WATERBIRDS ON THE FLOODPLAINS OF THE VASSE AND WONNERUP ESTUARIES; PATTERNS OF USAGE AND THE EFFECT OF DISTURBANCE

Final report to the Western Australian Department of Conservation and Land Management

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EXECUTIVE SUMMARY

The Vasse and Wonnerup Estuaries are a wetland of international importance in the South-West of Western Australia. Except for one small reserve, however, they are not gazetted for conservation and are set in a rural landscape close to a growing urban centre. Changing patterns of land use in the area make management of the estuaries crucial to the maintenance of their environmental values. The purpose of this study was to gather information that would aid in guiding this management. The two main aspects of the study were: i). to determine patterns of abundance and usage of waterbirds on the wetland in relation to habitat type, land use and management, with emphasis on the floodplain areas; ii). to examine the responses of waterbird species to experimental disturbance.

Waterbirds were found to be unevenly distributed on the two estuaries, with the greatest numbers of ducks and some other species on the Vasse, but the greatest numbers of most wader species on the Wonnerup. On the Vasse, the ducks were associated with ungrazed floodplain vegetation and most breeding records were along a shoreline of flooded sedges under paperbark trees. Most of the floodplain of the Wonnerup is grazed by cattle and horses. The large numbers of waders on the Wonnerup and the small number on the Vasse may have resulted from differences in the operation of the floodgates to the two estuaries. Since 1987, the Vasse floodgates have been opened in late summer to allow seawater to enter the estuary. Prior to 1987, the Vasse regularly supported large numbers of waders in late summer.

Waterbirds were most abundant on the estuaries in late spring, when water levels were well below their maximum and were declining. This could have been related to the productivity of detritivorous inverterbates in floodplain areas as seasonal aqautic vegetation died and decayed.

Waterbirds were observed on the open water of the estuaries, on the estuary shorelines and in floodplain habitats. However, with the exception of some species such as waders, floodplain habitats were more important for foraging than the estuary waters or shore. Furthermore, food supplies in the estuaries may depend upon the productivity of the floodplain. Floodplain pools and flooded samphire were especially important for a wide range of waterbirds.

The disturbance study collected baseline data on a range of species and found that species varied greatly in their sensitivity to disturbance. The sensitivity to disturbance of some species was affected by their activity, flock size and the presence of other species. Of importance to management was the greater sensitivity to disturbance of roosting than active birds.

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INTRODUCTION

The Vasse and Wonnerup Estuaries occupy an area of approximately 1000 ha immediately east north-east of the town of Busselton in the South-West of Western Australia. They are recognised as being of great conservation value and are one of only nine sites in Western Australia listed under the Ramsar Convention on Wetlands of International Importance (Department of Conservation and Land Management 1990). The site is also listed in the Western Australian section of 'A Directory of Important Wetlands in Australia' (ANCA 1993).

Despite its importance for conservation, only a small part of this wetland system lies within land gazetted for conservation (the 46 ha Sabina Nature Reserve, reserve number A31188). Much of the wetland area is freehold land or is vacant Crown Land leased for grazing, while the deeper parts of the estuaries are not subject to the Land Act. The wetland has been greatly modified by clearing of vegetation, a long history of grazing by cattle and horses and by a drainage and flood control system. It is also under increasing pressure from urban development, particularly around the Vasse Estuary which lies on the outskirts of Busselton.

The known conservation value of this wetland area rests mainly on its importance for waterbirds. For example, it was included in the waterbird surveys conducted from 1981-1985 by the Royal Australasian Ornithologists Union (Jaensch *et al.* 1988). Seventy-eight species of waterbirds have been recorded on the estuaries, of which 26 species are listed under international conservation treaties. Numbers of waterbirds are highest in summer, when counts of 33 000 have been recorded (January 1986), and the site supports nationally significant proportions of the populations of several waterbird species (see ANCA 1993 and Watkins 1993). Many thousands of waterbirds are also present from autumn through to spring. In winter and spring, the site is of importance for breeding waterfowl, in particular the Black Swan (Lane 1990). It is also reported to be of importance for moulting ducks in late spring (ANCA 1993).

While there is no question about the importance of the wetland for waterbirds, little is known about how the waterbirds use the site. Almost all surveys of waterbirds on the estuaries have consisted of counts with opportunistic records of breeding, but little information has been collected on what wetland habitat the birds were in or what they were doing there. Such detailed information is becoming important as patterns of landuse around the estuaries change. In particular, with growth of the Busselton urban area and private ownership of much of the wetland system, future proposals for urban development on the margins of the estuaries are to be expected.

The estuaries do not have discrete boundaries as they can be 2 km wide in winter and virtually dry in summer. They include broad areas of seasonally-inundated floodplain supporting pasture, the samphires *Halosarcia pergranulata* and *Sarcocornia blackiana*, sedgelands and remnants of once-extensive paperbark *Melaleuca* spp. woodland. The importance of these floodplain vegetation types to waterbirds is unknown. Information on the importance of these areas is needed to guide management and to ensure that development in the area does not compromise the conservation value of the site.

The primary purpose of this study was therefore to gather data on patterns of usage of the two estuaries by waterbirds, with emphasis on waterbird usage of floodplain areas. In addition, the study aimed to gather information on the impact of disturbance upon waterbirds, as disturbance will become a management issue of increasing importance as Busselton expands around the wetland area. Opportunistic records on other fauna were also collected to improve the general understanding of the biota of the wetland system.

METHODS

The project began in May 1994 with an initial review of literature to determine the most appropriate approach to the collection of data. Field trips then took place over the periods: 7-11 June, 9-13 August, 3-7 October, 10-13 December 1994 and 6-8 February 1995. Data collection for the survey of floodplain usage by waterbirds and for the impact of disturbance upon waterbirds was combined on these trips.

Water levels in the estuaries were noted on each field trip at the floodgates (see below). Water levels were low in June, high in August and October but had declined greatly by December and were very low in February. Variation in water levels over the period of the study is shown in Figure 1.

Date	Vasse Estuary	Wonnerup Estuary
10 June 1994	0.22 m	-0.16 m
11 Aug. 1994	0.33 m	0.12 m
12 Aug. 1994	0.28 m	-
07 Oct. 1994	0.40 m	0.26 m
10 Dec. 1994	0.12 m	0.0 m
07 Feb. 1995	-0.09 m	-0.25 m

Waterbird Usage of Floodplains

Because of seasonal variation in water level and the gentle slope of the land around most of the wetland area, it was difficult to define the extent of the floodplains around the Vasse and Wonnerup Estuaries. While the upper limit of flooding and therefore of the floodplains is at *ca.* AHD 1.5 m, the lower limit of the floodplains is less easily recognised. Around part of the Vasse Estuary, there are lines of vegetation which mark the limits of the main basin of the estuary, but such natural disjunctions are not always present and are absent from some of the Wonnerup Estuary. Therefore, the floodplain could not be surveyed as a discrete entity. Rather, the surveys were based upon a suite of 47 sites which provided an almost total coverage of the wetland system, encompassing open areas of the estuaries as well as floodplain habitats (see Fig. 2). To examine the distribution of waterbirds across the estuaries, the sites were grouped into eight zones (see Appendix 3). These zones were not equal in size and the areas of habitat within each varied seasonally with changes in waterlevel. Therefore, only subjective comparisons of numbers of each waterbird species between zones could be carried out.

The suite of sites covered all wetland habitat types around the estuaries. Individual sites were not habitat-based but were selected for ease of access. Therefore, a site could contain several different habitats, from floodplain habitats like pasture and samphire to the open water of an estuary. The same route was taken on each survey of a site and the time and duration of each survey were recorded. Weather conditions were also noted. Site descriptions were prepared on the first survey and were updated on subsequent visits, noting vegetation type and condition, water level, grazing and any changes due to human activities.

On each survey of each site, the abundance and activity of waterbirds in different habitat types were recorded. The distinction between birds using different floodplain and estuarine habitats were thus made within the sites. For each record of a species of bird (which could be a single bird or a flock) on a visit to a site, there was therefore a record of the number observed, the habitat type and the activity in which the birds were engaged. Twenty habitat categories and 7 activity categories were recognised (Appendix 1A). Figure 3 illustrates some of the main habitat types. The field record sheet used in the study is presented in Appendix 1C.

The intention of the survey was not to count waterbirds *per se* but to record the distribution of waterbirds in terms of activity and habitat type. Recording the same birds in different sites was therefore not a problem, although birds appeared to be very site faithful over the period of a field trip. There were few instances when it was believed that the same birds were encountered in more than one site.

Most data collection took place in daylight, but night-time surveys using light-enhancing binoculars were undertaken in August and December. The aim of these surveys was to determine the abundance and activity of waterbirds at night and focussed on site 11, in samphire of the Vasse Estuary.

Note that in the floodplain usage study, the term record applies to any single observation of one or more individuals of a species engaged in a particular activity in a particular habitiat. Thus, one record may contain a large number of individuals of that species. Numbers of records and of individuals used in different analyses vary slightly, as records of some activities and in some habitats were so rare that they were excluded where they contributed nothing to, or complicated, an analysis.

Response of Waterbirds to Disturbance

A preliminary review of the literature revealed that the study of disturbance is complicated by factors such as the nature of the disturbance, the nature of the response, the species involved, the activity and age of the birds, the presence of several species of birds, season, weather and habituation. In a theoretical overview of research into the impacts of disturbance upon waders, Cayford (1993) noted that the study of disturbance is complicated by the many variables that can be involved. Therefore, he suggested that there is a need for field manipulations to establish baseline data under more or less controlled conditions. Such data would then assist in the prediction and explanation of the impacts of disturbance under "natural" conditions. This idea of field manipulations was the basis for the approach taken in the Vasse Wonnerup Project. A simple approach to the study of disturbance was therefore adopted. This approach minimized the number of variables that could influence the results and had the intention of gathering data on how different species responded to a standardized disturbance.

The bulk of data on disturbance was collected opportunistically during surveys of the floodplain usage study. As birds were approached during this study, the distance at which they altered behaviour and the distance at which they moved away were recorded using either a hand-held distance meter or by estimation and pacing, with the distance metre enabling estimation and pacing to be calibrated. The distance at which birds altered behaviour was taken as the disturbance distance and generally differed little from the distance at which the birds moved away. In addition, note was made of the time, weather, wind direction in relation to the direction of the approach, the number of people causing the disturbance, the number of birds, the number of other species present, activity and habitat. Some opportunistic records were also made when members of the public were seen to approach waterbirds. Some of these records included disturbance by an unleashed dog. Appendix 1C presents the field data sheet developed for this project.

Disturbance data were also collected by walking along the development line of the Port Geographe residential development on the northern side of the Vasse Estuary. This development line crosses several areas of samphire and seasonally-inundated pools and, when the project is complete, will be the route for a road and dual use pathway. There is therefore the potential to repeat these surveys after development and to look at the responses of birds which are becoming habituated to the presence of people.

Observations on Other Species

Records of other species of fauna were collected opportunistically and are summarized in Appendix 4.

Statistical Analyses

All data were recorded on field data sheets (Appendix 1C) and were stored on computer spreadsheets which could be easily accepted by statistical packages or converted to a database. The structure of the spreadsheets is described in Appendix 1D. Data from the usage and disturbance surveys are presented as summaries, which provide baseline information and allow for some analysis and interpretation of results, followed by more detailed statistical analyses where these could be carried out.

In the floodplain usage study, the distribution of foraging and roosting birds across habitat types was examined with the two-way Chi-square test for those species with sufficient sample sizes. The magnitude of individual Chi-square values in relation to the overall Chi-square value provided an indication of where important differences in patterns of usage existed. This analysis used the number of individuals observed as the measure of abundance.

For the most regularly-recorded species, a second approach was possible with the Log-linear test for association (in the 'STATISTICA for the Macintosh' software package). This is a non-parametric test which can be used to determine the significance of associations between variables such as the abundance of a waterbird species, its activity, habitat type; and so on. Variables of greatest interest were abundance, activity and habitat type and record data for species were organised into a three-way contingency table based on these variables.

The application of the Log-linear test is limited by sample size and the distribution of data within the cells of the contingency table. It cannot be carried out when many of the cells in the table are empty. Over half the species were recorded so infrequently that there were insufficient data for the analysis to be conducted. In some cases, the lack of data was compounded by a strong bias of the species to one habitat type, but in these cases the strength of the bias made statistical analysis unnecessary. This occurred with the Red-necked Avocet and Banded Stilt.

The Log-linear test could not be carried out before some compression and simplification of data to reduce the number of empty cells in the contingency table. Simplification of data was also needed for other statistical approaches, such as the Multiple Regression test used in the analysis of disturbance data (see below). The abundance of waterbirds was initially recorded as actual counts, but these had to be categorised (eg. 1-5 birds = 1; 6-10 birds= 2; 11-20 birds = 3; 21-40 birds = 4; up to >300 birds = 9) for the Log-linear test as this is non-parametric. Both habitat and activity categories were simplified by exclusion of rarely-encountered categories and amalgamation of similar categories, as shown in Appendix 1A.

Even with the reduction in the number of categories, the three-way analysis of abundance, habitat and activity could not be performed on some species. In these species, a two-way analysis between habitat and activity was conducted. In the case of the two-way analysis, a significant result indicated that activity was not randomly distributed across all habitats. In the case of the three-way analysis, a significant result indicates that significant associations exist and a hierarchy of models was tested to determine these associations.

The analysis of disturbance data was carried out with an ANOVAR Table and by a Multiple Regression approach (using the 'STATISTICA for the Macintosh' software package). The ANOVAR analysis tested for differences in the distance at which disturbance occurred between species, between species with the same activity, and within species for different activities. For this analysis, birds were classed as either active (foraging) or inactive (roosting or loafing) and distance data had to be log transformed because of unequal variances, as described by Zar (1974).

