DISTURBANCE DISTANCES FOR WATER BIRDS AND THE MANAGEMENT OF HUMAN RECREATION WITH SPECIAL REFERENCE TO THE COORONG REGION OF SOUTH AUSTRALIA

David C. Paton, Mark Ziembicki, Peter Owen and Cybele Heddle
Department of Environmental Biology,
The University of Adelaide,
Adelaide, S.Australia 5005

Final report
for the
Migratory Waterbird component
of the
National Wetlands Program.
May 2000

Table of

Abstract

The distances at which various waterbirds responded to disturbances were measured by recording changes in the proportion of alert birds in roosting or foraging flocks as various types of disturbances were advanced towards them. The distance at which a significant disturbance was detected coincided with the distance at which the number of alert birds was significantly higher over a two minute period than the baseline undisturbed number. Five types of disturbance were considered: walking alone, walking with a dog, canoeing, boating and simulated jet-skiing.

In general, a significant increase in vigilance was detected at distances of 25-110m for various calidrine sandpipers, 26-204m for larger waders (stilts, avocet, godwit, curlew, oystercatcher) and from 85-347m for various waterbirds (ibis, duck, cormorant, swan). The distances at which birds eventually took flight also varied with flush distances ranging from 17-54 m for sandpipers, 8-128m for the larger waders, and 50-157m for the waterbirds that were studied. In general the distances at which the birds were flushed reflected the distances at which the birds first became alert to the disturbance with the larger waterbirds being the most sensitive, followed by the larger waders, with the smaller sandpipers being the most tolerant of an approaching disturbance.

Overall canoeing was the least disruptive human recreational activity and jet-skiing and walking along the shore with a dog the most disruptive.

For calidrine waders like Curlew Sandpipers the disturbance caused by someone walking along the shore to within 30m of them would result in the birds losing about a minute of foraging time. One or two such disturbances per hour would result in the birds potentially losing 20 minutes of foraging time per day. Current levels of disturbance in significant areas like the estuarine areas near the Murray Mouth are estimated at 0.5 per hour during weekdays and higher on weekends during summer. Given that human recreational activities are likely to increase in coastal areas like the Murray Mouth region, some attempt to manage recreational activity in areas that are important for the birds is warranted. Management may need to consider setting buffer zones around areas important for the birds, limiting the numbers of people using an area at any one time, limiting the type of recreational activity or a combination of these. Measurements of disturbance distances provide a basis for setting buffer distances. Ideally these should be set at those distances at which the most sensitive species are disturbed. Based on our measurements of disturbance distances, buffer zones of around 350m would be required for this. This is unlikely to be acceptable to the general public and some compromise will be needed. This compromise should be determined in advance and used to set limits on recreational activities before those limits are reached since this is likely to be more readily accepted by the general public, than attempting to reduce human recreational activity once it has established in an area.

Introduction

Increasing human recreation in estuaries and other wetlands is increasingly regarded as a major concern for the continued conservation and sustainable use of important waterbird and wader habitats (e.g. Davidson 1991; Davidson and Rothwell 1993). In addition to shore-based developments such as barrages, marinas and housing, which contribute to habitat loss, many concerns relate to direct disturbance of feeding and roosting birds from recreational activities. Such recreational activities may be water-based (e.g. boating, jet-skiing, water-skiing), land-based (e.g. walking, trail bikes, four-wheel driving, dog walking) or airborne (e.g. low-flying light aircraft). Such activities appear to be or are likely to increase in frequency, intensity, coverage and duration in the coastal regions of South Australia, particularly in the Coorong region an area listed as a Wetland of International Importance under the Ramsar Convention. Many of the recreational activities take place simultaneously within these wetlands and may be particularly concentrated at particular times (e.g. summer holidays). There is, therefore, the potential for a complex interplay between the effects of a variety of activities and their resulting disturbance to waterbirds.

There is little quantified and experimental assessment of the effects of recreational and other types of disturbance to waterbirds and little understanding of the extent of such impacts. Such information, however, is vital to wetland managers to ensure a balance between the needs of human development and the need to protect key sites for aquatic birds. In Australia there is no information available on the responses of waders to different types of human recreational activities.

Disturbances to waders may vary in their intensity, frequency, duration, coverage and predictability. Furthermore, there is often great inter-specific (and intra-specific) variation in susceptibility of birds to disturbance which is likely to vary with age, season, weather, location and the degree of habituation to disturbance (Burger 1991; Cayford 1993; Smit and Visser 1993; Rodgers and Smith 1995, 1997). Generally, however, disturbances are localised in time and space. There are two potential consequences of sustained, localised disturbance to migratory waders. Firstly, birds may have to shift to alternative, perhaps less favourable feeding grounds (Goss-Custard and Verboven 1993), and secondly, their feeding rate may be reduced by having to increase time devoted to vigilance and anti-predator behaviour (Burger 1991; Burger and Gochfeld 1991, 1998; Roberts and Evans 1993).

Waders preferably forage in areas where prey density, prey availability and intake rates are relatively high and where energy expenditure is low (Goss-Custard and Charman 1976). Densities, therefore, tend to reach a maximum in the best and most preferred feeding areas (Goss-Custard *et al.* 1982). Where disturbances force birds to shift to alternative feeding areas, questions arise as to whether such areas are adequate, whether they can accommodate displaced individuals and what effect increased bird density has on intake rates and ultimately the fitness of those individuals which move. Goss-Custard (1980) suggests that as bird density increases, average intake rates decline in some species as a result of increased competition, increased prey depletion and greater proportion of the population feeding in sub-optimal areas. Where populations are limited, or are close to limitation, by the quality and availability of habitat, disturbance can have a particularly negative impact on wader populations by affecting fitness, ability to fatten adequately during pre-migratory periods and increasing mortality.

Numerous studies of the effects of human disturbance have attempted to correlate observed distributions of waders with measures of the intensity and frequency of human use of individual sites (e.g. Erwin 1980; Burger 1981; Bamford *et al.* 1990; Pfister *et al.* 1992; Pierce *et al.* 1993; Salvig *et al.* 1994). Cayford (1993) notes that similar approaches have used regression or multivariate methods to model observed waterbird distributions with characteristics of wetland sites and then attempted to explain deviations from predictions of densities in terms of disturbance. This approach measures the potential of sites for waders and then assesses the degree to which this potential is reduced by disturbance (Owen 1993). This technique has been adopted, for example, by Hunt (1972), Tuite *et al.* (1984), Bell and Fox (1991), and Fox *et al.* (1994). A problem with this approach, however, is that a large fraction of the variation in bird density must be explained by the models on which predicted wader use is based. As Cayford (1993) states this level of precision is rarely achieved with ecological data, especially where many environmental and social factors affect the variable in question, in this case feeding density.

Alternative studies have sought to measure the behavioural responses of waders to disturbing stimuli and thereby attempted to establish a cause and effect between disturbance and dispersion (e.g. Burger 1991; Yalden and Yalden 1990). Such studies have considered actual recreational activities (as opposed to experimentally controlled and applied disturbance activities) thereby providing data on relative levels of disturbance at different sites and comparative information on the responses of species to different stimuli. However, in such studies, the frequency, predictability and intensity of disturbing stimuli are highly variable and the effects of the disturbance are likely to be additive, so frequency data are limited in their usefulness. Cayford (1993) recommends a more controlled experimental approach whereby species can be targeted and confounding variables such as habituation, season, time, etc. can be experimentally controlled.

Some recent studies that have attempted to experimentally assess the impact of disturbance on waterbirds have predominantly used the bird's flight response as an index of disturbance. Others have only crudely estimated alert distances (e.g. Rodgers and Smith 1995, 1997). In such studies, a disturbance is introduced and the distance of the birds from the disturbance at point of flight measured. On this basis a number of recommended buffer distances have been suggested. For example, Rodgers and Smith (1995; 1997) recommended 100 metres for wading bird nesting colonies, 180 metres for mixed tern/skimmer breeding colonies and 100 metres for foraging and loafing waterbirds for pedestrian, terrestrial vehicle and motor boat approaches in Florida. Distances from 50-200 metres for tern species (Buckley and Buckley 1976; Erwin 1989) and 100-250 metres for wading (Ardeidae) species (Vos *et al.* 1985; Erwin 1989) have also been recommended, while Anderson (1988) suggested a distance of 600 metres to protect a Brown pelican colony in Mexico.

