Corella, 2001, 26(2): 33–37

DAY-NIGHT HABITAT USE BY DOUBLE-BANDED PLOVERS *Charadrius bicinctus* IN THE RICHMOND RIVER ESTUARY, NORTHERN NEW SOUTH WALES

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Received: 25 May 2001

Night and day habitat use by Double-banded Plovers *Charadrius bicinctus* was studied in the Richmond River estuary, northern New South Wales. Habitat use was documented through direct observation of birds at two intertidal sandflats and by radio-tracking four birds. Comparison of plover density between day and night failed to record a significant difference. However, radio-telemetry identified substantial differences in habitat use between the two time periods for two birds. At night some Double-banded Plovers responded to the improved visual conditions provided by artificial lights from urban areas by moving to mudflats that received high amounts of artificial light. During the full moon phase plovers were recorded at a greater number of sites, including sites that received no artificial light.

INTRODUCTION

The Double-banded Plover *Charadrius bicinctus* is a small shorebird that breeds in New Zealand during summer. After breeding, part of the population migrates to Australia where they spend the winter months (Lane 1987). Although recorded as far north as Cairns in Queensland and in the south-western corner of Western Australia the majority of Double-banded Plovers reside in southeastern Australia (Marchant and Higgins 1993). Double-banded Plovers are known to utilize a variety of habitat types although the majority of individuals utilize coastal areas particularly intertidal habitats in estuaries and on ocean beaches (Marchant and Higgins 1993).

Despite the regular occurrence of this species and its widespread distribution in Australia, there is limited information regarding its use of intertidal foraging habitats, and in particular its nocturnal behaviour. Dann (1991) provided baseline information on nocturnal behaviour and suggests that Double-banded Plovers may utilize a different feeding technique at night. Information on the nocturnal activity of shorebirds is not only important to understand daily energy requirements, it is also essential for the management of species and their habitats (McNeil 1991; Dodd and Colwell 1998).

Current evidence suggests that some species of shorebird may utilize different habitats and/or sites at night to those used during the day (Robert *et al.* 1989; McNeil *et al.* 1992; Rohweder and Baverstock 1996). Changes between day and night may involve the use of different habitats, or the use of different sites but the same habitat.

Changes in the use of different sites at night are also of critical importance as current management focuses on the number of species and individuals recorded at a specific site during the day. The aim of the present study was to collect information on habitat use by Double-banded Plovers to determine if individuals utilized the same sites between day and night.

STUDY AREA AND METHODS

Study area

Habitat use by Double-banded Plovers was studied in the Richmond River estuary, northern New South Wales (Fig. 1). Direct observations of birds were made at two intertidal sandflats within the estuary, Mobbs Bay and RSL (Fig. 1). Both sandflats were characterized by a sandy substratum and at night received some artificial light from the township of Ballina. RSL, which is situated close to the town centre received higher levels of artificial light than Mobbs Bay. The Double-banded Plover population in the Richmond River estuary was estimated at 60 individuals during the period of the survey. During day high tides birds congregated into a single flock, roosting either on the Serpentine sandflat or at South Ballina Beach. The main nocturnal roosts was undetermined (Rohweder 2001), although mist netting at Serpentine at night suggested at least some individuals may use this site.

Methods

The density of plovers was compared in 0.5 hectares quadrats at two feeding areas, Mobbs Bay and RSL. The number of plovers was counted at 10-minute intervals over a four-hour period surrounding low tide. During each 10-minute observation the number of birds within the quadrat was counted and the microhabitat used by each individual recorded. Microhabitats included dry sand, moist sand, and the water edge. A distinction was made between individuals that were foraging, and those that were loafing. Birds that were walking through the quadrat or were alert were regarded as foraging. A minimum of forty observation periods was conducted at each site, 20 during the day and 20 at night.

Observations were scheduled around the four lunar phases, with each site visited during each lunar phase. Daytime observations were made using a 20 × 80 millimetres spotting scope, and night observations were made using a combination of the spotting scope, a Litton GEN III image intensifier and a 50-watt spotlight with an infrared filter. Observations were conducted between May and June 1995 and May and July 1997.

