)
Perches (fringing habitat)	7	(43.7%)
Wet salt marsh	3	(18.7%)
Other (fringing habitat)	3	(18.7%)
*Shallow water	2	(12.5%)
Dry salt marsh	1	(6.2%)
*Deep water basin	1	(6.2%)
*Perches (open water habitat)	1	(6.2%)

* = open water habitat sub-units.

Some habitat sub-units shared similar waterbird usage patterns, while others had their own distinctive characteristics. The waterbird usage and likely conservation value of each sub-unit is summarised below.

Deep water basin, shallow water, tidal flats and sandbars. The deep water basin, shallow water, tidal flats and sandbars in Leschenault Inlet estuary appear to have similar functional uses. They are all favoured by a large number and variety of waterbirds and together support 58% of all waterbirds recorded in the estuary. These habitat sub-units are used mainly for feeding and resting (roosting and loafing). The shallower sub-units (tidal flats, sandbars and shallow water) also attract a large number and variety of waterbird species scheduled under international migratory bird agreements, mainly comprising small shorebirds. The tidal flats are particularly favoured by migratory shorebirds for feeding. In the out-lying wetlands these habitat sub-units are characterised by relatively small numbers of waterbirds and a smaller variety of species, consistent with the smaller area they occupy. All habitats are used for feeding and resting except for the sandbars, which are only used for roosting. The deep water basin and shallows supported small numbers of feeding young, which would have hatched nearby. The deep water basin, shallow water, tidal flat and sandbar habitat sub-units appear to have very important conservation value to waterbirds in both the estuary and out-lying wetlands.

Wet salt marsh, bare shoreline and pools. In the estuary, the wet salt marsh, bare shoreline and pools all attract a

large variety of waterbirds in large-moderate numbers, including a large variety of species scheduled under international migratory bird agreements. The wet salt marsh and bare shoreline also attract high numbers of these migratory waterbirds. Waterbirds mainly feed and rest (roost or loaf) in these habitats. During hot, dry summers waterbirds may utilise the fresh water seeps. The fresh water comes from ground water mounds under the dunes of Leschenault Peninsula. It discharges into the western side of the estuary, diluting the tidal pools and attracting a variety of waterbirds (Cresswell 2000). In the out-lying wetlands the pools, wet salt marsh and bare shoreline habitat sub-units are characterised by relatively smaller numbers of waterbirds, consistent with the smaller area they occupy, but a large variety of species. However, they attract only a small variety and number of species scheduled under international migratory bird agreements. The wet salt marsh and pools also attract small numbers of a moderate variety of waterbirds, which utilise them for breeding activity. These three habitat sub-units appear to have significant conservation value to waterbirds in both the estuary and out-lying wetlands.

Dry salt marsh. In the estuary the dry salt marsh habitat sub-unit attracts a moderate variety of species in small-moderate numbers, including a small variety of species scheduled under international migratory bird agreements in moderate numbers. This habitat is used almost entirely for roosting. In the out-lying wetlands the dry salt marsh habitat has a similar function, but much smaller numbers and variety of waterbirds use it and no species scheduled under international migratory bird agreements were found there. When this supra-tidal area is inundated it presumably assumes the same functional uses as the wet salt marsh and its conservation value would shift from moderate to high.

Mangroves. The mangroves in the out-lying wetlands are used by a small variety of species in small numbers for feeding. Considering that this habitat sub-unit was only recognised at one sample site (site 40) in this study, and is a very small in area, it is likely to be of greater importance to waterbirds than the surveys suggest. Notably, during the dry season site 40 was used as a dry season refuge by many waterbirds. The small mangrove areas in the estuary, which were lumped with other sub-units in the present study, may be used similarly. Mangroves are likely to be of moderate conservation value to waterbirds.

Drains. The drains transverse through a variety of habitats in the fringing wetlands. In the estuary and out-lying wetlands, they are used by a very small number and variety of waterbirds, but appeared to be a little more used in the out-lying wetlands. Based on the findings of Storey *et al.* (1993), who investigated waterbird usage in many types of wetlands, they are likely to have low conservation value to waterbirds.

Perches in fringing and open water habitats. In the estuary, perches attract a moderate variety of species in moderate numbers. Considering these habitat elements comprise a minute proportion of the areas sampled in the estuary (fence post protruding out of the water, edges of paper bark thickets that were easily visible to the observer, dead trees *etc.*), waterbirds show strong disproportionate preference for them for roosting. They are similarly favoured in the out-lying wetlands, where they are also used for breeding. Perches supported 50% of all waterbirds exhibiting evidence of breeding including many colonial nesting species. Perches would appear to be important habitat elements in the estuary and out-lying wetlands, and of particularly high conservation value when they support breeding.