Many foraging animals, including most migratory waders, are often disrupted from their 'normal' behaviour well before a flight response is elicited (Lazarus 1979; Greig-Smith 1981). Van Der Meer (1985) (cited in Smit and Visser 1993) has shown that some birds are alerted at distances on average 30% greater than those at which they take flight while in Brent Geese it was as much as 95%. Following detection of a disturbance the animal may spend time assessing the degree of threat it is under in order to balance the risk of remaining in an area with the benefits, such as continued foraging. This may be particularly significant to migratory shorebirds during the pre-migratory period of fat accumulation. Since there is an increase in food requirements during this period waders seek to maximise their net rate of resource acquisition and so invest more time in foraging at the expense of other activities, for example, anti-predator behaviour (Metcalfe and Furness 1984). As such, the cost of feeding less outweighs the additional risk of predation that results from the decrease in vigilance. Nonetheless, frequent and intense disturbance is likely to affect wader behaviour and reduce the time they spend foraging. Reductions in feeding may then affect the capacity of waders to fatten at an adequate rate and therefore prolong the pre-migratory feeding period and delay departure. Such delays in migration departure from wintering grounds can seriously affect breeding success of migratory birds (Metcalfe and Furness 1984). Parmalee and McDonald (1960) and Clapham (1979) compared departure dates of migratory Ruddy Turnstones (*Arenaria interpres*) with dates of arrival in the arctic and found that the migration is rapid and synchronised. All breeding birds normally arrive on their arctic breeding grounds within several days of each other, and pairs are established on breeding territories within a week (Parmalee and MacDonald 1960). As Metcalfe and Furness (1984) suggest, late arriving individuals may be at a severe disadvantage in the competition for mates and territories, indicating not only the importance of building up enough migratory reserves prior to departure, but doing so at the correct time and rate.

In our study we have employed a direct, experimental technique for determining disturbance distance by presenting five types of recreational disturbance common in the Coorong and Lower Lakes region to groups of foraging and resting migratory shorebirds and waterbirds and measuring their responses. Waterbirds other than shorebirds were included in the trials because disturbances can disrupt a more sensitive species that then disturbs another nearby species. The recreational activities included walking, boating, canoeing, jet-skiing (simulation) and walking a dog on a leash. The objectives of the study were to determine the distances at which various waders responded to humans approaching them with the intention of using the bird's responses to recommend distances or buffer zones that would minimize the effects of human disturbance on the birds.

Methods

Study sites

Experimental trials were carried out in the Murray Mouth estuary and northern Coorong region and at the Penrice Salt Fields and adjacent Barker Inlet near St. Kilda, South Australia. The Coorong and estuarine areas of the Murray Mouth have been identified as one of the top five areas in Australia for shorebirds (Lane 1987) and are also important summer refuges for other waterbirds particularly in drought years. Because of this the Murray Mouth, associated estuary, and the adjacent Coorong and Lower Lakes were designated as a Wetland of International Importance under the Ramsar convention in November 1985. The estuary, northern Coorong and wetlands around Hindmarsh Island are also popular recreational destinations and subject to intense human activity particularly during the summer months. The Penrice Salt Fields near St Kilda on the western shore of Gulf St Vincent consist of an extensive series of shallow saltpans. Areas of samphire and shallow tidal pools separate the salt pans from the coastal mangroves that fringe the coast. These samphire areas, sandy islands within the saltpans and extensive areas of open water provide important roosting habitat for waders and other waterbirds in South Australia. The adjacent area of Barker Inlet consists of tidal mudflats that provide significant feeding habitat for a wide range of aquatic birds during low tide. Access to the salt fields is restricted and the Barker Inlet is not readily accessible, so these areas experience little disturbance relative to the northern Coorong and Murray Mouth estuary.

Trials were conducted from December 1997 to April 1998 from 0700 to 1900 on any day of the week at Penrice Salt Fields but were limited to weekdays in the northern Coorong-Murray Mouth region to avoid the frequent disruption to trials due to weekend recreational activities.

Field observations and experimental procedures.

The response of birds to disturbances and the distances at which they responded were measured by finding flocks of birds and recording changes in the behaviour of the flock as a particular disturbance was advanced towards the flock. All flocks were observed through a spotting scope at distances and from positions where the birds were not being influenced by the observer. This observer scanned the flock and recorded the number of individuals that were resting, preening, foraging, or alert and vigilant. Alert birds were defined as birds with their heads up often with their necks extended that were watching the approaching disturbance or scanning the surrounding area. A trial began by repeatedly counting the number of birds in each behaviour in a flock every 10 seconds for a period of 2-3 minutes in the absence of human disturbance to establish a baseline, 'undisturbed' measure of the birds' behaviour. These counts were then repeated as different types of human recreation took place at progressively closer distances to the flock until the birds had taken flight.

All observations were made on single species flocks (except for cormorants) that were more or less isolated from other species of birds, since responses of individual species often differed when the birds were in mixed species flocks (pers. obs.). In mixed species flocks the most sensitive species often alerted other less sensitive species long before they would have responded if on their own. By selecting only single species flocks for trials we eliminated the possibility that the birds were simply responding to the alert responses of a more sensitive nearby species. However, we collected data on a wide variety of species including small sandpipers, larger waders and waterfowl to determine which species were the most sensitive, assuming that effective buffer zones to prevent disturbance for all species would need to prevent the most sensitive species from being disturbed.

Five types of disturbance were performed: walking; walking with dog on leash; boating; canoeing; and jet-skiing (simulation). Walking trials consisted of a single person walking directly towards a flock of resting or foraging birds at a rate of ~1m/sec. At intervals of 10-30 metres the walker would stop and remain in a stationary position for 2-3 minutes while the behaviour of the birds was re-scored through a spotting scope by another observer. This would continue until the birds took flight. The positions where the walker paused were marked by dropping a metal peg. The position of the walker when the birds took flight was also marked with a peg. Distances between these pegs and the position of the flock were subsequently measured with a tape measure. A similar procedure was adopted when walking with a dog on a leash except that the person and dog would walk back and forth a few steps at a distance parallel to the flock rather than remain stationary at each pause location.

The water-based disturbances were based on the same procedure as above but used floats with sinkers to mark the positions of pauses. Specifically, canoeing involved one person paddling directly towards a flock of foraging or resting birds on or near the shoreline in a 4m canoe at a rate of 2m/sec. At each pause the canoeist continuously paddled back and forth a few canoe lengths at a parallel distance from the birds. The boating trials aimed to simulate fishing boats and involved a 14ft aluminium dinghy with an outboard motor approaching a flock of shore-based birds at a rate of ~2.5m/sec. At each pause the outboard motor was switched off and the anchor dropped overboard while a land-based observer recorded the behaviour of the birds.

Due to mechanical problems with a hired jet-ski, jet-ski trials were simulated using a 12ft aluminium dinghy with a 9.9 horse-power motor that was driven in an erratic and noisy manner (similar to the way jet-skis are used) at high speed towards the birds. At pause distances the boat was driven at a relatively constant distance from the birds in erratic circles.

Statistical analyses

In this study we compared the numbers of birds that showed vigilant or alert behaviour at each distance with the baseline undisturbed values for these behaviours. We used non-parametric Mann-Whitney U tests, and defined the distance at which birds were initially disturbed as that distance at which a significantly higher number of vigilant or alert birds was sustained over the first 2 minutes of counts (i.e. the first 12 consecutive scans; p's < 0.05). These disturbance distances are, however, conservative, in that (a) the birds may have shown a significant response at distances somewhere between this distance and the previous pause and (b) the birds often showed a short-term (for ~30 sec.) response at greater distances but this was not sustained.

Results

Responses of birds to disturbances

Shorebirds and waterbirds increased the amount of time they spent alert and vigilant as a disturbance approached. The intensity and duration of the response increased progressively as the distance between the birds and the disturbance was reduced. For example, in a flock of shorebirds, like Curlew Sandpipers, only 2% of birds were alert and vigilant when undisturbed, and the number of vigilant birds did not increase when a walker was within 120m of the birds. However, when the walker was within 85m, up to 30% of the birds were initially alert, but the number of agitated birds declined over the next 1-2 minutes and by the third minute the number of alert birds was equivalent to the undisturbed state again (Figs 1, 2). At progressively closer distances more birds became alert and although the numbers of birds showing alert behaviour declined over the next 2-3 minutes, the proportion that remained alert throughout the 3 minute period gradually increased, and did not return to the baseline undisturbed state.