A range of abiotic variables was measured at hourly intervals during each observation period. Air temperature in °C was measured at 15

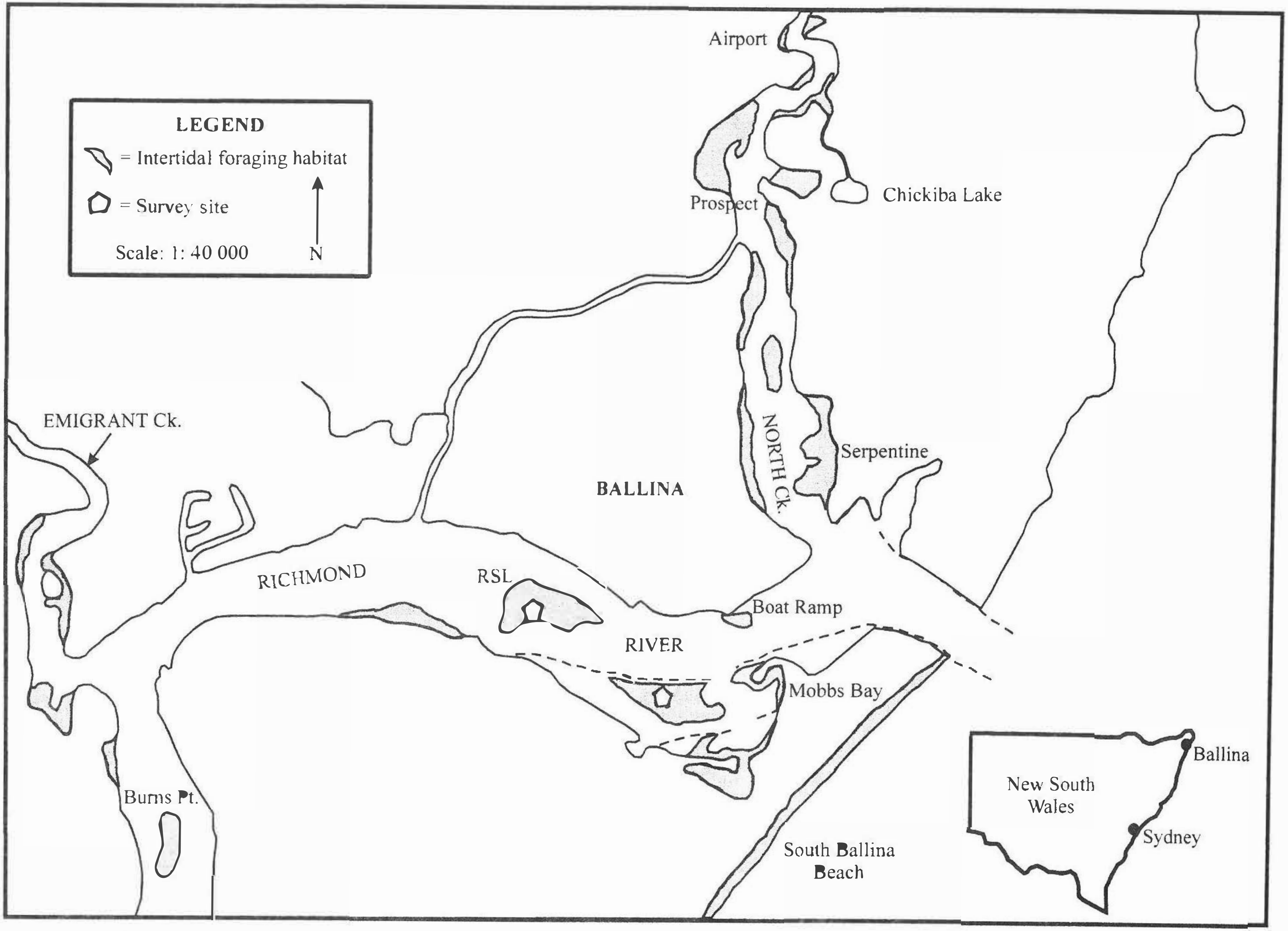

Figure 1. *Map of the Richmond River estuary, showing the location of observation sites and the mudflats used by radio-tagged Double-banded Plovers.*

centimetres above the substratum, and substratum temperature (°C) was measured at a depth of 5 centimetres. Both temperature measures were taken from the observation points, which were situated on the same substratum type approximately 10 metres from the quadrats. Wind direction was assessed using a compass, and wind speed was estimated using a subjective scale from 1–4; 1 = nil, 2 = light (light rippling of the water), 3 = moderate (small chop produced on the water), 4 = strong (waves and swell on the water and water in shallow pools ripples).