'Other' habitat in the fringing wetlands. The 'other' fringing wetland habitat sub-unit is a miscellaneous category comprising roads, car parks, grassed areas, fly-ash dumps and telephone poles. In the estuary these habitat elements together support roosting activity in a moderate variety of waterbirds, in small-moderate numbers. These were predominantly Silver Gull (*Larus novaehollandiae*) using grassed areas and car parks. In the out-lying wetlands they support both roosting and feeding in a moderate variety and number of waterbirds including a small variety and number of species scheduled under international migratory bird agreements. These were mainly Great Egrets *(Ardea alba).* Small low-lying grassed areas can be a useful compliment to adjacent wetland conservation areas, particularly when wet, as they will readily be used by ibis, gulls, lapwings and some duck species for feeding. If they contain large mature trees with hollows, these may also be used by ducks for breeding and egrets, herons and wetland raptors for perching.

Role of Leschenault Inlet estuary

Waterbirds are generally very mobile using a wide network of wetlands and wetland habitats to provide them with the necessities of life. In southern Western Australia, a given waterbird may utilise different wetlands for feeding, roosting or breeding on the same day. While the availability of food and suitable breeding and roosting habitat and migration routes are probably the ultimate determinants of waterbird distribution at any given time, waterbird abundance correlates with wetland size, depth, vegetation structure, primary productivity and rainfall via its effects on food production and provision of fresh water for young to drink (*e.g.* Frith 1967; Jaensch *et al.* 1988; Storey *et al.* 1993).

The results of the present study, and the large-scale survey data gathered by Birds Australia, together suggest that the Leschenault Inlet estuary is an important waterbird habitat within southern Western Australia and is likely to be a critical integral component of the wetland network used by waterbirds in the south-west. The estuary is one of the largest waterbodies in southern Western Australia (2 600 ha) and is permanent. It attracts a very large and rich waterbird fauna throughout the year. The greatest numbers of waterbirds occur in mid spring and summer, suggesting it is used as a dry season refuge at these times when many coastal and inland wetlands are dry. It is significant to species scheduled under international migratory bird agreements, supporting a high richness of these species in significant numbers particularly in spring and summer. In summer and autumn many migrant shorebirds leave. More waterbirds leave in autumn after autumn rain has occurred on the coastal plain and inland. They presumably leave to take advantage of

food resources on these freshly wet areas. However, even in winter, when numbers of waterbirds are reduced, the estuary has still supported over 1 000 waterbirds comprising at least 24 species. As a result the estuary ranks in the top 5% of ranked wetlands in southern Western Australia in terms of median numbers of waterbirds, reflecting its constant use. While the estuary itself supports few nesting waterbirds, most observations on breeding behaviour suggest that it provides a food source for young that have been largely hatched in the nearby out-lying wetlands and perhaps elsewhere.

The out-lying wetlands appear to be a complementary part of a wider wetland network. Ornithologically speaking the Leschenault Inlet estuary and out-lying wetlands appear to be complementary parts of the same wetland system. Although the out-lying wetlands support smaller numbers of waterbirds, they support five species that have never been recorded in the Leschenault Inlet estuary (Appendix). They support most waterbirds in mid spring decreasing into winter. Most of the out-lying wetlands are deserted in the dry season, however three sites support waterbirds throughout the year. Most notably, site 40 supported more than a hundred waterbirds during each survey conducted in the dry season. The out-lying wetlands are also important for breeding activity. They supported the majority of waterbirds exhibiting evidence of breeding and the majority of breeding species recorded in the Leschenault Wetland System during the present study. The most notable wetland for breeding waterbirds is Marriot Road Swamp (site 25) which has supported 55% of all breeding in the area. Breeding takes place in the Leschenault Wetland System between June and December, with 90% of it occurring in August to October. It is likely that many waterbirds hatched in the out-lying wetlands feed and grow in the nearby estuary, however only mark and recapture techniques could resolve this question.