Disturbance distances

The distances at which birds responded to various disturbances varied substantially between species, with the type of disturbance and between replicates involving the same disturbance on the same species of bird (Tables 1, 2). For example, the distance at which Red-necked Stints responded by increasing their level of alertness to someone walking towards them varied from 25m to 71m for four separate trials (Table 1). In general, a significant increase in vigilance was detected at distances of 25-110m for various calidrine sandpipers, 26-204m for larger waders (stilts, avocet, godwit, curlew, oystercatcher) and from 85-347m for various waterbirds (ibis, duck, cormorant, swan; Table 1). The distances at which birds eventually took flight also varied with flush distances ranging from 17-54 m for sandpipers, 8-128m for the larger waders, and 50-157m for the waterbirds that were studied (Table 2). In general the distances at which the birds were flushed reflected the distances at which the birds first became alert to the disturbance with the larger waterbirds being the most sensitive, followed by the larger waders, with the smaller sandpipers being the most tolerant of an approaching disturbance.

For most species of shorebird the mean distances at which they showed a significant alert response or took flight were less for an approaching canoeist than for other types of disturbance (Figs 3, 4). Canoeing caused significant increases in vigilance for shorebirds at mean distances of 47-108 m with the birds taking flight at mean distances of 17-52 m. Walking and boating were similar with respect to the mean distances for alert or flight responses with various shorebirds showing an alert response at mean distances of 44-199m and 55-130m for walking and boating respectively (Figs 3, 4). Mean flight responses to an approaching walker ranged from 20-97m and ranged from 28-61m to an approaching boat (Figs 3, 4). Walking with a dog was somewhat more disruptive to shorebirds than just walking with the birds becoming significantly alarmed at distances of 61-127 m and taking flight at mean distances of 33-80 m (Figs 4, 5). For the five species of waders where we had information on response distances for both walking and walking with a dog, the distances at which the birds showed a significant alert response and took flight were further away when the walker had a dog. Jet-skiing appeared to be the most disruptive of the five types of disturbances trialed. Flight responses to simulated jet-skiing ranged from 33-92 m while alert responses ranged from a mean of 68m for Red-necked Stints to a mean of 139 m for the Common Greenshank (Figs 3, 4).

Similar patterns in the distances of responses to different types of disturbances were observed amongst waterbirds with the birds generally responding to jet-skiing at greater distances than for canoeing and boating (Figs 5, 6).

Table 1. Distances(m) at which aquatic birds showed a significant increase in vigilance when approached by various types of disturbance. Values are means ± s.d. (n).

Species	Walking	Walk with dog	Boating	Canoeing	Jet-skiing
Red-necked Stint	43.7 ± 23.8 (4)	60.7 ± 3.1 (3)	55.0 ± 23.7 (3)	46.7 ± 25.0 (3)	67.5 ± 16.3 (2)
Curlew Sandpiper	78.1 ± 15.7 (4)		76.7 ± 7.5 (3)	63.9 ± 7.0 (3)	98.0 ± 8.5 (2)
Sharp-tailed Sandpiper	84.2 ± 15.6 (5)	102.5 ± 6.5 (2)	80.3 ± 26.1 (3)	68.0 ± 9.1 (4)	96.5 ± 19.1 (2)
Banded Stilt	69.4 ± 27.2 (8)	100.1 ± 17.0 (2)	89.3 ± 22.2 (4)	64.6 ± 24.4 (5)	110.5 ± 12.0 (2)
Black-winged Stilt	89.3 ± 30.0 (3)	109.0 ± 2.8 (2)	99.0 ± 15.6 (2)	78.0 ± 9.9 (2)	
Red-necked Avocet	121.3 ± 6.7 (3)		112.0 (1)	108.0 (1)	
Common Greenshank	88.7 ± 8.1 (3)	126.5 ± 2.1 (2)	93.0 ± 8.9 (3)	67.0 ± 25.5 (2)	138.7 ± 16.9 (3)
Bar-tailed Godwit	110.0 ± 11.3 (2)		130.0 ± 1.4 (2)	97.1 ± 19.7 (2)	
Eastern Curlew	183.5 ± 19.1 (2)				
Pied Oystercatcher	199.2 ± 7.4 (2)				
White Ibis	187.6 ± 107.1 (2)		205.3 ± 25.7(3)	85.1 ± 16.8 (2)	123.0 (1)
Grey Teal	153.5 ± 9.2 (2)		114.0 ± 31.1(2)	156.5 (1)	244.0 (1)
Australian Shelduck	145.0 (1)				
Cormorants (4 spp.)	207.0 ± 45.3 (2)	159.0 ± 9.9 (2)	193.5 ± 43.1 (2)	161.5 ± 27.6(2)	254.8 ± 82.7 (3)
Black Swan	313.0 (1)				

Table 2. Distances (m) at which aquatic birds took flight when approached by various types of disturbance. Values are means ± s.d. (n).

Species	Walking	Walk with dog	Boating	Canoeing	Jet-skiing
Red-necked Stint	20.0 ± 3.5 (4)	32.6 ±13.8 (3)	28.1 ± 1.8 (3)	17.3 ± 4.2 (3)	33.1 ± 7.7 (2)
Curlew Sandpiper	34.8 ± 6.0 (4)		29.8 ± 4.8 (3)	26.8 ± 2.9 (3)	46.5 ± 10.6 (2)
Sharp-tailed Sandpiper	33.2 ± 3.9 (5)	39.3 ± 3.7 (2)	35.7 ± 4.2 (3)	28.1 ± 4.0 (4)	39.7 ± 3.8 (2)
Banded Stilt	32.8 ± 23.7 (8)	40.2 ± 11.0 (2)	28.8 ± 8.1 (4)	24.7 ± 7.7 (5)	43.5 ± 12.0 (2)
Black-winged Stilt	39.3 ± 22.9 (3)	43.5 ± 14.9 (2)	33.5 ± 2.1 (2)	35.8 ± 14.5 (2)	
Red-necked Avocet	60.4 ± 7.8 (3)		57.0 (1)	43.0 (1)	
Common Greenshank	70.0 ± 11.8 (3)	80.3 ± 13.2 (2)	60.7 ± 4.0 (3)	51.5 ± 3.5 (2)	92.4 ± 5.0 (3)
Bar-tailed Godwit	48.6 ± 0.9 (2)		53.5 ± 7.8 (2)	41.9 ± 4.5 (2)	
Eastern Curlew	97.5 ± 23.3 (2)				
Pied Oystercatcher	82.5 ± 64.4 (2)				
White Ibis	80.8 ± 2.5 (2)		62.2 ± 26.2 (3)	58.3 ± 37.8 (2)	70.0 (1)
Grey Teal	106.9 ± 10.1 (2)		59.0 ± 8.5 (2)	49.5 (1)	119.5 (1)
Australian Shelduck	145.0 (1)				
Cormorants (4 spp.)	71.2 ± 12.0 (2)	97.5 ± 9.2 (2)	63.5 ± 23.3 (2)	57.7 ± 9.4 (2)	113.9 ± 59.2 (3)
Black Swan	149.0 (1)		113.0 (1)		