The Multiple Regression examined the dependence of the distance at which a species was disturbed upon the number of birds in the flock; the number of other species present; and the number of people conducting the disturbance. Separate analyses were carried out for active (foraging) and inactive (roosting or loafing) birds. Sufficient data for analysis were collected for six species only.

RESULTS

Patterns of Foraging and Habitat Selection by Waterbirds

Fifty-three waterbird species were recorded on the wetland system and 1395 records were made, each record consisting of an observation of one or more individuals of a waterbird species engaged in a particular activity in a particular habitat type. The total number of observations was 50 847. Table 1 summarizes the species, the numbers of records, the numbers of individuals seen in each field trip and the overall distribution of each species between floodplain and estuary habitats. Seventeen species or 32% of all the species recorded in the study were represented by fewer than 10 individuals and only 27 or 51% were represented by more than 100 individuals.

Waterbirds were most abundant in December with a total count of 22 660, compared with the lowest count of 5877 in February (Table 1). Thus, numbers were highest when water levels were dropping in late spring and early summer. In December, the water level in both estuaries was on the edge of fringing vegetation of the floodplain, while pools on the floodplain were shallow or dry.

Seasonal changes in abundance of most species reflected the overall pattern, although a few species displayed differences which could be related to their habitat usage of the wetland system. Similar numbers of Black Swans were seen in October and December, whereas other common waterbirds (Australian Shelduck, Pacific Black Duck, Grey Teal and Black-winged Stilt) were much more abundant in December than October. Even more distinctive was the Australasian Shoveler which was most abundant on the system in August, with only small numbers present in October, December and February. Some waders, including Red-necked Stints, Curlew Sandpipers, Red-capped Plovers and Banded Stilts, were most abundant in February when the only water in the system occurred in shallow pools in the middle of the estuaries. The White-fronted Chat appeared not to vary in abundance. The low count in August was probably associated with changes in behaviour due to breeding, while the low count in February resulted from superficial surveys of some sites which were dry and clearly supported no other waterbirds.

Despite the great abundance of waterbirds in December when water levels were low and many floodplain areas were dry, the proportion of individual waterbirds observed in floodplain habitats was often high (Table 1). Some species were represented by only a small number of individuals and little importance can be attributed to proportions based upon such small samples, although the high proportion of species such as the Australasian Grebe in floodplain habitats is almost certainly due to habitat preferences.

Some common species were regularly seen in floodplain habitats, however. Frequently-recorded species for which over *ca.* 70% of observations were in floodplain areas were: White-faced Heron, Great Egret, Australian White Ibis, Straw-necked Ibis, Yellow-billed Spoonbill, Australian Wood Duck, Greenshank and White-fronted Chat. In addition, 49.0% and 49.6% of Australasian Shovelers and Pacific Black Ducks respectively were seen in floodplain areas, while the figures for the Black Swan (30.4%) and Black-winged Stilt (30.3%) indicate only a moderate reliance on floodplain habitats. Frequently-recorded species which were seen mainly on the estuary water or shoreline with less than 25% of individiduals on floodplain habitats were: Australian Shelduck, Grey Teal, Eurasian Coot, Red-necked Stint, Curlew Sandpiper, Red-capped Plover, Banded Stilt, Red-necked Avocet and Silver Gull. Waders in particular seemed to favour the waters and shore of the estuaries.

For all species combined, the majority of individuals were observed on the estuary waters and shore but the floodplain habitats were disproportionately important for foraging (Figure 4). In floodplain habitats, 74% of all observations were of foraging birds, compared with 37% of all observations on the estuary waters and shore.

More detail on habitat preferences and patterns of usage of all waterbird species is given in Table 2. This presents the number of birds of each species in each habitat class and the proportion of those birds which were active (foraging). For example, White-faced Herons were observed mainly in estuary waters, pools on the floodplain, flooded samphire and on pasture and were usually foraging in these habitats. The small number observed on the estuary shore was dominated by inactive or roosting birds. The numbers of birds in different habitats cannot be directly compared as the areas of the habitats vary. However, habitats such as pools and flooded samphire were not greatly larger in area than other habitats but supported much larger numbers of White-faced Herons, suggesting that they are particularly important for this species.

While caution must be exercised when comparing numbers of waterbirds in different habitats, the distribution of numbers of active and inactive birds can be compared between habitats with the Two-way Chi-square test. In the case of the White-faced Heron, 92% of the large Chi-square value was due to the unexpectedly low proportion of foraging birds but high proportion of roosting birds along the estuary shoreline. The Australian Pelican had a similar significant bias towards roosting on the estuary shore.

The Australian White Ibis and Straw-necked Ibis were recorded in all habitats except dry samphire. The Straw-necked Ibis was particularly abundant on pasture (54.4% of individuals), whereas the White Ibis was abundant in flooded samphire (50.3% of individuals), with only 15.8% of birds on pasture. The majority of individuals were active except on the estuary shore, with 77% and 82% of the Chi-square values for the White Ibis and Straw-necked Ibis respectively being due to the high proportion of roosting birds on the shoreline. The Yellow-billed Spoonbill was more restricted in distribution than the ibis species with 86.1% of individuals in pools or flooded samphire, and the only inactive birds being three individuals on the estuary shore.

The Black Swan, Australian Shelduck, Pacific Black Duck, Grey Teal and Australasian Shoveler showed broadly similar patterns of distribution and usage. In particular, all appeared to be using the estuary shore for roosting but to be foraging elsewhere. The Black Swan was most abundant in estuary waters but it was the smaller samples in pools and flooded samphire which were dominated by foraging birds. The Pacific Black Duck had a similar pattern of abundance and foraging, whereas the Australasian Shoveler displayed a very strong bias towards foraging in pools (mostly in samphire). The high proportion of foraging Shovelers on pools contributed 60% to the significant Chi-square value, whereas in all other swan and duck species it was the proportion of roosting birds on the estuary shore which made the greatest contribution to Chi-square values.

The Australian Shelduck displayed the highest proportion of active birds on estuary waters compared with other waterfowl, but the small sample of birds on pasture consisted almost entirely of active birds. The Grey Teal was the most abundant waterbird with the greatest proportion of active birds on pools. The proportion of active birds in flooded samphire, however, was low.

The Australian Wood Duck differed from other ducks in being observed mainly on pasture although some birds did roost on the estuary shore. The Wood Duck was also regularly seen around farm dams in the region.

The Greenshank was the most catholic of the waders in terms of habitat selection and the greatest numbers were observed on pools and in flooded samphire. Few roosting Greenshanks were observed but all were on the estuary shore or in shallow waters of the estuary. This was not statistically significant, however, and the Greenshank was the only waterbird species that was regularly recorded and did not show significant differences in habitat usage. Red-necked Stints were only observed on the estuary shore while Curlew Sandpipers were observed on the estuary shore and in shallows of estuary waters. Most Red-capped Plovers were observed foraging on the estuary shore but one flock of 200 birds was observed foraging on grazed pasture. The absence of roosting Red-capped Plovers on pasture contributed 72% to the Chi-square value.

The Black-winged and Banded Stilts were similar in their habitat usage although a greater proportion of Black-winged Stilts than Banded Stilts (29.5% compared with 19.7%) used pools and flooded samphire. Roosting birds were found mainly on the estuary shore and this bias contributed 87% and 92% of the Chi-square values of the Black-winged and Banded Stilts respectively. The Red-necked Avocet differed in that it foraged and roosted primarily on the estuary waters. It was the most estuary-dependent of the frequently-recorded species.

The White-fronted Chat was the only frequently-recorded species to regularly use dry samphire, although 40% of the 25 observations of the Little Grassbird were in this habitat. The White-fronted Chat also used the estuary shore, but the 36 observations in this habitat included 16 birds drinking from a freshwater soak.

The habitat usage of the most frequently-recorded species was broken down by field trip to determine if any seasonal patterns could be observed (Table 3). Changes in the distribution of some species across the habitats reflected changes in water level and availability of habitats. For example, the White-fronted Chat was recorded mostly in flooded samphire when water levels were high (June, August and October) and in dry samphire when water levels were low (December and February). Similarly, a high proportion of Black-winged Stilts was observed on pools and in flooded samphire when water levels were high in August and October, with low proportions in June and December. In some other species, seasonal changes were more complex.

Black Swans were recorded mainly (83.8% of observations) in floodplain habitats in June but in later field trips most birds were on the estuaries (28.1%, 23.6% and 7.4% on floodplains in August, October and December respectively). This result in August and October was probably due to the shift of birds onto the estuaries when chicks had hatched, while the low value in December can be attributed to low water levels. In all field trips, the proportion of birds that were foraging was higher on the floodplains than on the estuaries, although the estuaries became important for foraging in December when the floodplain was mostly dry.

The Australian Shelduck displayed a similar seasonal swing towards the estuaries. For example, 95.6% of observations in June were on floodplains even though water levels were low, while 38.9% of observations in October were on floodplains when water levels were high. Sample sizes of Australian Shelducks were too variable to be confident about changes in the proportion of foraging birds in different habitats, but there appeared to be an increase in dependence upon the estuaries for foraging associated with low water levels in December and February.

The Black Duck also displayed a decline in the proportion of birds on the floodplains with rising waterlevels from June (76.6%) to October (59.0%). The proportion of birds on floodplains in August was particularly low (45.2%). Floodplains were important for foraging in all seasons with an increase in the proportion of foraging birds on the open water of the estuaries with low water levels in December.

The Grey Teal resembled the Black Duck in distribution of numbers and activities, except that it was the only species to consistently use flooded samphire for roosting. The Australasian Shoveler also roosted in flooded samphire in August, but numbers of this species were generally too low to clearly establish patterns of usage. It was more dependent on pools on the floodplains for foraging than other species.

Log-linear analyses were carried out on the most frequently recorded species to further examine relationships between abundance, habitat and activity. Many species could not be tested as the Log-linear test used record rather than observation data and there were too few records for most species. These tests found significant two-way associations between habitat and activity for the Black Swan ($X^2 = 49.23$, $p < 0.001$), Pacific Black Duck ($X^2 = 114.62$, $p < 0.001$) and Grey Teal ($X^2 = 40.13$, $p < 0.001$), due to some activities being more prevalent in some habitats than others. These results reinforce those of the Chi-square tests. It is important to note that the Log-linear analyses for these species did not find significant associations between either abundance and habitat or abundance and activity. This indicates that the number of birds in a record was independent of habitat or activity. With the Australian Shelduck, however, abundance was significant in a three-way association with habitat and activity ($X^2 = 336.1$, $p < 0.0001$). This suggests that flock size was greater in some habitats than others and with some activities than others. Australian Shelducks, more than other waterfowl, were commonly recorded in pairs and small groups when foraging on pasture and pools, but in large flocks when foraging or roosting on the estuary and estuary shore.

Observations on Nocturnal Foraging by Waterbirds

Nocturnal observations were restricted by the availability and effectiveness of equipment and few quantifiable data were obtained. Despite this, some subjective observations were made and the general impression gained was that waterbirds were foraging extensively at night. Site 11 was surveyed in daylight and at night on 10 August 1994 and the following numbers of birds were seen, with the nocturnal counts being approximations only.

	Diurnal	Nocturnal
Little Pied Cormorant	1	-
White-faced Heron	2	-
Great Egret	1	-
Black Swan	3	2
Australian Shelduck	1	3
Pacific Black Duck	24	10
Grey Teal	-	4
Australasian Shoveler	10	10
Marsh Harrier	1	-
Purple Swamphen	-	1
Black-winged Stilt	3	6
(Total	46	36)

Numbers in daylight and at night were similar but it is suspected that more birds were present at night than were recorded, as visibility amongst flooded samphire made identification and counting very difficult. The Australasian Shovelers in particular may have been more abundant than indicated, as they were heard rather than seen.

Distribution of Waterbirds on the Estuary System

While the survey zones were unequal in size, making direct conparisons of waterbird numbers difficult, it was apparent that waterbirds were unevenly distributed on the estuary system (Table 4). Zones 3 and 4 around the Vasse Estuary (see Appendix 3 and Figure 2) supported the largest numbers of most species and the greatest total numbers of individuals. Although these zones were large and encompassed much of the Vasse Estuary, several species were disproportionately abundant in them relative to the size of the zones. There were approximately as many Grey Teal seen in Zone 3, for example, as on the whole of the Wonnerup Estuary (4872 compared with 4602). More extreme examples included the Pacific Black Duck, with 3221 individuals in Zone 4 compared with only 968 individuals on the Wonnerup

Estuary, and the Yellow-billed Spoonbill with 110 seen in Zone 2 and 98 in Zone 3, compared with only 13 seen on the Wonnerup Estuary. In contrast to these species, the Black Swan appeared to be more evenly distributed across the wetland system, with numbers in the different zones roughly proportional to the areas of the zones.

Despite the importance of several zones within the Vasse Estuary, a few species were most abundant in parts of the Wonnerup Estuary. In particular, many species of waders were largely or completely confined to Zone 7. These included abundant species such as the Red-necked Stint (all of 1292 individuals in Zone 7), Curlew Sandpiper (all of 260 individuals in Zone 7), Red-capped Plover (Zone 7 contained 76% of 564 individuals) and Banded Stilt (Zone 7 contained 65% of 3083 individuals). Zone 7 was also the only zone where four infrequently-observed waders were recorded.