Cloud cover was recorded as the percentage of sky covered. Rainfall was recorded as either present or absent. Nocturnal visibility was assessed on a subjective scale (good, moderate, poor) using the quadrat marker pegs as a guide. Visibility was regarded as good when the marker pegs at the rear of the quadrat were visible with the naked eye, and poor when the marker pegs at the front of the quadrat were only just discernible with the naked eye. The presence or absence of disturbance by people and raptors was recorded as it occurred.

Radio telemetry

Birds were mist netted at night, at two sites, Mobbs Bay and Serpentine. Mist netting at Mobbs Bay was undertaken on the falling tide, with nets opened as the sandflats became exposed. Mist netting at Serpentine was conducted at high tide on one night.

Single-stage radio-transmitters (Titley Electronics) were attached to four Double-banded Plovers as per the method described by Rohweder (1999). The position of radio-tagged plovers was determined at mean low water during the day and night over at least three consecutive days during each of the four lunar phases. Data collection commenced after a three-day 'settling in' period had elapsed. After a bird was located on a particular mudflat, its position was determined by taking a number (usually three) of fixes at different points around the mudflat. Birds that were not detected during a low tide survey were thought to be using habitats outside the study area, and their position was recorded as 'unknown'.

Data analysis

Quadrat density estimates were calculated by dividing the total number of birds counted during one observation period by the total number of 10-minute observations within that period. Only those individuals that were foraging were included in the density estimates. To ensure that the variances were homogeneous, mean densities were transformed using the square root transformation (Sokal and Rohlf 1981). Data were analysed using two-way Repeated Measures Analysis of Variance in Statview 4.0 (Abacus Concepts 1992). Variables used in the analysis included: day or night; height of low tide (0.1–0.4 m and 0.5–0.7 m); lunar phase (new, full, first quarter and last quarter moons); and night visibility (good, moderate, poor).

Each of the dependent variables were analysed with day/night to determine if significant differences existed between the two time periods, and to identify possible interactions between day/night and the dependent variables. Data for each quadrat were analysed separately.

Environmental variables were analysed using partial correlation analysis in Statview 4.0. Environmental variables used in the analysis included cloud cover (%), substratum temperature (°C), air temperature (°C), and wind speed. During partial correlation analysis day and night were analysed separately in an attempt to identify possible environmental factors that influenced habitat use during each time period.

RESULTS

Frequency of occurrence

Double-banded Plovers were present in a similar proportion of day (100%) and night (95%) observations at RSL, but were more frequently recorded at night (75%) than during the day (60%) at Mobbs Bay. Comparison between each month of the survey provided varied results. Double-banded Plovers were recorded in 100 percent of day and night observations at RSL in May and June, but were present in only 86% of night observations in July.

At Mobbs Bay, Double-banded Plovers displayed considerable variability in their frequency of occurrence between day and night, and between months. Double-banded Plovers were recorded in only 29 per cent of day observations but 100 per cent of night observations in May. The reverse trend occurred in June when Double-banded Plovers were present in 83 per cent of day observations but only 62 per cent of night observations. Double-banded Plovers were present in a similar proportion of observations at day (71%) and night (75%) in July.

Comparison of density

The density of plovers did not vary significantly between day and night (d/n) at either RSL or Mobbs Bay (Table 1). The only significant difference was recorded between lunar phases at Mobbs Bay, with a greater density of birds present during new and full moons than quarter moons ($p = 0.03$; df 3, 16; $F = 3.839$). No significant differences were recorded for the interaction between d/n and lunar phase, or between d/n and tide height or night visibility (Table 2). The total number of plovers using each site

TABLE 1

Average density of Double-banded Plovers recorded during day and night, at two sites in the Richmond River estuary. SE = standard error, n = sample size. Density = the number of birds/0.5 hectares.

Site		Density Day	Night
Mobbs Bay	Mean	0.89	0.54
	SE	0.22	0.12
	n	20	20
RSL	Mean	1.95	1.55
	SE	0.17	0.17
	n	20	20

TABLE 2

Average density (No./0.5 ha) of Double-banded Plovers recorded at two sites in the Richmond River estuary at day and night during the full, new, and quarter moon phases, spring and neap tides, and at different visibilities. SE = standard error, n = sample size, na = not applicable.