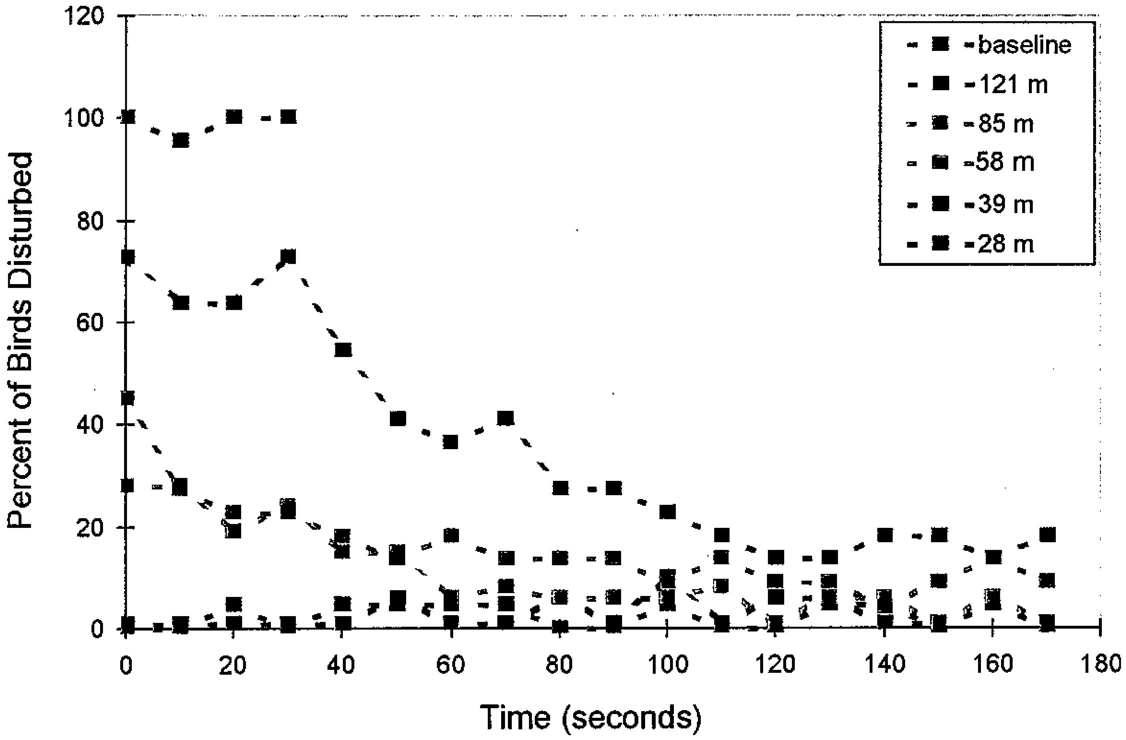

Figure 1. Percent birds with a flock of Curlew Sandpipers that showed vigilant behaviour in response to a person walking towards them. The figure shows the percentage of birds that were alert every ten seconds for the next three minutes after a single person had walked to within a certain distance of the birds.

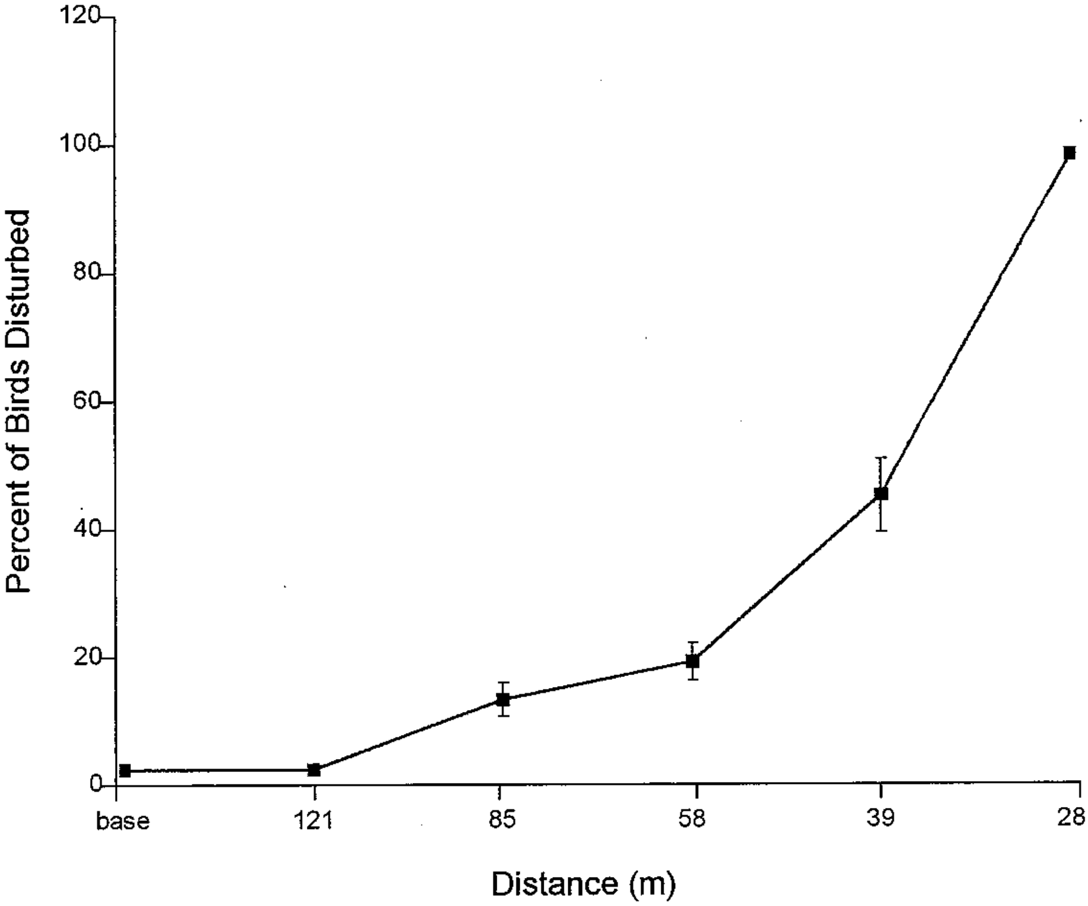

Figure 2. Percent birds within a flock of Curlew Sandpipers that showed vigilant behvaiour in response to a person walking towards them. The figure shows percent disturbance averaged over the first 12 consecutive scans of the flock after a single person had walked to within a certain distance of the birds. The 12 scans were taken at 10sec. intervals (see Fig. 1 for details).