Breeding Observations

Breeding observations are summarized in Tables 5 and 6. Most observations consisted of a group of dependent young. Exceptions were one observation of an Australasian Shoveler (assumed to have a nest in dense grass of site 18 because of its behaviour), and Black Swan nests with eggs in sites 9, 25 and 30-34. The locations of swan nesting mounds were not generally recorded but 13 mounds were built (although not used) in grazed samphire in Zone 7. Some of these nests were old (pre-1994) but all had been added to in 1994. Of all species, the Black Swan was recorded breeding most frequently with most broods observed on the Wonnerup Estuary. Of 42 breeding records of the eight other species, only three records were on the Wonnerup Estuary and most were confined to Zones 1, 2 and 4 on the Vasse Estuary. With the Australasian Grebe and Eurasian Coot, breeding was largely confined to the freshwater pools surrounded by pasture of Zone 1. Most breeding records of the Australian Shelduck were in Zone 4, which covered a large area, but most records of the Pacific Black Duck were in the small Zone 2. The density of Black Duck broods was particularly high along an undisturbed shoreline of sedges and tall grass under paperbark trees. Six broods were found along less than 200 m of shore.

Pools within floodplain vegetation were an important location for breeding records of most species (Table 6). The White-fronted Chat, however, nested in both dry and flooded samphire, while the greatest number of Black Duck broods were located in flooded sedges.

Disturbance

Disturbance events were recorded for 25 species with the most events recorded for the Black Swan, Australian Shelduck, Pacific Black Duck, Grey Teal and Black-winged Stilt (Table 7 and figure 5). For all species where both active and inactive birds were recorded, there were significant differences in the distance at which disturbance occurred between species ($F_{9, 177} = 9.92$, $p < 0.001$), between species when engaged in the same activity ($F_{1, 177} = 10.59$, $p < 0.01$) and between inactive and active birds irrespective of species ($F_{9, 177} = 1.94$, $p < 0.05$). The difference between species when engaged in the same activity indicates that the overall difference between species was not due to differences in the proportion of active and inactive birds in the sample of each species. The difference between active and inactive birds irrespective of species indicates that a common relationship exists between the activity of a bird and the distance at which it is disturbed, regardless of species, although this relationship might not apply to all species.

For most species for which data were available, the distance at which disturbance occurred appeared greater for inactive than active birds. Comparisons of mean disturbance distances for species with adequate data in both activity classes (more than 3 records in each class), found the distance to be significantly greater for inactive than active birds with the Australian Shelduck ($T = 1.87$, $p < 0.05$), Grey Teal ($T = 2.11$, $p < 0.025$) and Black-winged Stilt ($T = 4.54$, $p < 0.001$). No significant differences were found with the Black Swan ($T = -1.038$) and Pacific Black Duck ($T = -0.77$).

Differences between species were sometimes great (Table 7). The Grey Teal, for example, was more sensitive to disturbance than the Australian Shelduck and Pacific Black Duck, while the Black-winged Stilt could sometimes be approached to within 20 m. The data suggest that differences may exist between similar species such as the Australian White and Straw-necked Ibises, but additional records would be valuable.

The distance at which disturbance occurred was independent of flock size, the number of other species present and the number of people approaching the birds for the Australian White Ibis, Black Swan and Pacific Black Duck (Table 8). The response to disturbance of inactive Australian Shelducks and active Grey Teal was also unaffected by flock size, the presence of other species and the number of people approaching. However, active Australian Shelducks, inactive Grey Teal and active Black-winged Stilts were affected by at least one of these variables (Table 8). For active Australian Shelducks, the distance at which disturbance occurred was positively linked to flock size. Thus, a large flock of active Australian Shelducks would be expected to be disturbed at a greater distance than a small flock. The same positive relationship between flock size and distance at disturbance was found with inactive Grey Teal. For active Black-winged Stilts, however, the distance at which disturbance occurred was positively linked to the number of other species present only. Black-winged Stilts were generally tolerant of disturbance but would take flight if another species took flight. This sort of interaction between species was observed on several occasions but the responses and movements of birds were complicated and difficult to quantify. On one occasion, a mixed flock of roosting Grey Teals, Pacific Black Ducks, Australian Shelducks and White-faced Herons, with Black-winged Stilts foraging in adjacent shallows, took flight at an estimate 170 m. This appeared to be initiated by the teals. All ducks left the area, but the herons returned and the stilts flew closer to the source of disturbance and resumed feeding!

DISCUSSION

Patterns of Foraging, Habitat Selection and Distribution of Waterbirds on the Estuary System

The numbers of waterbirds recorded on the Vasse and Wonnerup Estuaries during this project were consistent with numbers previously reported (eg. Jaensch *et al.* 1988). The Cattle Egret had not been reported for the site previously while the maximum count of White-faced Herons (450 in December 1994) exceeded the previous highest count for this species in the South-West (Jaensch *et al.* 1993).

Previous studies (eg. Jaensch *et al.* 1988) recognized that waterbird abundance on the Vasse Wonnerup Estuary system peaks in late spring/early summer. This was also found in 1994 and peak abundance of waterbirds overall occurred when water levels were declining. This could be related to the availability of food. Crome (1986) discussed the importance of changes in water level and particularly the effect of declining water level on the availability of food for waterbirds. He found that breeding of waterbirds coincided with a rise in water level which followed a fall, and even with a fall in water level. This contrasts with the traditional association between breeding by Australian waterbirds and a rise in water level *per se* (Frith 1974). According to Crome (1986), declining water levels result in the death of aquatic vegetation which supports high populations of the detritivorous larvae of midges (*Chironomus* spp.). These are food for young waterbirds and may be more important for adult waterbirds than has been previously believed (Briggs *et al.* 1985). A rise in water level shortly after a fall results in the inundation of dead, aquatic vegetation, creating especially favourable conditions for midge larvae. Crome (1986) points out that his observations are consistent with a wide body of information collected in the northern hemisphere relating wetland productivity to declining and rising water levels.

The coincidence of large numbers of waterbirds on the estuaries with low and declining water levels could therefore be explained by an increase in the abundance of midges, this abundance being due to the annual death of aquatic vegetation. In December, groups of waterbirds, including Grey Teals and Greenshanks, were observed apparently feeding on emerging midges on floodplain pools and the shallows of the estuaries.

Another factor that could have affected the abundance of waterbirds on the estuaries when water levels were low and falling was the accessibility of aquatic invertebrates. Aquatic invertebrates such as Cladocera ("daphnia") were abundant amongst flooded vegetation and might have become readily accessible only when the water level dropped below the level of most fringing vegetation. It must be recognized, however, that at least part of the increase in waterbirds on the estuaries in early summer was due to the movement of birds from temporary wetlands in the region.

Species which were not at their most abundant in December included the Australasian Shoveler, which was found to forage in flooded samphire and in floodplain pools to a greater extent than other species. It became scarce on the wetland system when such habitats became scarce due to falling water levels. The Yellow-billed Spoonbill was also most abundant when water levels were high and foraged estensively in pools and flooded samphire. It foraged also in the estuaries close to flooded vegetation and was scrace when the water dropped below these habitats. Some waders, such as the Banded Stilt and Red-necked Stint, were abundant only when water levels were low and the estuaries consisted of extensive shallows or mud-flats.

Despite the large numbers of waterbirds present in December when there was little floodplain habitat available, a large proportion of the total observations of many species of birds were on floodplain habitats. The activity of almost all bird species for which there were sufficient data was unevenly distributed across habitats. High proportions were recorded active (foraging) in floodplain habitats, especially pools and flooded samphire, while the estuary shore was host to a disproportionately high proportion of inactive (roosting) birds. This pattern, particularly the high proportion of roosting birds on the estuary shore, was also found on the Leschenault Estuary by Ninox Wildlife Consulting (1989). Even with species where the majority of observations were on the estuary waters, the proportion of active birds on the floodplain was often greater. Thus, the large numbers on the estuary may have been related to the juxtaposition of floodplain habitats. While several species foraged on the open water of the estuaries, few species foraged primarily in this habitat and the Red-necked Avocet was the only frequently-observed species to do so.

Seasonal variation in distribution and activity in habitats displayed an inconsistency with changes in water level in some species. In the Black Swan, Australian Shelduck, Pacific Black Duck and Grey Teal, the proportion of birds observed in floodplain habitats declined as water levels rose in winter and early spring. This may be related to Crome's (1986) observations of an increase in aquatic invertebrates in recently flooded areas. The aquatic invertebrates feed on the dead and decaying aquatic vegetation that grew during the previous episode of flooding. Therefore, there may have been a flush of food for waterfowl when the floodplains were first inundated in early winter.

Across the survey zones of the estuaries, the greatest numbers of birds were recorded where the floodplain is subject to the least disturbance. Numbers of ducks in particular were high on the Vasse Estuary and adjacent floodplains where the floodplain vegetation included samphire, sedgelands and paperbarks where grazing was restricted. Numbers of ducks were low on the Wonnerup Estuary where grazing occurs around most of the shoreline and into the estuary.

The abundance of most species of waders followed a different pattern from that seen with ducks, as most wader species were observed in large numbers on the Wonnerup Estuary only. This could be due to any one or a combination of a number of factors. Grazing could alter the aquatic invertebrate fauna to species favoured as prey by waders. The low numbers of ducks, perhaps because livestock disturb roosting waterfowl, could also result in there being more aquatic invertebrates for waders to feed upon when water levels are very low. Another factor could be differences in the operation of the floodgates of the Vasse and Wonnerup Estuaries. Since 1987, the Vasse floodgates have been opened in late summer to release seawater into the Vasse Estuary to prevent fish-deaths, and this may adversely affect the aquatic invertebrate fauna. The main basin of the Vasse Estuary connects directly to the floodgate and therefore the seawater can spread throughout the estuary. The Wonnerup floodgates are not normally opened and even if they were, the main basin of the Wonnerup Estuary is isolated from the floodgates by a shallow channel. In February 1995, the Wonnerup Estuary contained an isolated pool that would have been unaffected by the operation of the floodgate.

Unfortunately, data on the Wonnerup Estuary were not routinely collected during the surveys of Jaensch *et al.* (1988) so it is not known if the Wonnerup Estuary was regularly favoured over the Vasse Estuary by waders in the early 1980s, before the practice of releasing seawater into the Vasse Estuary began. However, the counts of waders presented by Jaensch *et al.* (1988) for the Vasse Estuary are much higher than were found in 1994/'95. These were the maximum counts obtained from 61 surveys over 4 years, but examination of the complete, unpublished data (including some data collected after the publication of Jaensch *et al.* (1988), all unpublished material held by WARAOU and WADCALM) indicates that the Vasse Estuary consistently held large numbers of waders in late summer/autumn each year. The numbers of Red-necked Stint, Curlew Sandpiper, Sharp-tailed Sandpiper and Red-capped Plover (pooled) were: January 1982 - 1000 (identified as waders only, count incomplete); February 1983 - 1800; February 1984 - 2607; February 1985 - 1100; March 1986 - 1345; March 1987 - 140 (count incomplete); March 1988 - 200 (count incomplete). The low counts in 1987 and 1988 coincided with the beginning of the practice of opening the Vasse floodgates to allow seawater to enter the system. Even these counts, however, are much higher than the numbers of these species seen in February 1995 on the Vasse Estuary (a total of 9 birds; all Red-capped Plovers).

The distribution of breeding records of ducks reflected the distribution of ducks, with almost all breeding records on the Vasse Estuary. The greatest concentration of breeding by ducks was along an ungrazed shoreline of sedges under paperbarks. The scarcity of duck breeding on the Wonnerup Estuary suggests that grazing the estuary shore and floodplain makes conditions unsuitable for ducks. In contrast, Black Swans are able to breed where grazing occurs, although most breeding was on islands or on the ungrazed eastern end of the Wonnerup (Swan Lake). Nest-mounds were constructed by Swans on grazed shorelines but were not used.

Disturbance

The study of disturbance aimed to gain an understanding of the sensitivity of different species and the importance of factors such as the activity of the birds, the presence of other species and the intensity of the disturbance. Some other studies have looked at the sensitivity of different species of birds and at their sensitivity to different sources of disturbance (including pedestrians, dogs, shooters, bait-diggers, off-road vehicles, helicopters and military aircraft), but the importance of activity and of the presence of other species has received little attention.

Many studies in the literature have tried to assess the impact of disturbance upon waterbird populations, rather than looking at disturbance *per se* (eg. Kirby *et al.* 1993). This general approach has arisen because it is believed that disturbance can adversely affect populations by reducing survival and recruitment. Owen (1993), however, reviewed available information and was unable to find clearly documented cases of waterbird populations declining as a result of disturbance. This was attributed to the complexity of variables affecting populations, making it impossible to isolate disturbance as a factor affecting populations in the long term. There were many examples of short-term effects where birds altered their foraging behaviour and use of roosting sites as a result of disturbance. Davidson and Rothwell (1993) noted that waterbirds could compensate for disturbance to some degree, such as by increasing rates of food intake, but that some documented impacts would be expected to have long-term effects. For example, disturbance of waterfowl preparing for migration has been shown to reduce the numbers of birds at staging areas and to adversely affect their accumulation of energy reserves. Davidson and Rothwell (1993) also report that duck-shooting is banned in parts of Europe during severe weather. At such times, the birds are unable to feed and therefore rely on stored energy, and it is recognised that disturbance can lead to the depletion of that stored energy. The breeding success of some waders (Pienkowski 1993, Schultz and Bamford 1987) and terns (Hill *et al.* 1988) has been reported to be adversely affected by disturbance, and this has been implicated in the decline of regional populations.

It has been found to be difficult to generalize about the impact of disturbance. Impacts are extremely variable, with accounts of species displaced from a site for long after a disturbance event, to species which return almost immediately. The type of disturbance, the species involved and their familiarity with that form of disturbance can affect the result. Minimal disturbance with rapid return when the disturbance ceased was found at Herdsman Lake, Perth, when model power boats were raced in an area frequented by waterbirds (Bamford *et al.* 1990). In contrast, fishermen dispersed over an entire mudflat at low tide were found to displace waders from the entire area (Townshend and O'Connor 1993).