Variables			Time Day	Night
Lunar Phase	Full Moon	Mean	1.64	1.25
		SE	0.3	0.17
		n	10	10
	New Moon	Mean	1.9	0.82
		SE	0.33	0.37
		n	10	10
	First Quarter	Mean	1.01	0.84
		SE	0.33	0.23
		n	10	10
	Last Quarter	Mean	1.1	1.24
		SE	0.27	0.26
		n	10	10
Tide	Spring Tide	Mean	1.47	1.03
		SE	0.24	0.22
		n	14	19
	Neap Tide	Mean	1.4	1.05
		SE	0.21	0.16
		n	26	21
Visibility	Good	Mean	*na*	1.29
		SE	*na*	0.17
		n	*na*	15
	Moderate	Mean	*na*	1.16
		SE	*na*	0.27
		n	*na*	15
	Poor	Mean	*na*	0.47
		SE	*na*	0.13
		n	*na*	10

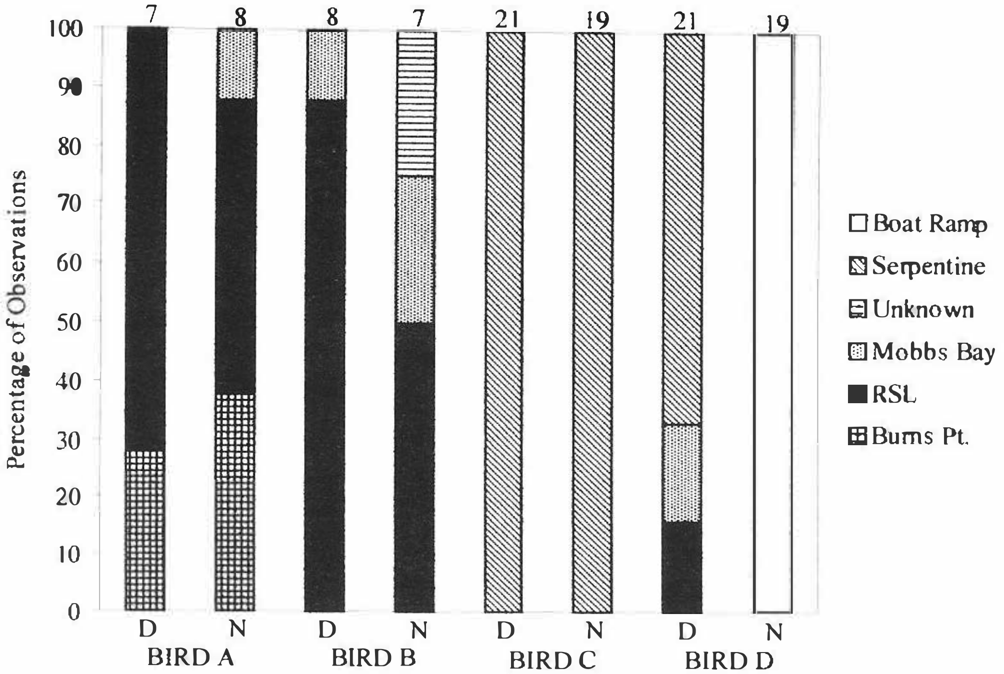

Figure 2. *Habitats used during the day and night by four Double-banded Plovers radio-tracked in the Richmond River estuary. The number of fixes is shown above each error bar. One fix = one low tide period. D = day, N = night*

varied between surveys. The number of individuals recorded at Mobbs Bay ranged from 0 to 11, whilst the range at RSL was 0 to 8. Zero values were recorded only at night.

Environmental variables

Three significant ($P < 0.05$) correlations were recorded between the density of plovers and environmental variables. A significant negative correlation was identified between substratum temperature and Double-banded Plover density (-0.459) during the day at Mobbs Bay. A significant positive correlation was recorded between plover density and air temperature at the same site (0.452). At RSL a significant positive relationship was recorded between cloud cover and plover density (0.481).

Radio-telemetry

Each of the plovers that were radio-tracked displayed differences in habitat use between day and night (Fig. 2). Birds A and B displayed distinct movements in relation to the lunar phase, foraging predominantly at the RSL during dark nights, but moving to other sites, such as Burns Point or Mobbs Bay during the full moon when visibility was good (Fig. 1). Although bird C foraged at Serpentine during both the day and night this individual used different parts of the mudflat between the two time periods. During the day bird C always foraged on the northern edge of the mudflat, but moved to the southern edge to forage at night (Fig. 1). The southern edge of the Serpentine mudflat receives greater amounts of artificial light. Bird D foraged predominantly at Serpentine during the day but spent all nights feeding at the Boat Ramp sandflat, in an area that received large amounts of artificial light.