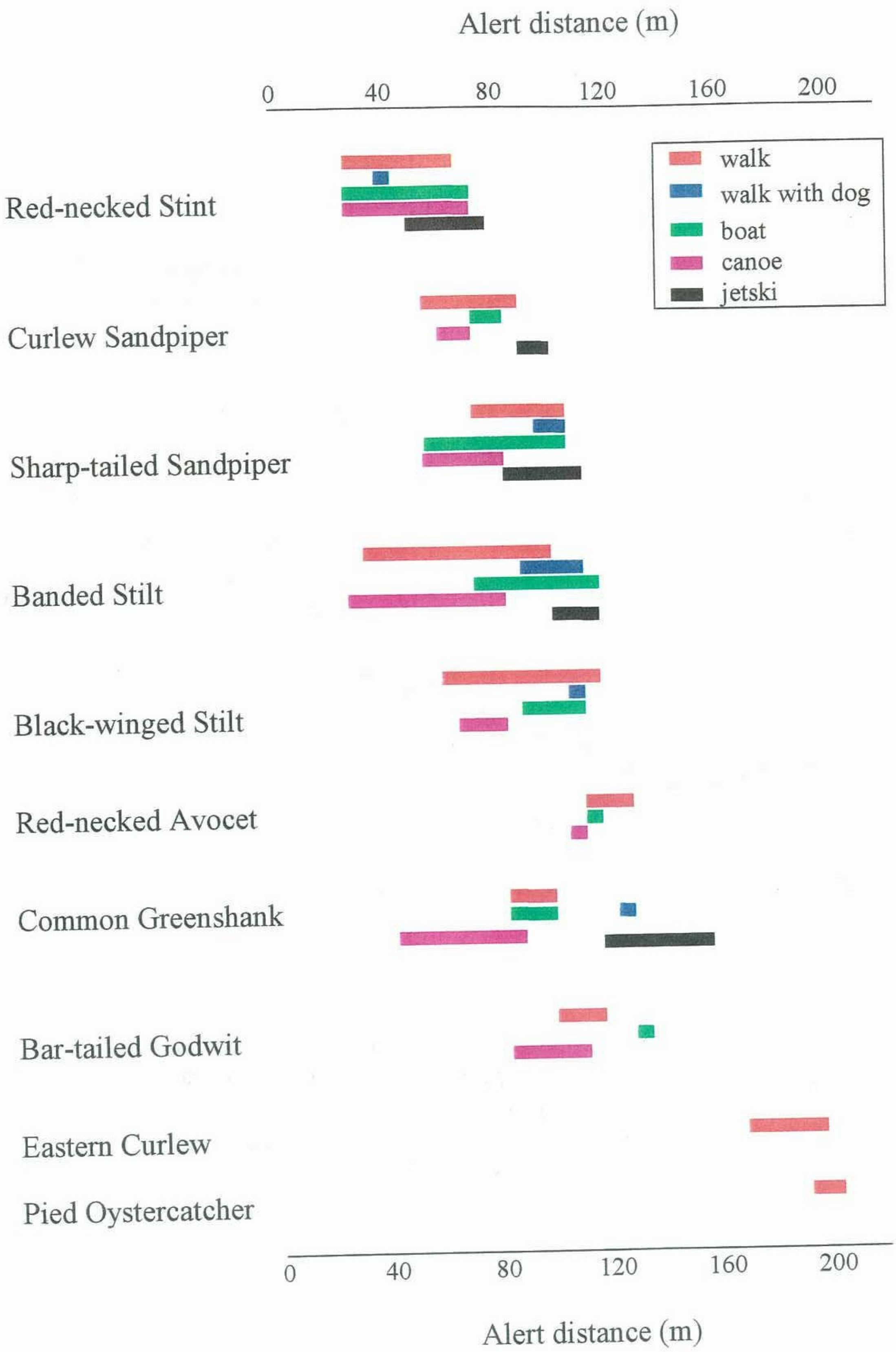

Figure 3. Ranges in distances at which different species of shorebirds showed a significant alert response to different types of disturbance.

Figure 4. Ranges in distances at which different species of shorebirds took flight in response to different types of disturbance.

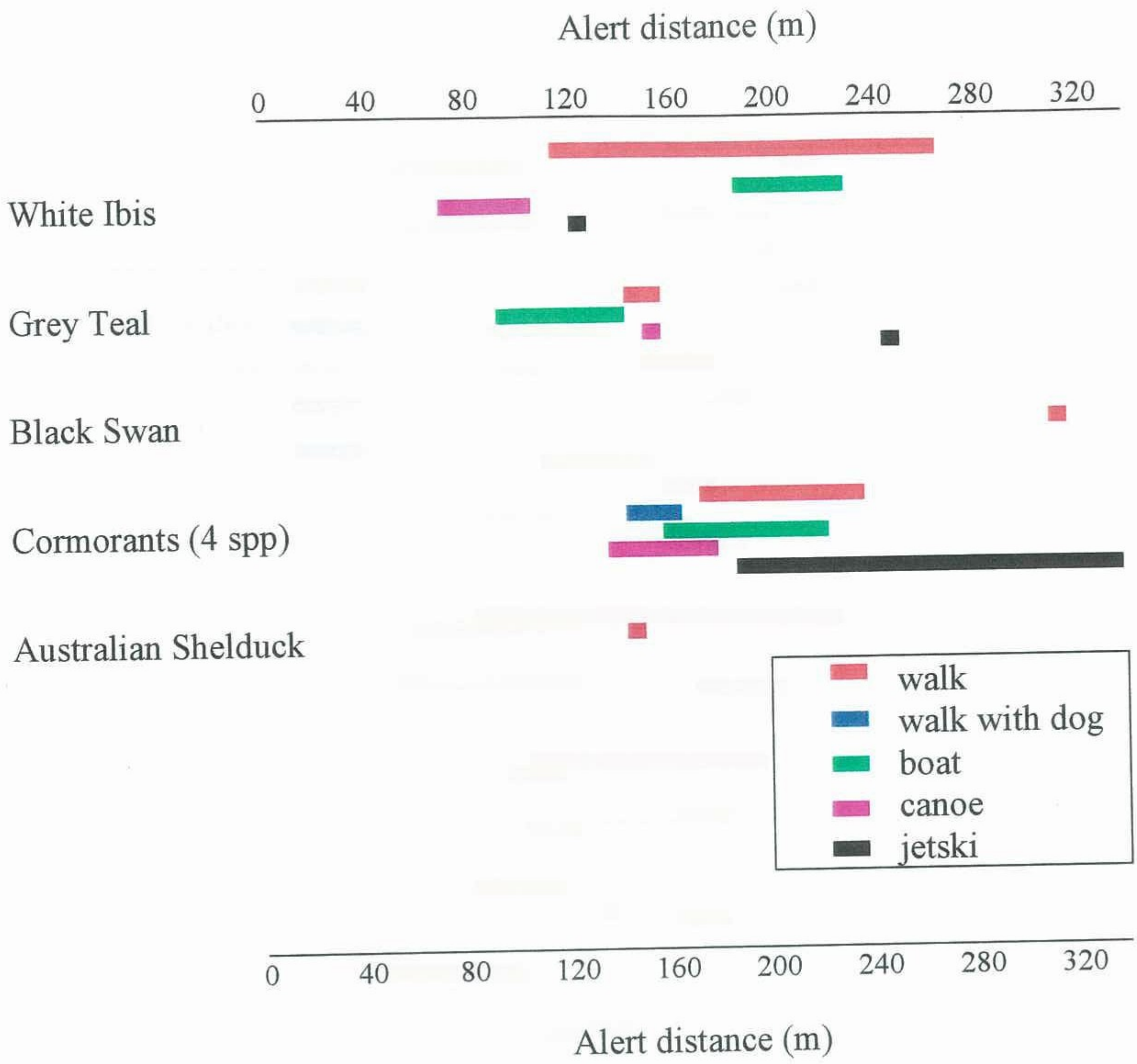

Figure 5. Ranges in distances at which different species of waterbirds showed a significant alert response to different types of disturbance.

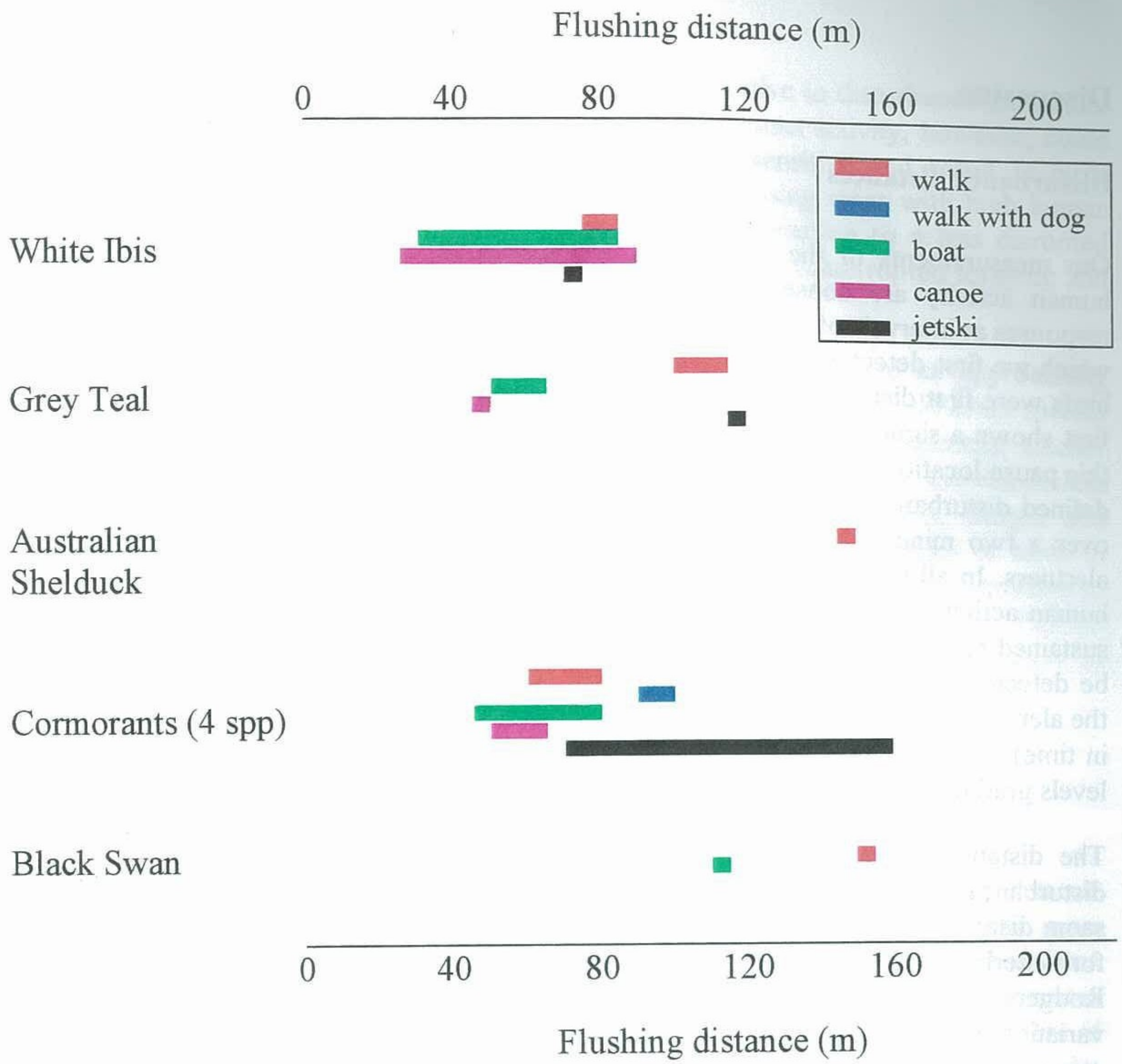

Figure 6. Ranges in distances at which different species of waterbirds took flight in response to different types of disturbance.