The results of the disturbance study on the Vasse and Wonnerup Estuaries recorded baseline responses of waterbirds to controlled disturbance at a location where the birds have had little opportunity for habituation. Thus, species such as the Black Swan and Pacific Black Duck were more sensitive to disturbance than would be expected on an urban lake, where both can be readily approached. The Grey Teal was more sensitive to disturbance than these species, which may explain its low numbers on sites regularly used by people.

The difference in sensitivity to disturbance between active and inactive birds of several species is important and has implications for management (see below). The difference is probably adaptive as birds that are active may be able to take evasive action more quickly than birds that are inactive. Thus, inactive birds need to become alert and alter their behaviour at a greater distance from a potential threat than active birds. Only the Pacific Black Duck and Black Swan were not more sensitive to disturbance when inactive than when active. In both cases, many of the foraging birds were observed on grazed samphire and pasture and responded to disturbance by walking back to the water. Inactive birds, particularly Black Swans, tended to be at the water's edge or in the shallows, so had a short distance to go to the safety of the open water.

The effect of flock size upon the distance at which active Australian Shelducks and inactive Grey Teal responded to disturbance may be linked to the probability of the presence of "nervous" birds. A large flock is more likely to contain a "nervous" individual who will set the whole flock off. Note that there was no significant association between number of birds in a record and activity except with the Australian Shelduck, so the greater sensitivity of inactive birds to disturbance cannot be explained by the increased likleihood of "nervous" individuals being present.

The effect of other species upon the response of Black-winged Stilts to disturbance suggests that more "nervous" species can set off species that would otherwise not be alarmed by a disturbance. The Grey Teal was responsible for this in many cases but insufficient data were collected with most species for this to be apparent.

The intensity of the disturbance was assumed to vary because from one to three people approached the birds, but this did not affect the distance at which birds were disturbed. This was probably because the people stayed within a few metres of each other. Townshend and O'Conner (1993) found that single people created a "zone of exclusion" (which varied in size between species) around them within which birds would not remain, and that people scattered across an area efectively excluded all birds. The disturbance distance of a species of bird might be the same when approached by a single person as when approached by people spaced apart, but the multiple approach might have a synergistic effect. Thus, when approached by several people from different angles, birds might be disturbed at a greater distance than when approached by the same number of people in a group. Even if the multiple approach does not disturb birds at a greater distance than the single approach, it is important to note that the total area of disturbance will be greater.

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

While the Vasse and Wonnerup Estuaries may be viewed as a single site, waterbirds vary in their patterns of distribution and usage on them. The Vasse Estuary supports more of most waterbird species than the Wonnerup with the exception of waders. The importance of the Vasse probably lies with its extensive areas of undisturbed floodplain habitat, used by waterbirds for both foraging and breeding. The exception with waders may be related to the direct or indirect impact of grazing on aquatic invertebrates in the Wonnerup, to the release of seawater into the Vasse in late summer, or to both.

Waterbirds occurred on both the open waters of the estuaries and on the floodplains but the floodplains were, in general, more important for foraging. Furthermore, the peak in abundance of waterbirds on the estuaries could have been linked to the abundance of invertebrates on the floodplains when water levels were falling. Thus, the ability of the estuaries to support waterbirds may depend upon the productivity of the floodplains to an even greater extent than indicated by the data. The distribution of waterbirds on the estuaries is consistent with large areas of undisturbed floodplain producing the greatest amount of food. The implications of this are that the large areas of undisturbed floodplain around the Vasse Estuary are crucial to maintaining the abundance of waterbirds on the site. It is probable that both the size of these floodplains and the lack of grazing are important. Shorelines of undisturbed sedges beneath paperbark trees are especially favoured for breeding by ducks, while undisturbed samphire is important for foraging by a wide range of waterbirds. Samphire is able to recover rapidly from the effects of grazing, as observed during the five years following the removal of horses from the northern side of the Vasse (pers. obs.).

The disturbance studies indicate the importance of providing roosting areas free from disturbance, with the estuary shore (especially bare shore and bare islands) being the principle areas for roosting. Important roosting sites should be identified and afforded protection in any proposed developments. The respose of species sensitive to disturbance, such as the Grey Teal, suggests that a minimum distance of *ca.* 200 m between roosting sites and sources of disturbance is appropriate. The creation of roosting sites, such as islands, could also be considered. Other studies (see literature cited) suggest that forms of disturbance which might be significant on the Vasse Wonnerup system in the future include pedestrians and unleashed dogs.

Disturbance dispersed over large areas is more disruptive than disturbance concentrated in small areas. Waterbirds become habituated to localized disturbance but react naively when disturbance moves into areas where it does not normally occur. Thus, confining disturbance to pathways and specific areas is desirable.

On the basis of this study, a number of recommendations for future work should be considered.

i). Investigate aquatic invertebrate abundance, particularly as water levels fall in late spring, and look for evidence of flushing of invertebrates from the floodplain into the open water of the estuaries.

ii). Investigate aquatic invertebrates in late summer, particularly to compare the Vasse and Wonnerup Estuaries and to examine the impact of allowing seawater to enter the system. It may be possible to vary the timing of opening the Vasse floodgates so that deleterious effects upon aquatic invertebrates and waders do not occur. For example, if the floodgates are opened when the salinity of the estuary is the same as that of the ocean, then invertebates would not be exposed to the osmotic shock that may occur currently. However, invertebrate abundance may depend upon the estuary water becoming hypersaline in late summer.

iii). The distribution and activity of waterbirds at night received inadequate attention and should be investigated. This could be achieved through observations on a set of readily accessible sites in both daylight and at night. Work at the RGC Wetlands Centre by Mr F. Doyle (pers. comm.) suggests that some sites may be very important for waterbirds at night. This may be due to vertical migration of aquatic invertebrates at night.

iv). Monitor waterbird numbers in conjunction with the loss of floodplain habitat on the Vasse Estuary and in late summer on the Vasse and Wonnnerup Estuaries with reference to the operation of the floodgates.

v). More extensive and intensive work on the impact of disturbance upon waterbirds is needed. This could investigate aspects of different sources of disturbance likely to be significant on the Vasse Wonnerup Estuaries and other urban and near-urban wetlands. More baseline data are also needed on many species. Such studies could provide information valuable in the development of guidelines for the layout of pedestrian and dual-use pathways. Information on habituation to disturbance could be gained by monitoring impacts of disturbance with increasing human usage around the Vasse Estuary. An important site for this would be the edge of the Port Geographe Development where pre-development data have been collected.

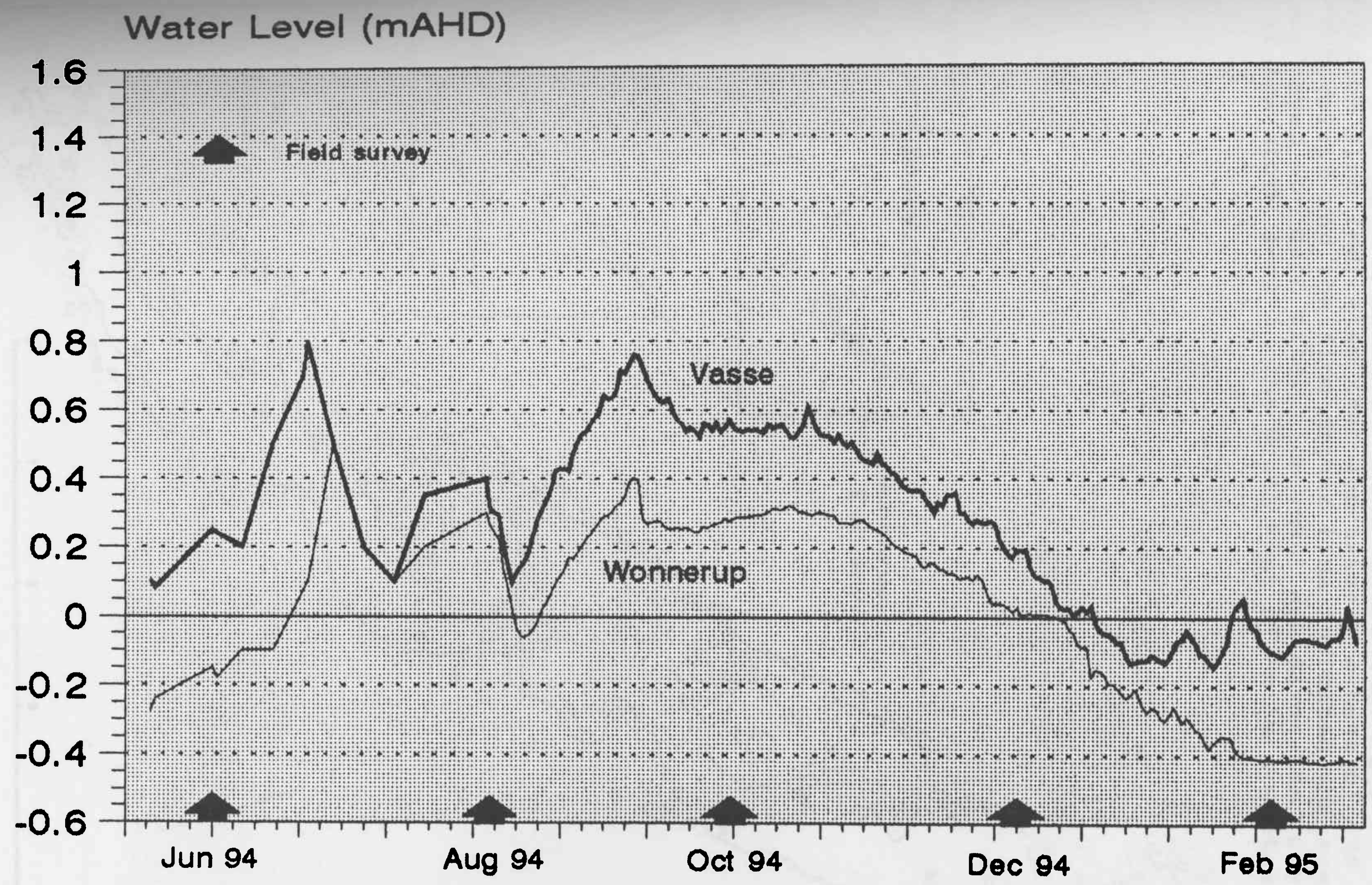
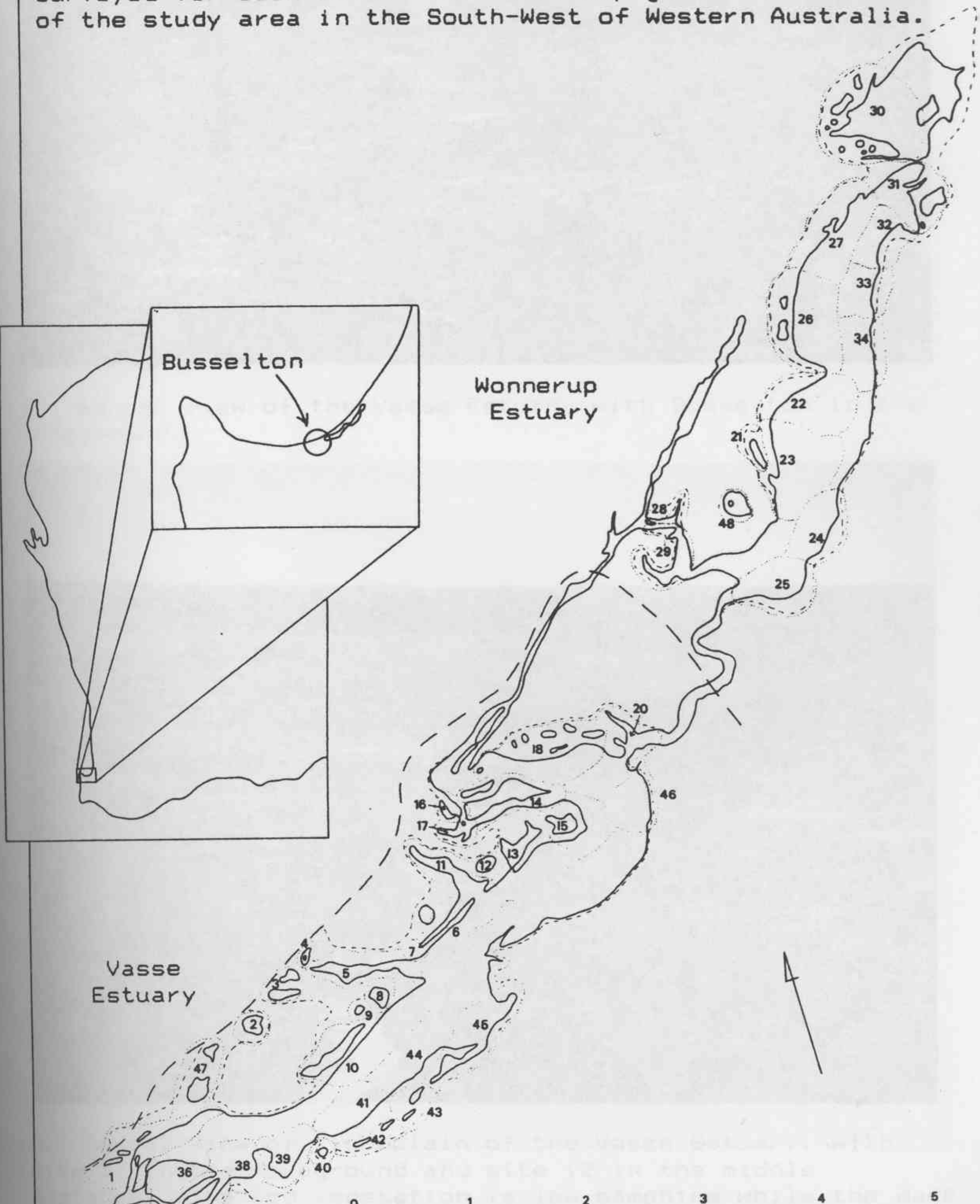


Figure 1. Water level variation of Vasse & Wonnerup Estuaries, 1994-95.