Acknowledgements: We wish to acknowledge the Mosquito Control Review Committee, Waterways Commission (1988) for funding the original project for which the data were collected, Australasian Ecological Services for funding the production the present paper and Birds Australia (Royal Australasian Ornithologists Union) for access to the Birds Australia data bank (1999). We wish to thank the following biologists who assisted in collecting the original data: D Watkins, S McNee, M and A Bamford, and A Peacey. We also wish to thank V Semeniuk for general assistance, A Burbidge who provided comments on an earlier version of the manuscript, and the two anonymous referees.

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Appendix

Waterbird species recorded on the Leschenault Inlet estuary and out-lying wetlands during the surveys by Ninox Wildlife Consulting (1989). *Breeding Species. +Species recorded in the out-lying wetlands only. # Species scheduled on international migratory bird agreements. Nomenclature and order follow Christidis & Boles (1994).

ANATIDAE		
	Musk Duck	*Biziura lobata*
*	Black Swan	*Cygnus atratus*
*	Australian Shelduck	*Tadorna tadornoides*
*	Australian Wood Duck	*Chenonetta jubata*
*	Pacific Black Duck	*Anas superciliosa*
	Australasian Shoveler	*Anas rhynchotis*
*	Grey Teal	*Anas gracilis*
PODICIPEDIDAE		
*	Australasian Grebe	*Tachybaptus novaehollandiae*
	Hoary-headed Grebe	*Poliocephalus poliocephalus*
ANHINGIDAE		
	Darter	*Anhinga melanogaster*
PHALACROCORACIDAE	**be**	
*	Little Pied Cormorant	*Phalacrocorax melanoleucos*
*	Pied Cormorant	*Phalacrocorax varius*
*	Little Black Cormorant	*Phalacrocorax sulcirostris*
	Great Cormorant	*Phalacrocorax carbo*
PELECANIDAE		
	Australian Pelican	*Pelecanus conspicillatus*
ARDEIDAE		
*	White-faced Heron	*Egretta novaehollandiae*
	Little Egret	*Egretta garzetta*
	White-necked Heron	*Ardea pacifica*
*#	Great Egret	*Ardea alba*
+	Nankeen Night Heron	*Nycticorax caledonicus*
THRESKIORNITHIDAE		
*	Australian White Ibis	*Threskiornis molucca*
	Straw-necked Ibis	*Threskiornis spinicollis*
*	Yellow-billed Spoonbill	*Platalea flavipes*
ACCIPITRIDAE		
	Osprey	*Pandion haliaetus*
	Swamp Harrier	*Circus approximans*
RALLIDAE		
*	Buff-banded Rail	*Gallirallus philippensis*
	Spotless Crake	*Porzana tabuensis*
+	Purple Swamphen	*Porphyrio porphyrio*
*+	Dusky Moorhen	*Gallinula tenebrosa*
+	Eurasian Coot	*Fulica atra*
SCOLOPACIDAE		
#	Black-tailed Godwit	*Limosa limosa*
#	Whimbrel	*Numenius phaeopus*
#	Eastern Curlew	*Numenius madagascariensis*
#	Common Greenshank	*Tringa nebularia*
#	Common Sandpiper	*Actitis hypoleucos*
#	Grey-tailed Tattler	*Heteroscelus brevipes*
#	Ruddy Turnstone	*Arenaria interpres*
#	Great Knot	*Calidris tenuirostris*
#	Red Knot	*Calidris canutus*
#	Red-necked Stint	*Calidris ruficollis*
#	Sharp-tailed Sandpiper	*Calidris acuminata*
#	Curlew Sandpiper	*Calidris ferruginea*
HAEMATOPODIDAE		
	Pied Oystercatcher	*Haematopus longirostris*
RECURVIROSTRIDAE		
	Black-winged Stilt	*Himantopus himantopus*
	Banded Stilt	*Cladorhynchus leucocephalus*
	Red-necked Avocet	*Recurvirostra novaehollandiae*
CHARADRIIDAE		
#	Pacific Golden Plover	*Pluvialis fulva*
#	Grey Plover	*Pluvialis squatarola*
	Red-capped Plover	*Charadrius ruficapillus*
#	Greater Sand Plover	*Charadrius leschenaultii*
	Black-fronted Dotterel	*Elseyornis melanops*
+	Banded Lapwing	*Vanellus tricolor*
LARIDAE		
	Silver Gull	*Larus novaehollandiae*
#	Caspian Tern	*Sterna caspia*
	Crested Tern	*Sterna bergii*
	Fairy Tern	*Sterna nereis*
SYLVIIDAE		
	Little Grassbird	*Megalurus gramineus*