Discussion

Disturbance distances

Our measurements of the distances at which various waterbirds were disturbed by human activity are conservative for two reasons. First, we measured the birds' responses at intervals of 10 to 30 metres and not continuously and used the distance at which we first detected a significant response ($p < 0.05$) as the distance at which the birds were first disturbed. In reality the actual distance at which the birds would have first shown a significant response would have been at a distance somewhere between this pause location and the previous pause, 10 to 30 metres further away. Second, we defined disturbance distances as the distance at which the alert response of the birds over a two minute period was significantly higher than their baseline 'undisturbed' alertness. In all trials, however, the birds detected and responded to the presence of human activity well before this distance was reached, but the alert response was not sustained for sufficient time for a significant ($p < 0.05$) response over two minutes to be detected using non-parametric statistical comparisons. In general, the intensity of the alert response (proportion of birds in a flock showing alert behaviour at any instant in time) and the length of time that the flock's alertness was elevated above baseline levels gradually increased as human activity approached the birds (e.g. Figs 1,2).

The distances at which birds responded to disturbances varied with the type of disturbance, the species of bird and between flocks of the same species exposed to the same disturbance (Figs 3-6). Similar variability has been reported for flush distances for waterbirds in other studies (eg Burger 1991; Cayford 1993; Smit and Visser 1993; Rodgers and Smith 1995, 1997) and many factors are likely to contribute to the variation in response distances.

Within a species, the size and activity (eg roosting, foraging) of the flock at the time of the disturbance and the physical environment may both influence the distances at which birds respond. Flocks with more vigilant birds should detect an approaching danger earlier than other flocks. In our study, the numbers of vigilant birds within a flock varied from flock to flock and may have accounted for some of the variability in response distances. In general, larger flocks had more vigilant birds than smaller flocks, and more birds were vigilant when the birds were foraging than when they were roosting. The alert and flush distances might also depend on the proximity of other areas and the quality of these compared to the current area. When alternative areas of comparable quality are nearby the birds might respond and take flight at greater distances than when alternative areas are further away or of poorer quality. None of these factors, however, were considered in our study.

Frequent human activity in an area may also influence the distances at which the birds respond. Birds exposed to frequent human activity may become habituated and so not respond as quickly but there are no convincing data. Burger (1991), for example, measured flush distances and argued that migratory shorebirds and herons were more easily disturbed compared to other species, possibly because these migratory birds interacted less with humans compared with resident species. However our results for both alert and flush distances suggest the opposite. Migratory shorebirds particularly smaller species, like stints and sandpipers, were less sensitive to disturbance than other larger waterbirds (Figs 3-6). Frequent disturbance by human activity, however, could just as easily make the birds more, rather than less, sensitive and result in birds responding at greater distances. Waterbirds and waders using areas with high human activity would clearly benefit by responding early and departing to a less disrupted area. Doing this would provide them with longer periods of uninterrupted foraging and more efficient energy acquisition.

Despite the variability in the distances at which birds responded to an approaching disturbance, there were some obvious differences in the sensitivities of different species and in the responses of birds to different types of disturbance. In general smaller species were less sensitive to disturbances than larger species, and shorebirds less sensitive than other waterbirds (Figs 3-6). In contrast to these results, Burger and Gochfield (1991b) observed shorter flushing distances for larger species of birds in India. Amongst the shorebirds in our study, stints and sandpipers were less sensitive to disturbance than larger waders like Common Greenshanks, avocets and stilts. Eastern Curlews and Pied Oystercatchers were particularly sensitive, but not as sensitive as ducks and cormorants.

Influence of type of disturbance

Walking alone and canoeing were the least disruptive of the five activities that we presented to the birds, while walking with a dog and 'jet-skiing' were the most disruptive. Differences between boating, canoeing and 'jet-skiing' may have been related to the way these three activities were presented to the birds. Boat disturbances involved moving the boat to a stationary position and dropping an anchor (as if fishing). So boating involved less constant movement than canoeing where the canoeist continued to paddle slowly back and forth or in a tight circle. The 'jet-skiing' treatment involved much more erratic movements in a boat that mimicked the rapid and abrupt changes in direction typical of a jet-ski, and the birds may simply be responding to the type of movement. Our 'jet-skiing' treatment, however, is likely to underestimate the disruptive nature of jet-skis in that jet-skis are louder, faster and more manoeuvrable than a boat and expel a 4-6m jet of water.

Our simulation of a person walking a dog is also likely to underestimate this type of disturbance in that it only considered responses to a single dog on a leash and under firm control of one person. Often dogs are not on a leash and may move erratically or even run rapidly at and chase the birds. Thus an unconstrained dog, or someone walking with more than one dog even if on a leash, are both likely to increase the distance at which the birds respond. Similarly the birds may respond at greater distances when more than one person with or without a dog approaches a flock of birds simultaneously. Consequently our measures of responses to all types of disturbances should be used as minimums.

Other studies report differences in the flush distances of birds to different disturbances. For example, Rodgers and Smith (1995) found that flushing distances for waterbirds were generally shorter when the birds were approached by a person in a boat than when they were approached by a person walking. Similarly foraging waterbirds were more easily disturbed by foot traffic than vehicle traffic (Klein 1993) while boating activity generally caused least disturbance to Great Blue Herons (Vos *et al.* 1985).

Our measures of disturbance distances were all conducted on single species flocks and flushing distances for some species may increase when they flock with a more skittish species (Thompson and Thompson 1985; Stinson 1988; Rodgers and Smith 1995). For example, in mixed flocks of ducks, greenshanks and sandpipers, the ducks were the first to respond and subsequently flush thereby disturbing the other species well before the distance at which they would have responded if they were on their own (pers. observ.).

Buffer zones and managing human activity in areas used by waterbirds.

Management of human activity around important areas for wildlife usually involves restricting the type, frequency and proximity of different human activities in key areas for fauna. Successful implementation of any restrictions also depends on public acceptance which is likely to be linked to the current extent that humans use the area. The public are generally more likely to accept restrictions on their activities for areas where there is little human activity far easier than for areas where there is already extensive use. Unfortunately many coastal and estuarine wetlands around southern Australia are used extensively by humans and so the eventual management of the effects of human disturbance on waterbirds will undoubtedly be compromised. Possible compromises include: (i) establishing buffer zones around some but not all of the important sites for birds within a wetland system; (ii) having smaller than complete buffer zones that prevent the intensity of the disturbance but not the frequency; (iii) limiting the number of people recreating in areas to reduce the frequency of disturbances; or (iv) a combination of any of these. Key factors in these deliberations are how large the area needs to be to buffer the birds from unwanted disturbance, whether key areas are predictable in space and time, and whether the level of disturbance is a limiting factor for the birds or is likely to be a limiting factor for the birds some time in the future.

Numerous studies have attempted to assess the distances at which waterbirds become disturbed and have recommended buffer zones to protect them. These buffer zones are primarily based on the distances at which birds are flushed or take flight. Erwin (1989) using a formula based on the mean flushing distance (±SD) recommended a buffer distance of 100 metres for Least Terns and wading birds and 200 metres for Black Skimmers and Common Terns. Vos *et al.* (1985) recommended buffers zones of 150-250 metres for Great Blue Herons while Rodgers and Smith (1995,1997) suggested that buffer zones for waterbirds in Florida should be set at the mean flush distance plus 1.65 times the standard deviation of this mean (i.e. the distance at which only 5% of flocks would have taken flight) plus 40m. The additional 40 metres was based on qualitative observations that nesting birds generally became agitated 25-40 metres prior to flushing from the nest. Based on this formula, they recommended buffers of 100 metres for wading birds in nesting colonies, 180 metres for mixed tern/skimmer breeding colonies and 100 metres for foraging and loafing waterbirds for pedestrian, terrestrial vehicle and motor boat approaches in Florida.