FIGURE 2. The Vasse and Wonnerup Estuaries, indicating the locations of study sites (numbers 1-48; note there there was no site 19). The solid line gives the approximate extent of open water when water levels are high, the fine broken line indicates that approximate extent of the floodplain and the fine dotted line indicates the area surveyed for each site. The inset map gives the location of the study area in the South-West of Western Australia.



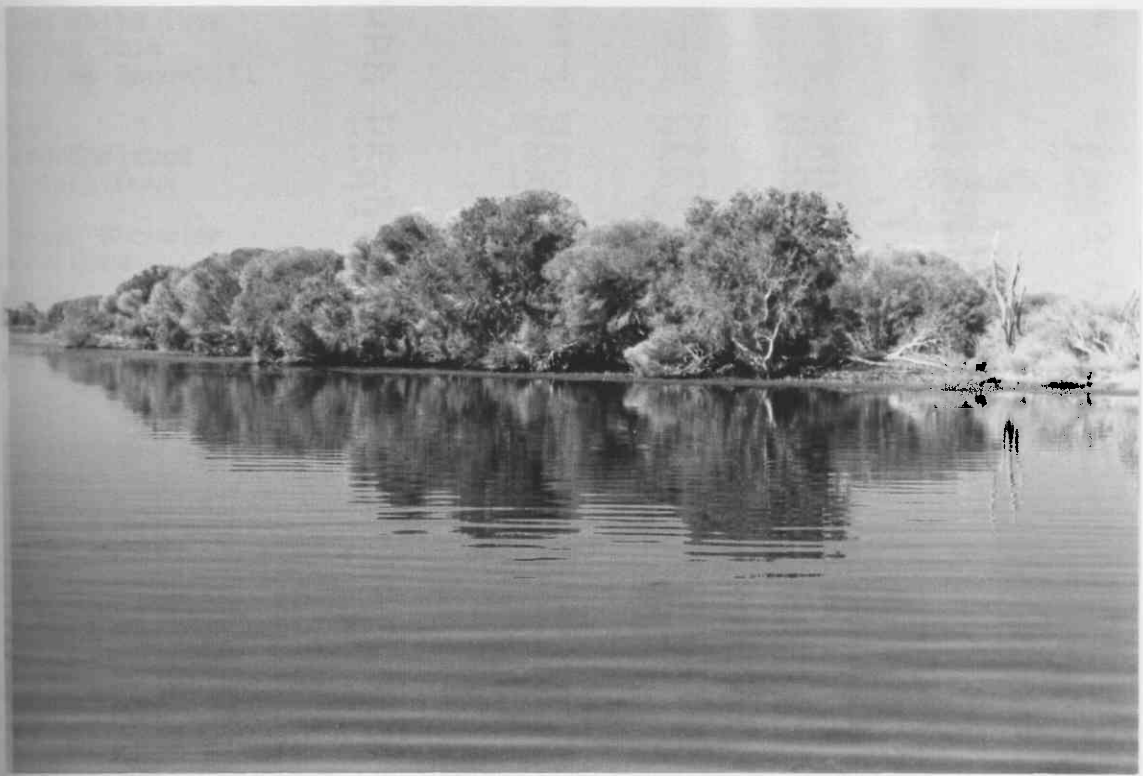
1. Aerial view of the Vasse Estuary with Busselton in the foreground.

2. Aerial view of floodplain of the Vasse Estuary, with site 11 in the foreground and site 12 in the middle distance. The red vegetation is low samphire while the dark grey-green vegetation encircling site 12 is tall samphire.

3. Dry, low samphire (site 1).

4. Flooded, low samphire.

5. Horses grazing on the shoreline of the Wonnerup Estuary (site 23).



6. A remnant *Melaleuca* thicket on the shoreline of the Vasse Estuary (site 36).

Table 1. Summary of waterbird observations on the Vasse and Wonnerup Estuaries, giving the number of records of each species, the count of each species (adults only) in each field trip and the percentage of the total count of each species observed in floodplain habitats (% FP) in italics. Floodplain habitats were all habitats except open water, shallows and shore of the estuaries. + indicates that a species was observed but not counted.

		Total count in:					
Species	N Records	June	Aug	Oct	Dec	Feb	% FP
Hoary-headed Grebe	9	+	21	30	50	-	*1.0*
Australasian Grebe	5	1	9	10	2	-	*86.0*
Australian Pelican	16	+	12	3	125	-	*4.2*
Darter	1	-	+	1	+	-	*0.0*
Pied Cormorant	5	-	-	12	89	-	*0.0*
Little Black Cormorant	11	2	62	60	13	-	*2.2*
Little Pied Cormorant	19	2	44	25	40	1	*2.5*
White-necked Heron	9	-	-	2	13	-	*73.3*
Little Egret	1	-	1	-	1	-	*50.0*
White-faced Heron	108	185	39	96	450	43	*79.4*
Great Egret	49	6	33	25	27	-	*69.8*
Cattle Egret	1	-	2	-	-	-	*100.0*
Glossy Ibis	1	-	1	-	-	-	*100.0*
Australian White Ibis	32	15	22	30	129	8	*77.0*
Straw-necked Ibis	37	+	749	8	739	-	*75.3*
Yellow-billed Spoonbill	27	14	141	27	18	2	*88.1*
Black Swan	143	982	1227	2028	1784	3	*30.4*
Australian Shelduck	178	228	209	1754	4395	1209	*23.2*
Pacific Black Duck	221	1780	595	1523	2751	150	*49.0*
Grey Teal	129	2007	2645	1376	7105	294	*19.3*
Australasian Shoveler	44	59	488	68	17	10	*49.6*
Pink-eared Duck	2	-	100	-	100	-	*0.0*
Hardhead	2	-	-	20	40	-	*11.7*
Maned Duck	9	-	33	78	53	-	*78.0*
Musk Duck	5	+	11	7	-	-	*0.0*
Osprey	1	1	-	-	-	-	*1*
White-bellied Sea Eagle	4	-	1	1	1	1	*50.0*
Marsh Harrier	12	2	2	6	3	-	*80.0*
Buff-banded Rail	1	-	1	-	-	-	*100*
Spotless Crake	2	-	1	2	-	-	*100*
Dusky Moorhen	1	-	1	1	-	-	*50.0*
Purple Swamphen	8	1	6	6	1	-	*100*
Eurasian Coot	7	1	192	116	+	-	*9.4*
Wood Sandpiper	1	-	-	15	-	-	*100*
Common Sandpiper	2	-	-	1	-	1	*0.0*
Greenshank	38	10	22	34	65	18	*71.8*
Red Knot	1	-	-	-	4	-	*0.0*
Sharp-tailed Sandpiper	3	-	-	3	53	-	*5.4*
Red-necked Stint	8	2	-	-	70	1230	*0.0*
Long-toed Stint	1	-	-	-	1	-	*0.0*
Curlew Sandpiper	2	60	-	-	-	200	*0.0*

Table 1 (cont.)

Species	N Records	Total count in: June	Aug	Oct	Dec	Feb	% FP
Pacific Golden Plover	1	–	–	–	7	–	*0.0*
Red-capped Plover	28	–	60	65	125	325	*24.8*
Greater Sand Plover	1	–	–	–	1	–	*0.0*
Black-fronted Dotterel	1	–	–	–	2	–	*0.0*
Black-winged Stilt	85	160	400	568	1770	21	*30.3*
Banded Stilt	12	883	–	–	200	2001	*19.7*
Red-necked Avocet	14	599	2	10	1520	–	*1.0*
Silver Gull	26	5	–	54	810	308	*18.2*
White-winged Black Tern	1	–	–	–	–	1	*0.0*
White-fronted Chat	57	68	32	116	83	46	*90.9*
Clamorous Reed-Warbler	2	–	–	1	1	–	*100*
Little Grassbird	13	2	4	15	3	2	*100*
Totals		6991	7100	8200	22660	5877	

FIGURE 4. The total number of observations of all species in each habitat class with the number of observations of active (foraging) birds shaded. Habitats are: EW - estuary waters; ES - estuary shore; PlS - pools in samphire; FlS - flooded samphire; DyS - dry samphire; past - pasture; RuS - rushes and sedges.

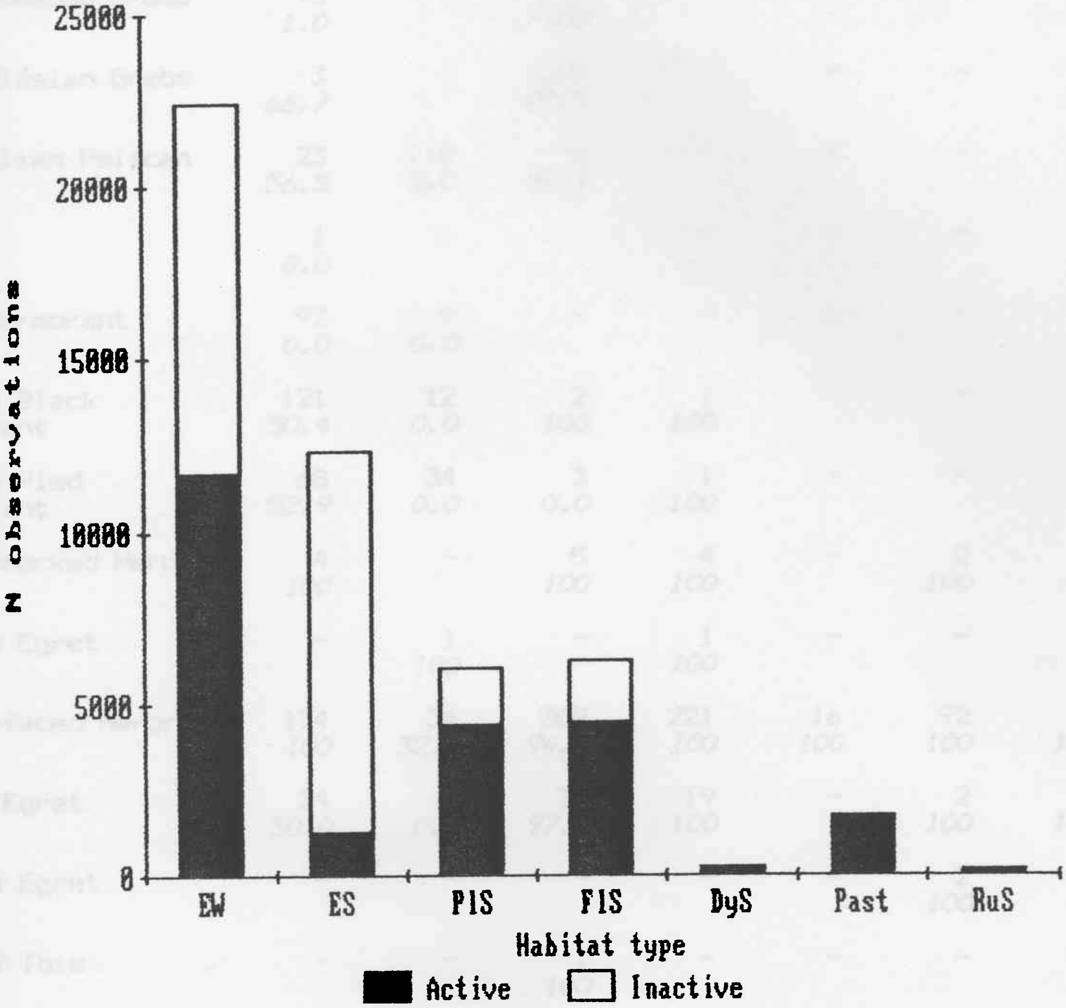


TABLE 2. The total number of each species of waterbird in each habitat category throughout the study, with the percentage of these classified as active (foraging or drinking) in italics. Habitat categories have been simplified as given in Appendix 1b, except that estuary waters includes open water and shallows of the estuaries; and pasture includes flooded pasture and pools on pasture. The X^2 value is the result of a Two-way Chi-square test on numbers scored as active and inactive across habitats, excluding habitats where fewer than 6 observations were made. Significance levels are: NS not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

			Floodplain					
Species	Estuary waters	Estuary shore	Pools	Flood samph	Dry samph	Past	Rush & sedge	X^2
Hoary-headed Grebe	95 *1.0*	-	1 *100*	-	-	-	-	-
Australasian Grebe	3 *66.7*	-	19 *89.5*	-	-	-	-	-
Australian Pelican	23 *56.5*	115 *0.0*	6 *83.3*	-	-	-	-	82.26 ***
Darter	1 *0.0*	-	-	-	-	-	-	-
Pied Cormorant	92 *0.0*	9 *0.0*	-	-	-	-	-	-
Little Black Cormorant	121 *50.4*	12 *0.0*	2 *100*	1 *100*	-	-	-	10.97 **
Little Pied Cormorant	68 *52.9*	34 *0.0*	3 *0.0*	1 *100*	-	-	-	27.82 ***
White-necked Heron	4 *100*	-	5 *100*	4 *100*	-	2 *100*	-	-
Little Egret	-	1 *100*	-	1 *100*	-	-	-	-
White-faced Heron	134 *100*	34 *32.4*	309 *94.4*	221 *100*	16 *100*	92 *100*	8 *100*	305.5 ***
Great Egret	24 *50.0*	5 *0.0*	37 *97.3*	19 *100*	-	2 *100*	9 *100*	34.20 ***
Cattle Egret	-	-	-	-	-	2 *100*	-	-
Glossy Ibis	-	-	1 *100*	-	-	-	-	-
Australian White Ibis	11 *100*	31 *3.2*	17 *100*	92 *88.0*	-	29 *100*	3 *100*	124.8 ***
Straw-necked Ibis	153 *100*	213 *0.0*	16 *100*	290 *84.1*	-	806 *100*	3 *100*	1180 ***

TABLE 2 (cont.)