DISCUSSION

Double-banded Plovers foraged mainly on sandy habitats that had a light film of water at low tide. This result is similar to Dann (1991) who found that Double-banded Plovers in Victoria spent 88 per cent of each low tide period foraging on moist sandy areas. In the Richmond River estuary Double-banded Plovers were also recorded using dry sandy habitats and occasionally seagrass beds. No evidence of birds using saltmarsh habitats or pastures was recorded during the study (Lane 1987; Dann 1991), although one radio-tagged Double-banded Plover could not be found in the estuary during two night low tides. This individual could have been foraging in pastures or saltmarsh adjacent to the estuary.

The focus on low-tide observations means that the use of different habitats during mid-tide periods would be undetected, particularly at night. Regular observations at high-tide during the day always recorded the entire flock of Double-banded Plovers roosting within the estuary, and casual observations suggested that birds moved directly from high tide roosts to intertidal feeding areas. The use of alternate habitats at mid-tide seems unlikely, at least during the day.

A variety of reasons have been suggested to explain why shorebirds use different feeding habitats between day and night, including changes in the availability of prey (Dugan 1981; McNeil *et al.* 1992), predator avoidance (Robert *et al.* 1989; Thibault and McNeil 1994, 1995), human avoidance (Burger and Gochfeld 1991), and artificial light (Rohweder and Baverstock 1996). The movement of radio-tagged Double-banded Plovers to sites close to artificial light suggests a response by at least some individuals to take advantage of the improved nocturnal feeding conditions created by increased light levels.

The visual method of foraging used by plovers means that they are likely to benefit from increased visibility at night. Increased light levels at night may enable plovers to increase their feeding rate above that which they can achieve during low light levels. A small number of studies have identified changes in the foraging behaviour of plovers in relation to the lunar phase (Pienkowski 1983; Thibault and McNeil 1995), with birds achieving the highest feeding rates during the full moon when visibility is at its greatest (Pienkowski 1983). Given the influence of lunar phase on foraging it seems likely that plovers would benefit from artificial light, which creates conditions similar to the full moon.

The results of the present study indicate that nocturnal habitat selection by Double-banded Plovers is influenced by ambient light levels, and in the Richmond River estuary by artificial light from urban areas. The results suggest that Double-banded Plovers take advantage of the improved visual conditions provided by artificial light from the township of Ballina by moving to areas that receive large amounts of artificial light. The radio-tagged birds did not actually change the habitats used at night but they did change their feeding site.

Another possible explanation for the differences recorded by radio-tagged birds may be avoidance of human disturbance. During the day plovers may prefer to forage at Boat Ramp and along the southern edge of Serpentine but are prohibited from doing so by high levels of human activity. Although this is possible neither of these sites received high levels of human activity during the period of the survey.

Despite the fact that some individuals displayed distinct changes in habitat use the results suggest that not all individuals capitalize on increased nocturnal visibility. Although the average density of plovers was less at night at both RSL and Mobbs Bay a significant difference in density did not occur between day and night at either site, and two of the four plovers radio-tracked used similar sites between day and night. There are a variety of reasons why some individuals may take advantage of increased nocturnal light levels, whilst others may not.

Some possible reasons include:

1) The presence of territorial birds that may prefer to defend the same feeding territories during both the day and night to maximize food intake via site familiarity, and by reducing the prey response to feeding birds (Dugan 1982; Dann 1991).

2) Age-related differences in familiarity with foraging habitats, and competitive ability. Older birds may be more familiar with habitats within the estuary, and are therefore at an advantage over young birds.

3) Limitations imposed by the area of habitat on the number of birds that can exploit enhanced visual conditions. Greater visibility may increase the level of intraspecific competition as the chances of more than one individual seeing and competing for the same prey item is likely to be increased (Turpie and Hockey 1993).

4) Some individuals may have a higher energy demand because they fed less efficiently during daylight. This could be related to a number of factors including breeding condition and disturbance during the day by humans.

The failure to record a significant difference in the density of plovers at RSL and Mobbs Bay, and the similar pattern of habitat use displayed by two of the radio-tagged birds may be due to the fact that these birds already achieved satisfactory feeding rates at night by foraging at the same sites. Both RSL and Mobbs Bay receive some artificial light, which may be sufficient for birds to not bother about moving to alternate sites. The variable habitat use displayed by some birds may also be due to the fact that birds obtain most of their daily energy intake during daytime low tides, and forage at night only to supplement daytime intake.

ACKNOWLEDGMENTS

The authors would like to thank David Charley for assistance with mist netting. Work was conducted under licence number A793 with approval from the Southern Cross University Animal Care and Ethics Committee.

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