In our study most species became alert well before taking flight with the mean distances between becoming alert and flushing ranging from 15-117 metres for various shorebirds and 47-164 metres for other waterbirds (Tables 1,2; Figs 3-6) depending on the species and type of disturbance. These results suggest that a distance of greater than 40m may need to be added to buffer zones that are based on mean flush distances.

Eliminating human disturbance of waterbirds completely would require setting buffer zones equal to the maximum distance at which the most skittish species responded to a disturbance. In our study this would result in a buffer zone with a radius of 347m, which would largely eliminate human recreation on and around many wetlands. Such a restriction is unlikely to be acceptable to the general community and a more realistic assessment of the effects of disturbance on the birds is required. The frequency with which the birds are disturbed, the length of time the birds remain disturbed and the type of response are also important. Disturbances clearly reduce the time birds can spend in other activities, like foraging and can result in birds flying to other possibly poorer areas to continue foraging or roosting. This not only adds to their daily energy expenditure but also reduces food intake if the new area is poorer.

In our study we can provide some indication of the time that the birds remain disturbed and the possible effects of this on the birds in terms of reductions in time available for other activities. For example, the numbers of vigilant birds in a flock of shorebirds (e.g. Curlew Sandpipers, Fig. 1) increased from a pre-disturbance level of around 2% to 20% for the first minute after a walker had approached to within 85 metres of the birds. Over the second minute, 6% of the birds remained alert but the level of their alertness was back to the baseline 2% for the third minute. If we assume this time reduces the time available to foraging and is spread evenly over the whole flock, then each bird loses on average 13.2 seconds of foraging each time a human walks to within 85 metres of the birds. This may seem trivial, but if there were 10 disturbances per hour (see below) then this amounts to losing 2.2 minutes of foraging each hour, the equivalent of 26.4 minutes over a 12 hour day. For migratory waders like Curlew Sandpipers losing 20 or more minutes of foraging time over a day may be critical, particularly if the birds need to fatten quickly prior to migration. Delays in departure for migratory waders can influence their ability to establish territories in the best areas on breeding grounds and affect their reproductive success (Parmalee and McDonald 1960; Clapham 1979; Metcalfe and Furness 1984).

Most disturbances however do not stop at 85 metres and may come much closer to the birds resulting in further losses in foraging time. For the Curlew Sandpiper example, a walker approaching within 58 metres would cost the sandpipers 25 seconds in foraging time. At 39 metres the birds would lose 60 seconds. If there were 10 such disturbances per hour this would be equivalent to losing 2 hours of foraging per day. If the walker comes even closer and the birds are flushed then not only do they lose foraging time but they also incur added costs in having to fly to a new location. If losses of 20 minutes in foraging time per day were considered to be significant then only 1.7 disturbances to within 39 metres per hour would be required to provide such a cost to the birds.

Our field simulations of disturbances, however, do not mimic a continuous approach by someone on foot, but consisted of a person walking and pausing at regular intervals.

Normally a person would walk along the shore at a more or less constant rate, come close to the birds and then walk past them. If we assume that Curlew Sandpipers first detected a person walking along the shore towards them at 85m and that the birds were in shallow water 30m off the shore line, then the person walking along the shore would remain within 30-85m of the birds for about 160m. Assuming this person walked at a speed of ~1m/sec then the birds could be disturbed for 160 seconds, and the number of birds showing an alert response at any one time would average around 50%. This is equivalent to individual birds losing around 80 seconds of foraging time each time someone walked past. This may slightly overestimate the time the birds are disturbed since several studies have suggested that a movement tangential to the birds is less disruptive than a direct approach (Burger and Gochfield 1981; Rodgers and Smith 1995). Furthermore the birds may return more quickly to baseline levels of alertness once the person has moved a safe distance past them particularly if they continue to move away. As a result of this they may only lose about a minute of foraging time each time a person walks past them within 30m. One or two such disturbances per hour then could easily reduce their foraging time by 20 or more minutes over a day.

Current levels of disturbance in the northern Coorong – Murray Mouth estuary area and management options

We have no accurate measures of the frequency with which birds are disturbed by humans in either of our study sites. However, approximately 15% of our trials in the northern Coorong-Murray Mouth region were disrupted by humans before they were completed. Given that a complete trial took approximately 20 minutes to complete, this rate of disturbance is equivalent to at least one significant disturbance every two hours (or ~0.5 disturbances per hour). On weekends the extent of human activity in this area was much higher than during week days such that we rarely found flocks that we could study and as a consequence sought an alternative site (Penrice Saltfields) where human activity was restricted. This suggests that on weekends at least the current level of human activity around the Murray Mouth estuary is already sufficient to disrupt many of the birds. Given that the Coorong and Murray Mouth region along with the Lower Lakes of the Murray River are listed as a Wetland of International Significance under the Ramsar convention, some attempt to minimise disturbance of waterbirds and manage human recreation in the area is required. This is even more important given that the level of human activity is likely to increase due to significant and ongoing human population growth in the region.

Habituation to human disturbance is often muted as a justification for allowing human recreational activity to continue with no controls on the types, frequency or areas where human recreation takes place. However, there is no strong evidence of habituation of waterbirds to human recreation, so arguments that birds will habituate to human activity should be ignored until solid evidence is provided not just for a few species but for all species of waterbird. This is particularly so for wetlands associated with the Murray Mouth, Hindmarsh Island and northern Coorong where there is some historical evidence of a wide range of waterbirds declining in recent years coincident with increased human presence in the area (Paton *et al.* 1989; Pedler 1994). For example, Paton *et al.* (1989) provided evidence that 27 species of waterbird had shown at least a 10% and often a 20% decrease in the frequency with which they were recorded in the area since the 1970s. Pedler (1994) recorded further declines in selected waterbirds, particularly some of the larger waders and reported that small waders typically flew about 100m when flushed, but continued approaches or prolonged disturbances resulted in the birds flying greater distances. Both Paton *et al.* (1989) and Pedler (1994) also reported that the greatest concentrations of waterbirds were in areas that experienced the least disturbance from humans, suggesting that the birds could be displaced from areas that experienced high human activity. Given this, wildlife managers in this region should probably guard against birds becoming increasingly sensitised (rather than habituated) to human disturbance. The best way of doing this is to prevent further increases in human activity, if not restrict the level of activity, in key areas until sufficient evidence for or against habituation has been obtained.

Effective management of human disturbances to waterbirds will require educating the community about the need for minimising disturbances and implementing some simple management guidelines. Although there are differences in the distances at which birds respond to different human activities and differences between species in the distances at which they respond, implementing different buffer zones for different species and different recreational activities is likely to confuse the general public. Instead the same-sized buffer zones should be established around each of the key sites irrespective of the types of birds or types of disturbance since this will be the least confusing for the general public. Based on our observations a buffer zone of approximately 150-200m will be required around key sites to eliminate disturbances for most species of waterbird and/or limit the extent of the disturbance for the most sensitive species. Such a distance is beyond the distances at which the most sensitive species are likely to take flight and generally beyond the distance at which most species first show a significant alert response (Tables 1,2). These distances are similar to the distances recommended for buffer zones in other countries where buffer zones are typically between 100 and 200m at least for colonies of breeding birds (Erwin 1989; Buckley and Buckley 1976; Vos *et al.* 1985; Rodgers and Smith 1995, 1997). Birds that are nesting, however, usually flush at closer distances than flocks of roosting or foraging birds. This is presumably because there are additional selective pressures on breeding birds to remain at nests for as long as possible to brood and protect eggs and nestlings from changes in temperature and/or predators (Rodgers and Smith 1995,1997).