Species	Estuary waters	Estuary shore	Floodplain: Pools	Flood samph	Dry samph	Past	Rush & sedge	χ^2
Yellow-billed Spoonbill	21 100	3 0.0	98 100	76 100	–	–	4 100	–
Black Swan	3493 *36.4*	710 *1.4*	1089 *92.7*	705 *99.1*	–	10 *100*	35 *100*	2705 ***
Australian Shelduck	2835 *65.3*	3064 *8.9*	825 *24.2*	678 *33.6*	12 *16.7*	264 *94.3*	2 *100*	2193 ***
Pacific Black Duck	1810 *35.7*	1299 *4.2*	1993 *67.1*	876 *86.8*	4 *50.0*	80 *88.8*	40 *100*	2023 ***
Grey Teal	6162 *30.0*	3988 *0.8*	846 *64.9*	1563 *25.4*	–	14 *100*	4 *100*	2197 ***
Australasian Shoveler	264 *6.8*	64 *1.6*	144 *77.8*	171 *29.2*	–	–	8 *100*	276.7 ***
Pink-eared Duck	100 *0.0*	100 *0.0*	–	–	–	–	–	–
Hardhead	53 *24.5*	–	7 *100*	–	–	–	–	–
Maned Duck	–	36 *0.0*	6 *66.7*	–	–	122 *58.2*	–	39.2 ***
Musk Duck	44 *4.5*	–	–	–	–	–	–	–
Osprey	–	–	–	1 *100*	–	–	–	–
White-bellied Sea Eagle	1 *100*	–	–	–	–	1 *100*	–	–
Marsh Harrier	2 *100*	–	1 *100*	6 *100*	–	–	1 *100*	–
Buff-banded Rail	–	–	–	–	–	–	1 *100*	–
Spotless Crake	–	–	–	3 *100*	–	–	–	–
Dusky Moorhen	–	1 *100*	–	1 *100*	–	–	–	–
Purple Swamphen	–	–	3 *100*	2 *100*	–	1 *100*	7 *100*	–
Eurasian Coot	280 *0.0*	–	29 *100*	–	–	–	–	280.0 ***
Wood Sandpiper	–	–	–	15 *100*	–	–	–	–
Common Sandpiper	–	2 *100*	–	–	–	–	–	–

TABLE 2 (cont.)

Species	Estuary waters	Estuary shore	Floodplain					X^2
			Pools	Flood samph	Dry samph	Past	Rush & sedge	
Greenshank	28 *92.9*	14 *92.9*	71 *100*	34 *100*	-	2 *100*	-	7.16 NS
Red Knot	4 *100*	-	-	-	-	-	-	-
Sharp-tailed Sandpiper	-	53 *100*	-	3 *100*	-	-	-	-
Red-necked Stint	-	1111 *100*	-	-	-	-	-	-
Long-toed Stint	-	1 *100*	-	-	-	-	-	-
Curlew Sandpiper	200 *100*	60 *100*	-	-	-	-	-	-
Pacific Golden Plover	-	7 *100*	-	-	-	-	-	-
Red-capped Plover	-	628 *92.0*	-	2 *100*	3 *100*	200 *100*	-	16.98 ***
Greater Sand Plover	-	1 *100*	-	-	-	-	-	-
Black-fronted Dotterel	-	2 *100*	-	-	-	-	-	-
Black-winged Stilt	1634 *93.9*	359 *8.9*	270 *100*	575 *99.1*	-	24 *100*	-	1872 ***
Banded Stilt	2465 *91.9*	50 *0.0*	118 *100*	500 *100*	-	-	-	628.3 ***
Red-necked Avocet	1614 *67.8*	-	15 *100*	2 *100*	-	-	-	7.17 *
Silver Gull	734 *60.0*	292 *0.0*	27 *100*	202 *100*	-	-	-	535.8 ***
White-winged Black Tern	-	1 *0.0*	-	-	-	-	-	-
White-fronted Chat	-	36 *100*	-	190 *100*	147 *100*	21 *100*	-	-
Clamorous Reed-Warbler	-	-	-	-	-	-	2 *100*	-
Little Grassbird	-	-	-	11 *100*	10 *100*		4 *100*	-

TABLE 3. The total number of each of the most common species of waterbird in each habitat category in each field trip, with the percentage of these classified as active (foraging or drinking) in italics. Habitat categories as in Table 2.

Species		Estuary waters	Estuary shore	Pools	Flood samph	Dry samph	Past	Rush & sedge
White-faced Heron								
	Jun	2	5	94	80	5	6	–
		100	*40.0*	*100*	*100*	*100*	*100*	
	Aug	–	2	7	17	–	13	–
			100	*100*	*100*		*100*	
	Oct	1	7	23	49	–	8	2
		100	*100*	*100*	*100*		*100*	*100*
	Dec	120	–	183	75	7	61	4
		100		*89.1*	*100*	*100*	*100*	*100*
	Feb	11	20	2	–	4	4	2
		100	*0.0*	*100*		*100*	*100*	*100*
Black Swan	Jun	144	30	428	461	–	10	–
		84.0	*0.0*	*93.7*	*100*		*100*	
	Aug	863	40	154	197	–	–	2
		37.8	*0.0*	*90.3*	*100*			*100*
	Oct	1301	170	381	41	–	–	33
		12.8	*5.9*	*90.3*	*100*			*100*
	Dec	1182	470	126	6	–	–	–
		55.8	*0.0*	*100*	*0.0*			
	Feb	3	–	–	–	–	–	–
		0.0						
Australian Shelduck								
	Jun	10	–	120	66	2	28	–
		60.0		*50.0*	*100*	*100*	*40*	
	Aug	53	29	29	24	–	64	–
		0.0	*0.0*	*93.1*	*100*		*100*	
	Oct	444	721	539	8	–	192	2
		4.5	*28.0*	*0.2*	*100*		*92.2*	
	Dec	1228	2205	132	580	10	–	–
		75.4	*0.0*	*84.8*	*22.4*	*0.0*		
	Feb	1100	109	–	–			
		81.8	*64.2*					
Pacific Black Duck								
	Jun	134	320	995	481	2	8	–
		3.0	*0.0*	*59.8*	*93.8*	*100*	*25.0*	
	Aug	268	32	120	131	2	29	3
		0.7	*0.0*	*85.0*	*95.4*	*0.0*	*100*	*100*
	Oct	409	216	641	184	–	39	37
		14.9	*25.0*	*64.9*	*100*		*97.4*	*100*
	Dec	989	631	197	80	–	4	–
		58.5	*0.0*	*93.4*	*0.0*		*50.0*	
	Feb	10	100	40	–	–	–	–
		0.0	*0.0*	*100*				

TABLE 3 (cont.)

Species		Estuary waters	Estuary shore	Pools	Flood samph	Dry samph	Past	Rush & sedge
Grey Teal	Jun	752	453	257	505	-	-	-
		13.6	*0.0*	*100*	*40.6*			
	Aug	1591	314	41	547	-	2	-
		0.4	*0.0*	*92.7*	*33.1*		*100*	
	Oct	684	203	512	11	-	12	4
		32.2	*1.5*	*42.6*	*100*		*100*	*100*
	Dec	2922	2948	35	500	-	-	-
		52.1	*0.7*	*100*	*0.0*			
	Feb	213	70	1	-	-	-	-
		0.0	*14.3*	*100*				
Australasian Shoveler	Jun	-	13	46	-	-	-	-
			0.0	*100*				
	Aug	225	50	62	171	-	-	-
		0.9	*0.0*	*77.4*	*29.2*			
	Oct	22	1	36	-	-	-	8
		27.3	*100*	*50.0*				*100*
	Dec	17	-	-	-	-	-	-
		58.8						
	Feb	-	10	-	-	-	-	-
			0.0					
Black-winged Stilt	Jun	102	20	44	44	-	-	-
		100	*0.0*	*100*	*88.6*			
	Aug	40	-	26	270	-	24	-
		100		*100*	*100*		*100*	
	Oct	147	2	178	241	-	-	-
		100	*100*	*100*	*100*			
	Dec	1331	337	12	20	-	-	-
		92.5	*8.9*	*100*	*100*			
	Feb	14	-	-	-	-	-	-
		100						
White-fronted Chat	Jun	-	15	-	57	22	20	-
			100		*100*	*100*	*100*	
	Aug	-	-	-	32	-	-	-
					100			
	Oct	-	2	-	99	17	1	-
			100		*100*	*100*	*100*	
	Dec	-	4	-	2	77	-	-
			100		*100*	*100*		
	Feb	-	15	-	-	31	-	-
			100			*100*		

TABLE 4. The distribution of waterbirds in survey zones (Appendix 3 and Fig. 2) on the Vasse and Wonnerup Estuaries. Values given are the total number of each species seen across all field trips (pooled).

Species	Zone number on: Vasse					Wonnerup		
	1	2	3	4	5	6	7	8
Hoary-headed Grebe	-	-	-	-	82	-	-	-
Australasian Grebe	17	-	2	2	-	-	-	-
Australian Pelican	-	-	18	12	-	95	-	16
Darter	-	-	-	-	-	1	-	-
Pied Cormorant	-	-	-	-	9	1	88	-
Little Black Cormorant	1	1	1	100	10	3	20	-
Little Pied Cormorant	1	7	-	34	-	35	31	2
White-necked Heron	1	1	1	3	-	1	1	8
Little Egret	-	-	1	-	1	-	-	-
White-faced Heron	17	48	169	188	44	34	54	68
Great Egret	2	18	9	44	3	5	1	9
Cattle Egret	-	-	-	-	-	-	2	-
Glossy Ibis								
Australian White Ibis	1	20	11	83	13	14	3	15
Straw-necked Ibis	-	212	201	233	2	30	157	643
Yellow-billed Spoonbill	1	110	98	9	2	7	-	6
Black Swan	4	210	1475	1527	257	615	847	1090
Australian Shelduck	172	629	937	3173	1131	126	790	845
Pacific Black Duck	223	732	753	3221	991	140	351	477
Grey Teal	73	843	4872	1964	1087	941	1804	1857
Australasian Shoveler	37	47	133	221	43	32	30	139
Pink-eared Duck	-	-	-	-	100	-	106	-
Hardhead	3	17	-	-	40	-	-	-
Maned Duck	4	128	-	-	29	2	1	-
Musk Duck	-	2	-	20	5	-	6	11
Osprey	-	-	-	-	-	1	-	-
White-bellied Sea Eagle	-	-	-	-	1	-	2	1
Marsh Harrier	-	4	2	3	2	-	1	1
Buff-banded Rail	-	-	1	-	-	-	-	-
Spotless Crake	-	-	-	3	-	-	-	-
Dusky Moorhen	-	-	-	1	-	-	-	-
Purple Swamphen	4	6	2	-	2	-	-	-
Eurasian Coot	29	30	-	-	100	-	150	-
Wood Sandpiper	-	-	-	15	-	-	-	-
Common Sandpiper	-	-	-	-	-	2	-	-
Greenshank	2	1	24	26	19	18	29	32
Red Knot	-	-	-	-	-	-	4	-
Sharp-tailed Sandpiper	-	-	3	-	-	-	53	-
Red-necked Stint	-	-	-	-	-	-	1292	-
Long-toed Stint	-	-	-	-	-	-	1	-
Curlew Sandpiper	-	-	-	-	-	-	260	-

Table 4 (cont.)

Species	Zone number on: Vasse						Wonnerup	
	1	2	3	4	5	6	7	8
Pacific Golden Plover	-	-	-	-	-	-	7	-
Red-capped Plover	-	1	53	73	6	4	427	-
Greater Sand Plover	-	-	-	-	-	-	1	-
Black-fronted Dotterel	-	2	-	-	-	-	-	-
Black-winged Stilt	106	68	563	584	92	112	205	500
Banded Stilt	-	-	200	-	13	755	2015	100
Red-necked Avocet	-	513	500	529	2	68	506	3
Silver Gull	-	24	452	62	304	9	113	224
White-winged Black Tern	-	-	-	1	-	-	-	-
White-fronted Chat	-	58	54	147	31	-	52	9
Clamorous Reed-Warbler	-	2	-	-	-	-	-	-
Little Grassbird	-	2	1	21	-	-	-	-
Number species	19	28	26	28	29	25	32	23
Number individuals	698	3736	10536	12334	4421	3051	8065	6061

TABLE 5. The distribution of breeding observations across survey zones in the Vasse and Wonnerup Estuaries. Breeding observations usually consisted of dependent young. See Figure 2 and Appendix 3 for locations and details of zones.

Species	Number of breeding observations in Zone: 1	2	3	4	5	6	7	8
Australasian Grebe	4	1	-	-	-	-	-	-
White-faced Heron	1	-	-	-	-	-	-	-
Black Swan	-	3	1	6	1	20	23	20
Australian Shelduck	-	1	1	6	-	1	1	-
Pacific Black Duck	3	11	-	1	-	-	-	-
Grey Teal	-	2	-	-	-	-	-	1
Australasian Shoveler	-	1	-	-	1	-	-	-
Eurasian Coot	4	-	-	-	-	-	-	-
White-fronted Chat	-	-	-	2	1	-	-	-

TABLE 6. The distribution of breeding observations across habitat types in the Vasse and Wonnerup Estuaries. Numbers for habitats correspond to code numbers used in Appendix 1B and are as follows: 1 - open water of estuary; 2 - estuary shallows; 3 - dry samphire; 4 - flooded samphire; 5 - pools in samphire or other floodplain vegetation; 6 - pasture; 8 - sedges and rushes; 9 - estuary shore.