For the Coorong-Murray Mouth estuary region, key areas used by birds should now be identified and buffer zones of 150-200m established around them immediately (even if the frequency of disturbance in some of these areas is low). This will protect these key areas from current and future increases in disturbances. These prohibited zones could be indicated with appropriate signs erected around the perimeter of the buffer zones. Given that some of the waterways in this region are narrow, some compromise with respect to the sizes of the buffer zones may be required in areas where current human activity is high, particularly if this activity cannot be shifted to other areas of less importance to the birds. For example, deepwater channels along waterways may need to be excepted from buffer zones to allow safe boat passage, or alternatively human recreational activity limited to one side of the waterway. Other exceptions might include walking paths that are hidden from waterbirds behind vegetation being permitted to encroach on buffer zones

.

Acknowledgments

This project was funded by a grant from the Migratory Waterbird component of the National Wetlands Program of Environment Australia. Richard Owen provided accommodation while fieldwork was being conducted in the Coorong region, and the Department of Evironmental Biology at the University of Adelaide provided field equipment and laboratory space. The project was conducted with approval from the University of Adelaide's Animal Ethics Committee (project approval #S/24/98).

References

Anderson, D. W. (1988). Dose-response relationship between human disturbance and Brown Pelican breeding success. *Wildlife Society Bulletin* **16,** 339-345.

Bamford, A. R., Davies, S. J. J. and Van Delft, R. (1990). The effects of model power boats on waterbirds at Herdsman Lake, Perth, Western Australia. *Emu* **90,** 260-265.

Bell, D. V. and Fox, P. J. A. (1991). Shooting disturbance: An assessment of its impact and effect on overwintering waterfowl populations and their distribution in the United Kingdom.

Buckley, P.A. and Buckley, F.G. (1976) Guidelines for the protection and management of of colonially nesting waterbirds. North Atl.Reg.Off., Natl Park Serv., Boston, Mass.

Burger, J. (1981). The effect of human activity on birds at a coastal bay. *Biological Conservation* **21,** 231-241.

Burger, J. (1991). Foraging behaviour and the effect of human disturbance on the Piping Plover (*Charadrius melodus*). *Journal of Coastal Research* **7,** 39-52.

Burger, J. and Gochfeld, M. (1991a). Human activity influence and nocturnal foraging of sanderlings (*Calidris alba*). *Condor* **93,** 259-265.

Burger, J. and Gochfeld, M. (1991b). Human disturbance and birds: tolerance and response distances of resident and migrant species in India. *Environmental Conservation* **18,** 158-165.

Burger, J. and Gochfeld, M . (1998). Effects of ecotourists on bird behaviour at Loxahatchee National Wildlife Refuge, Florida. *Environmental Conservation* **25,** 13-21

Cayford, J. (1993). Wader disturbance: a theoretical overview. *Wader Study Group Bulletin* **68,** 3-5.

Clapham, C. (1979). The turnstone populations of Morecambe Bay. *Ringing*

Migration **2,** 144-150.

Davidson, N. C. (1991). Human activities and wildlife conservation on estuaries of different sizes; a comment. *Aquatic Conservation* **1**, 89-92.

Davidson, N. C. and Rothwell, P. I. (1993b). Human disturbance to waterfowl on estuaries: conservation and coastal management implications of current knowledge. *Wader Study Group Bulletin* **68,** 97-105.

Erwin, M. R. (1980). Breeding habitat use by colonially nesting waterbirds in two mid-Atlantic US regions under different regimes of human disturbance. *Biological Conservation* **18,** 39-51.

Erwin, M. R. (1989). Responses to human intruders by birds nesting in colonies: experimental results and management guidelines. *Colonial Waterbirds* **12,** 104-108.

Fox, A. D., Jones, T. A., Singleton, R. and Agnew, D. Q. (1994). Food supply and the effects of recreational disturbance on the abundance and distribution of wintering Pochard on a gravel pit complex in southern Britain. *Hydrobiologia* **279,** 253-261.

Goss-Custard, J. D. (1980). Competition for food and interference among waders. *Ardea* **68,** 31-52.

Goss-Custard, J. D. and Charman, K. (1976). Predicting how many wintering waterfowl an area can support. *Wildfowl* **27,** 157-158.

Goss-Custard, J. D., Durell, S. E. A., McGorty, S. and Reading, C. (1982). Use of mussel, *Mytelis edulius* beds by oystercatchers, *Haematopus ostralegus,* according to age and population size. *Journal of Animal Ecology* **51,** 543-554.

Goss-Custard, J. D. and Verboven, N. (1993). Disturbance and feeding shorebirds on the Exe estuary. *Wader Study Group Bulletin* **68,** 59-66.

Greig-Smith, P. (1981). Responses to disturbance in relation to flock size in foraging groups of Barred Ground Doves *Geopelia striata. Ibis* **123,** 103-106.

Hunt, G. L. (1972). Influence of food distribution and human disturbance on the reproductive success of herring gulls. *Ecology* **53,** 1051-1061.

Klein, M. L. (1993). Waterbird behavioural responses to human disturbances. *Wildlife Society Bulletin* **21,** 31-39.

Lane,B.A. (1987). Shorebirds in Australia. Nelson, Melbourne

Lazarus, J. (1979). The early warning function of flocking in birds: an experimental study with captive Quelea. *Animal Behaviour* **27,** 855-865.

Metcalfe, N. B. and Furness, R. W. (1984). Changing priorities: the effect of pre-migratory fattening on the trade-off between foraging and vigilance. *Behavioural Ecology and Sociobiology* **15,** 203-206.

Owen, M. (1993). The UK shooting disturbance project. *Wader Study Group Bulletin* **68,** 35-46.

Paton, D.C., Pedler, L.P. and Pedler, J.A. (1989). An assessment of the avifauna of Hindmarsh Island. Unpubl. report. Dept of Environment & Planning, Adelaide.

Pedler, L.P. 1994. Waterbirds of the Murray Mouth region, February 1994. Unpubl.

report. Dept of Environment & Planning, Adelaide.

Parmalee, D. F. and MacDonald, S. D. (1960). The birds of west-central Ellesmere Island and adjacent areas. *National Museum of Canada Bulletin* **169**.

Pfister, C., Harrington, B. A. and Lavine, M. (1992). The impact of human disturbance on shorebirds at a migration staging area. *Biological Conservation* **60,** 115-126.

Pierce, G. J., Spray, C. J. and Stuart, E. (1993). The effect of fishing on the distribution and behaviour of waterbirds in the Kukut area of Lake Songkla, southern Thailand. *Biological Conservation* **66,** 23-34.

Roberts, G. and Evans, P. R. (1993). Responses of foraging sanderlings to human approaches. *Behaviour* **126,** 29-43.

Rodgers, J. A. and Smith, H. T. (1995). Set-back distances to protect nesting bird colonies from human disturbances in Florida. *Conservation Biology* **9,** 89-99.

Rodgers, J. A. and Smith, H. T. (1997). Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. *Wildlife Society Bulletin* **25,** 139-145.

Salvig, J. C., Laursen, K. and Frikke, J. (1994). Surveys of human activities and their effects on numbers and distribution of waterfowl in the Danish Wadden Sea. *Ophelia Supplement* **6,** 333-337.

Smit, C. and Visser, G. J. M. (1993). Effects of disturbance on shorebirds: a summary of existing knowledge from the Dutch Wadden Sea and Delta area. *Wader Study Group Bulletin* **68,** 6-19.

Stinson, C.H. (1988). Does mixed species flocking increase vigilance or skittishness? *Ibis* **130**, 303-304.

Thompson, D. B. A. and Thompson, M.L.P. (1985). Early warning and mixed species association: the 'Plover's Page' revisited. *Ibis* **127,** 559-562.

Tuite, C. H., Hanson, P. R. and Owen, M. (1984). Some ecological factors affecting winter wildfowl distribution on inland waters in England and Wales, and the influence of water-based recreation. *Journal of Applied Ecology* **21,** 41-62.

Van Der Meer, J. (1985). De verstoring van vogels op de slikken van de Oosterscheide. Report 85.09 Deltadienst Milieu en Inrichting. Middelburg: 37 pp

Vos, D.K., Ryder, R.A., and Grand, W.D. (1985). Response of gret blue herons to human disturbance in corthcentral Colorado. *Colonial Waterbirds* **8**, 13-22.

Yalden, P. E. and Yalden, D. W. (1990). Recreational disturbance of breeding Golden Plovers *Pluvialis apricarius*. *Biological Conservation* **51,** 243-262.