Species	Number of breeding observations in Habitat: 1	2	3	4	5	6	8	9
Australasian Grebe	-	1	-	-	4	-	-	-
White-faced Heron	-	-	-	-	1	-	-	-
Black Swan	13	11	-	14	30	-	5	11
Australian Shelduck	2	2	-	1	4	1	1	-
Pacific Black Duck	-	1	-	-	4	2	8	1
Grey Teal	-	-	-	-	2	-	1	-
Australasian Shoveler	-	-	-	-	1	-	-	1
Eurasian Coot	-	-	-	-	4	-	-	-
White-fronted Chat	-	-	2	1	-	-	-	-

TABLE 7. Summary of disturbance data, giving the mean, standard error (SE), median, 25th percentile and 75th percentile of the distance at which a species was disturbed when birds were inactive and active. All distances are in metres.

Species	Activity	N events	Mean	SE	Median	25 %	75 %
Australian Pelican	Inactive	3	223.3	53.60	250	120	300
White-necked Heron	Active	2	125	25.00	125	100	150
White-faced Heron	Inactive	1	150	-	-	-	-
	Active	6	74.2	8.21	75	60	90
Great Egret	Active	4	83.8	17.72	90	62	105
Australian White Ibis	Active	6	155.8	41.80	142.5	100	500
Straw-necked Ibis	Inactive	1	120	-	-	-	-
	Active	4	87.5	21.00	70	65	110
Yellow-billed Spoonbill	Active	6	86.7	4.22	90	80	90
Black Swan	Inactive	7	111.4	18.83	120	60	130
	Active	14	144.6	20.4	125	80	160
Australian Shelduck	Inactive	13	144.6	25.88	110	80	200
	Active	13	90.4	12.89	80	50	110
Pacific Black Duck	Inactive	32	76.6	4.43	75	55	90
	Active	18	83.3	8.56	77.5	60	90
Grey Teal	Inactive	21	172.4	19.63	150	110	200
	Active	11	110.0	15.90	100	70	150
Pink-eared Duck	Inactive	1	170	-	-	-	-
Black-winged Stilt	Inactive	4	115	15.54	115	90	140
	Active	40	54.2	3.95	50	40	62
Purple Swamphen	Active	1	8	-	-	-	-
Eurasian Coot	Active	1	30	-	-	-	-
Pacific Golden Plover	Active	1	60	-	-	-	-
Red-capped Plover	Inactive	2	30	0.0	30	30	30
	Active	3	20	2.89	20	15	25
Banded Stilt	Inactive	2	105	45.0	105	60	150

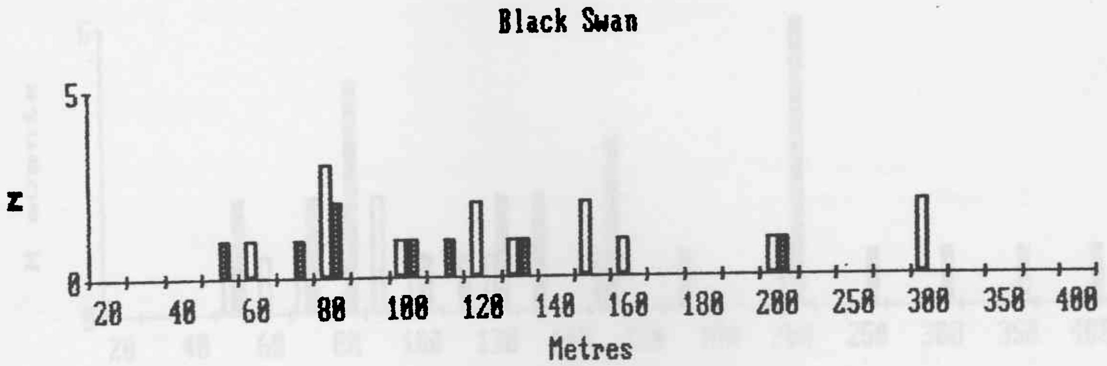
Table 7 (cont.)

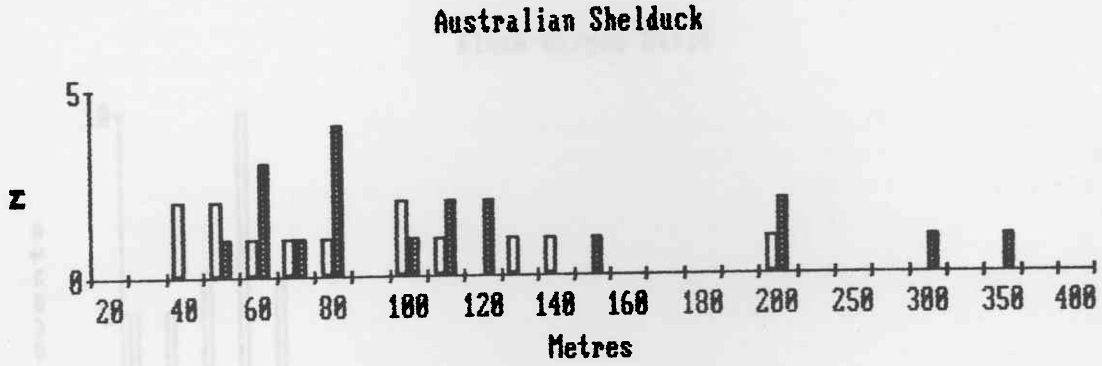
Species	Activity	N events	Mean	SE	Median	25 %	75 %
Red-necked Avocet	Active	2	60	10.0	60	50	70
Greenshank	Inactive	1	80	-	-	-	-
	Active	4	57.5	11.09	60	40	75
Sharp-tailed Sandpiper	Inactive	1	30	-	-	-	-
Red-necked Stint	Inactive	2	30	0.0	30	30	30
Curlew Sandpiper	Active	1	35	-	-	-	-
Silver Gull	Inactive	1	300	-	-	-	-
	Active	1	200	-	-	-	-
White-fronted Chat	Active	6	29.8	3.53	30	23	31
Total number of events:		225					

TABLE 8. Results of Multiple Regression tests to examine the impact upon the distance at which a species was disturbed of: flock size, the number of other species present and the number of people causing the disturbance. Active and inactive birds are treated separately. The beta weights determine the sources of significance. Significance levels are: NS - not significant; * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$.

Species and activity	F statistic	Level of significance		Beta weight	Level of significance	
Australian White Ibis						
Active	$f_{(3, 2)} = 0.58$, $p = 0.681$	NS				
Black Swan						
Inactive	$f_{(3, 10)} = 0.127$, $p = 0.94$	NS				
Active	$f_{(3, 3)} = 7.44$, $p = 0.067$	NS				
Australian Shelduck						
Inactive	$f_{(3, 9)} = 2.702$, $p = 0.108$	NS				
Active	$f_{(3, 9)} = 5.88$, $p = 0.017$	*	flock size	0.928	p = 0.0031	**
			N other spp	-0.091	p = 0.716	NS
			N people	0.218	p = 0.446	NS
Pacific Black Duck						
Inactive	$f_{(3, 28)} = 1.57$, $p = 0.22$	NS				
Active	$f_{(3, 14)} = 1.75$, $p = 0.203$	NS				
Grey Teal						
Inactive	$f_{(3, 17)} = 7.10$, $p = 0.0027$	**	flock size	0.716	p = 0.0006	***
			N other spp	-0.079	p = 0.67	NS
			N people	0.016	p = 0.93	NS
Active	$f_{(3, 7)} = 2.53$, $p = 0.14$	NS				
Black-winged Stilt						
Active	$f_{(3, 36)} = 5.48$, $p = 0.0033$	**	flock size	0.144	p = 0.324	NS
			N other spp	0.447	p = 0.0029	**
			N people	-0.217	p = 0.135	NS

FIGURE 5. The distribution of disturbance records for the Black Swan, Australian Shelduck, Pacific Black Duck, Grey Teal and Black-winged Stilt. Open bars are for active birds and shaded bars for inactive birds.





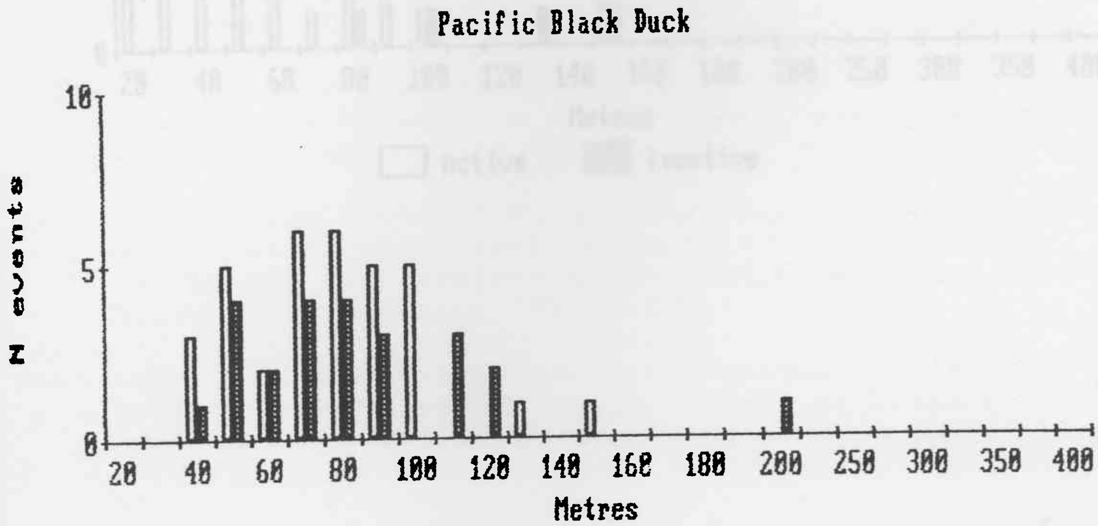
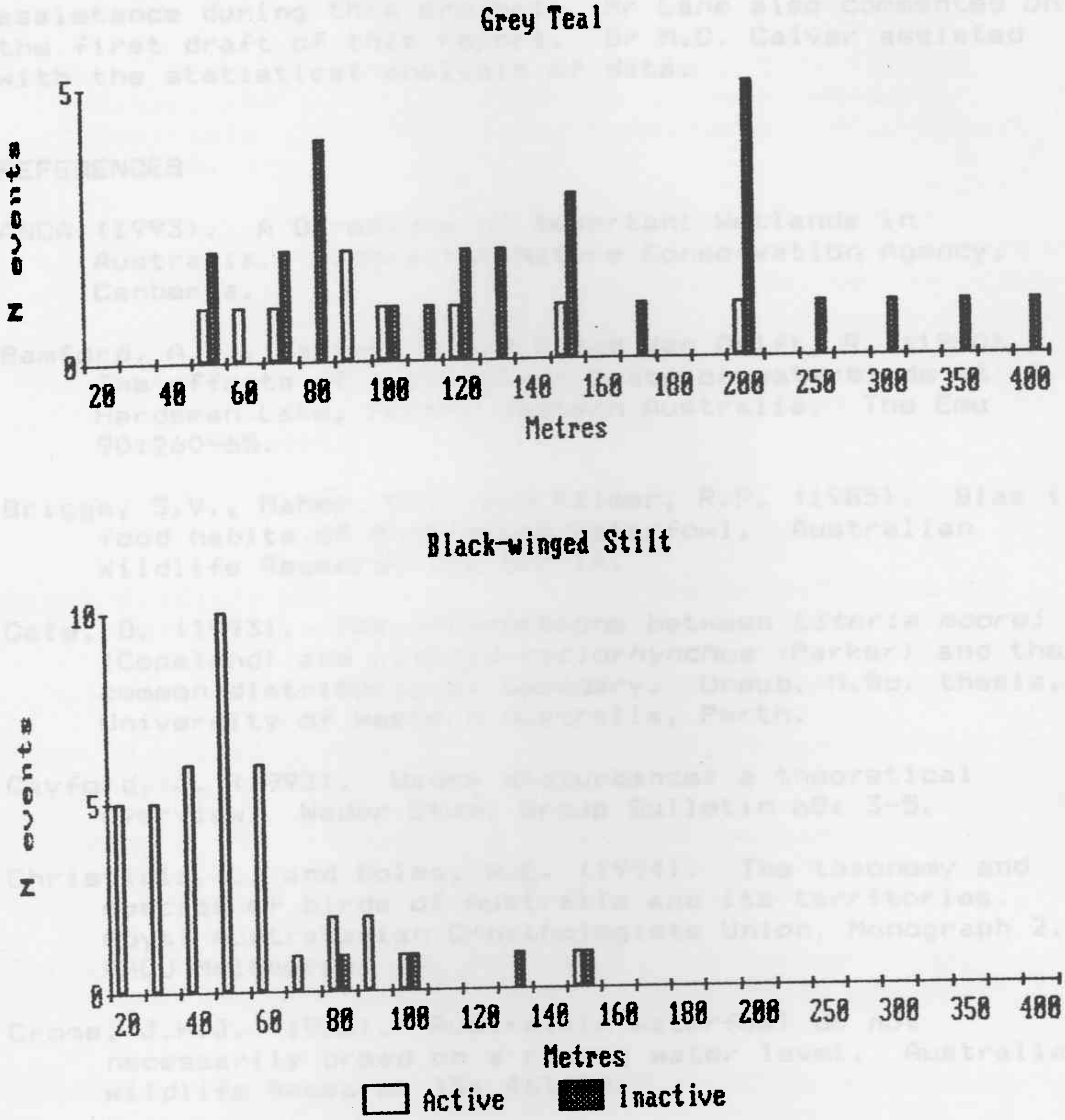


Figure 5 (cont.)



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APPENDIX 1A. Habitat and activity categories used during floodplain usage and disturbance surveys. Abbreviations were used on field record sheets but code numbers were used in the computer database. Note that database codes differed between the floodplain (FP) and disturbance (Dis) databases. NA indicates that a particular habitat or activity was not used in a database.

Field abbrev.	Description	FP code	Dis code
Activity			
L	Loafing; inactive on water	1	2
R	Roosting; inactive on land (shore or sandbank)	2	2
F	Foraging; actively feeding or searching for food	3	3
P	Perched; inactive on a tree or post	4	3
O	Overhead; flying through the site but not foraging	5	NA
D	Drinking	6	3
B	Breeding observed; note number of broods and number in each	7	NA
Habitat			
OWE	Open water of estuary	1	1
Eshall	Estuary shallows; within 10 m of shore	2	2
Eisl	Estuary island	4	9
pSa	Pool within *Sarcocornia* (<5% cover)	5	5
pHa	Pool within *Halosarcia* (<5% cover)	6	5
pPa	Pool on pasture (<5% cover)	7	7
fSa	Flooded *Sarcocornia*	8	4
fHa	Flooded *Halosarcia*	9	4
fPa	Flooded pasture	10	7
dSa	Dry *Sarcocornia*	11	3
dHa	Dry *Halosarcia*	12	3
Pas	Pasture dry or damp but not wet	13	6
OWp	Open water of pool within samphire	14	5
Shp	Shallows of pool within samphire	15	5
Ru	Tall rushes (*Typha* and *Baumea*)	16	8
Se	Flooded sedges and tall grasses	17	8
BS	Bare shoreline of estuary	18	9
GS	Grassy shoreline of estuary	19	9
AE	Aerial (flying)	20	NA
P	Perch; on tree or post	21	1

APPENDIX 1B. Species codes used for the completion of field data sheets and for entry into the computer spreadsheet. Names in parenthesis are the result of the revision by Christidis and Boles (1994) but were not current when field work took place.

Field code	Species	Computer code
AuGb	Australasian Grebe	061
HhGb	Hoary-headed Grebe	062
APel	Australian Pelican	106
Dart	Darter	101
PieC	Pied Cormorant	099
LPiC	Little Pied Cormorant	100
LBlC	Little Black Cormorant	097
PcHn	Pacific (White-necked) Heron	189
WfHn	White-faced Heron	188
CatE	Cattle Egret	977
GrtE	Great Egret	187
LitE	Little Egret	185
GloI	Glossy Ibis	178
AuWI	Australian White Ibis	179
StnI	Straw-necked Ibis	180
YbSb	Yellow-billed Spoonbill	182
BlkS	Black Swan	203
AShd	Australian Shelduck	207
AuWD	Australian Wood Duck	202
PaBD	Pacific Black Duck	208
GyTl	Grey Teal	211
AuSh	Australasian Shoveler	212
PeaD	Pink-eared Duck	213
Hard	Hardhead	215
MusD	Musk Duck	217
Ospy	Osprey	241
WbSE	White-bellied Sea-Eagle	226
MaHa	Marsh Harrier	219
BbaR	Buff-banded Rail	046
SpCr	Spotless Crake	051
DuMh	Dusky Moorhen	056
PuSh	Purple Swamphen	058
Coot	Eurasian Coot	059
PaGP	Pacific Golden Plover	137
RcaP	Red-capped Plover	143
GtSP	Greater Sand Plover	141
BfoP	Black-fronted Plover (Dotterel)	144
BwSt	Black-winged Stilt	146
BdSt	Banded Stilt	147
RnAv	Red-necked Avocet	148

Appendix 1B (cont.).

Field code	Species	Computer code
WooS	Wood Sandpiper	154
ComS	Common Sandpiper	157
Gank	Greenshank	158
RdKn	Red Knot	164
ShtS	Sharp-tailed Sandpiper	163
RenS	Red-necked Stint	162
LtSt	Long-toed Stint	965
CurS	Curlew Sandpiper	161
SiGu	Silver Gull	125
WwTn	White-winged Black Tern	109
CtdT	Crested Tern	115
StbQ	Stubble Quail	009
Ripi	Richard's Pipit	647
ClRW	Clamorous Reed-Warbler	524
LiGb	Little Grassbird	522
WfoC	White-fronted Chat	448

APPENDIX 1C. Copies of field data sheets used in the floodplain and disturbance components of the study. Abbreviations for activity and habitat were used as presented in Appendix 1A. Notes on weather conditions were made but not used in subsequent analyses. Temperature was estimated as: cool (<20°C); mild (20 - 30°C); or hot (>30°C). Rain was recorded as: none; occasional showers; or regular rain. Wind was estimated as: slight (<5 kph); moderate (5 - 20 kph); or strong (>20 kph). Cloud cover was recorded as: little cover (0 - 10%); moderate cover (10 - 50%); or heavy cover (>50%).

FIELD DATA SHEET
VASSE-WONNERUP PROJECT; FLOODPLAIN USAGE

Site No.: ____________ Date: ____________ Time: ____________

Notes: ______________________________ Weather: T__ R__ W__ C__

Spp.	N	Habitat	Activity	Spp.	N	Habitat	Activity

Additional notes: ______________________________

FIELD DATA SHEET
VASSE-WONNERUP PROJECT; DISTURBANCE STUDY

Date: ________ Weather: T__ ; R__ ; W__ ; C__ .

Species	Site	Time	N	Act.	Hab.	Type of disturb	Distance (m) alert	Distance (m) flight

Notes: ____________________

NB: Use codes as for floodplain usage survey.
With mixed flocks, record response of each species but indicate that the species are together with brackets.

APPENDIX 1D. Structure of spreadsheets used for statistical analyses. Code numbers used for species, habitat and activity are given in Appendices 1A and 1B. Date was not used in the spreadsheets but each trip was assigned a number: 1 = June; 2 = August; 3 = October; 4 = December; 5 = February.

Columns in floodplain usage spreadsheet.

1. Species codes (Appendix 1B).
2. Number of birds.
3. Trip number (1-5, see note above).
4. Time (taken at beginning of a survey of a site).
5. Site number.
6. Habitat code (Appendix 1A).
7. Activity code (Appendix 1A).

Columns in disturbance spreadsheet.

1. Species code (Appendix 1B).
2. Number of birds.
3. Trip number (1-5, see note above).
4. Time (classed into hourly intervals).
5. Habitat code (Appendix 1A).
6. Activity code (Appendix 1A).
7. Distance at which disturbance occurred (m).
8. Number of other species present.
9. Number of people forming disturbance.

APPENDIX 2. Common and scientific names of all waterbird species recorded during the study. Names and taxonomic order follow Christidis and Boles (1994).

Podicepididae (grebes)	
Hoary-headed Grebe	*Poliocephalus poliocephalus*
Australasian Grebe	*Tachybaptus novaehollandiae*
Pelecanoididae (pelicans)	
Australian Pelican	*Pelecanus conspicillatus*
Anhingidae (darters)	
Darter	*Anhinga melanogaster*
Phalacrocoracidae (cormorants)	
Pied Cormorant	*Phalacrocorax varius*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Little Pied Cormorant	*Phalacrocorax melanoleucos*
Ardeidae (herons and egrets)	
White-necked Heron	*Ardea pacifica*
Little Egret	*Egretta garzetta*
White-faced Heron	*Egretta novaehollandiae*
Great Egret	*Egretta alba*
Cattle Egret	*Ardeola ibis*
Plataleidae (ibis and spoonbills)	
Glossy Ibis	*Plegadis falcinellus*
Australian White Ibis	*Threskiornis molucca*
Straw-necked Ibis	*Threskiornis spinicollis*
Yellow-billed Spoonbill	*Platalea flavipes*
Anatidae (ducks, geese and swans)	
Black Swan	*Cygnus atratus*
Australian Shelduck	*Tadorna tadornoides*
Pacific Black Duck	*Anas superciliosus*
Grey Teal	*Anas gibberifrons*
Australasian Shoveler	*Anas rhynchotis*
Pink-eared Duck	*Malacorhynchus membranaceus*
Hardhead	*Aythya australis*
Maned Duck	*Chenonetta jubata*
Musk Duck	*Biziura lobata*
Pandionidae (osprey)	
Osprey	*Pandion haliaetus*
Accipitridae (kites, hawks and eagles)	
White-bellied Sea Eagle	*Haliaeetus leucogaster*
Marsh Harrier	*Circus aeruginosus*

APPENDIX 2 (cont.)

Rallidae (crakes and rails)	
Buff-banded Rail	*Rallus philippensis*
Spotless Crake	*Porzana tabuensis*
Dusky Moorhen	*Gallinula tenebrosa*
Purple Swamphen	*Porphyrio porphyrio*
Eurasian Coot	*Fulica atra*
Scolopacidae (sandpipers)	
Wood Sandpiper	*Tringa glareola*
Common Sandpiper	*Tringa hypoleucos*
Greenshank	*Tringa nebularia*
Red Knot	*Calidris canutus*
Sharp-tailed Sandpiper	*Calidris acuminata*
Red-necked Stint	*Calidris ruficollis*
Long-toed Stint	*Calidris subminuta*
Curlew Sandpiper	*Calidris ferruginea*
Charadriidae (lapwings and plovers)	
Pacific Golden Plover	*Pluvialis fulva*
Red-capped Plover	*Charadrius ruficapillus*
Greater Sand Plover	*Charadrius leschenaultii*
Black-fronted Dotterel	*Elseyornis melanops*
Recurvirostridae (stilts and avocets)	
Black-winged Stilt	*Himantopus himantopus*
Banded Stilt	*Cladorhynchus leucocephalus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Laridae (gulls and terns)	
Silver Gull	*Larus novaehollandiae*
Caspian Tern	*Hydroprogne caspia*
Crested Tern	*Sterna bergii*
White-winged Black Tern	*Chlidonias leucopterus*
Melaphagidae (honeyeaters and chats)	
White-fronted Chat	*Epthianura albifrons*
Sylviidae (old world warblers)	
Clamorous Reed-Warbler	*Acrocephalus stentoreus*
Little Grassbird	*Megalurus gramineus*

APPENDIX 3. Survey zones. See Figure 2 for locations of sites within zones. Zones 1-5 on Vasse Estuary, Zone 6-8 on Wonnerup Estuary.

Zone	Sites within zone	Floodplain vegetation
1	2, 3, 4	Seasonal, freshwater pools with some rushes, samphire and paperbarks. Partly grazed.
2	1,35,36,37	Samphire, with paperbarks and sedges along some shorelines and seasonal pools between densely-vegetated islands. Some areas of *Typha*. Mostly ungrazed except for site 35, which included pasture.
3	38, 39, 40, 41, 42, 43, 44, 45	Large areas of ungrazed samphire including seasonal pools. Some paperbarks and sedges.
4	5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	Extensive area of ungrazed samphire including seasonal pools within samphire. A low levee supporting sedges occurs between the estuary and samphire in some areas.
5	18, 20, 46	Ungrazed samphire including seasonal pools. Also pasture around Malbup Creek and fringing vegetation of sedges and water couch (site 46). A low levee supporting sedges between the estuary and samphire in site 18.
6	24, 25, 28, 29	Samphire and some areas of sedge. Sites 24 and 25 ungrazed, but parts of 29 and all of 28 grazed.
7	21, 22, 23, 26, 27, 48	Grazed samphire including some pools. Site 48 was a large, seasonal pool within pasture and appeared to have been modified to increase drainage.
8	30, 31, 32, 33, 34	Site 30 was ungrazed samphire with very extensive pools, site 31 was pasture with pools while the remaining sites were partly grazed with extensive beds of sedge and water couch.

APPENDIX 4. Opportunistic observations on other fauna.

Taxon	Comments
Crustacea Cladoceran (daphnia/water flea)	Extremely abundant in vegetated shallows around estuaries, amongst flooded sedges, samphire and in flooded pasture.
European Carp *Carassius carassius*	One in flooded track on edge of paddock in site 1 (August).
Glauert's Froglet *Crinia glauertii*	Calling at site 40 (June).
Sandplain Froglet *Crinia insignifera*	Recorded at sites 1, 17, 27, 32, 34, 36, 37, 38, 40, 42, 43 and 45, with all records in either June or August.
Guenther's Toadlet *Pseudophryne guentheri*	Recorded at sites 1 and 34 in June.
Pobblebonk *Limnodynastes dorsalis*	Recorded at site 2, 11 and 32 in August.
Slender Tree Frog *Litoria adelaidensis*	Recorded at sites 11, 17, 32, 35, 36 and 45 mainly in August.
Motorbike Frog *Litoria moorei*	Recorded at sites 1, 2, 13, 36, 37, 41 and 43. Most records in August and October. Records at site 1 in December included large tadpoles in the estuary and recently-metamorphosed frogs on the shoreline. Several specimens displayed a dark reticulum on the flank and inside of the thigh suggestive of hybrids with *Litoria cyclorhynchus* (Cale 1993).
Long-necked Tortoise *Chelodina oblonga*	Adults seen at sites 1, 32, 35 and Malbup Creek. Nest predated by Fox at site 39 (December).
King's Skink *Egernia kingii*	Several living in timbers of Wonnerup floodgates; seen in December and February.

Appendix 4 (cont.).

Taxon	Comments
Tiger Snake *Notechis scutatus*	Recorded at sites 1, 5, 10, 11, 16, 19, 25, 35, 37 and 45.
Water Rat *Hydromys chrysogaster*	One found dead on Layman's Road near Wonnerup House in August.
unidentified rat *Rattus* sp.	Tracks of a rat in damp mud at site 37 in December. Most likely the introduced Black Rat *R. rattus* or possibly the introduced Brown Rat *R. norvegicus*. The only possible native species is the Bush Rat *R. fuscipes*.