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COVER: *A group of waders (Bar-tailed Godwit, Great Knot, Mongolian Plover) at Lee Point (A Hertog)*

Effect of large herbivore exclusion on understorey biomass in three plant communities on Cobourg Peninsula

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Abstract

Gurig National Park on Cobourg Peninsula supports the only Australian feral herd of Banteng *Bos javanicus*. Previous correlative surveys suggested that the feral Banteng have a minor impact on the native vegetation in the Park. Three year experimental exclusion of large herbivores at one site on the largely treeless coastal plains suggested that grazing had no significant effect on the herb biomass compared to an adjacent unfenced plot. However herb biomass in fenced eucalypt savanna and savanna-rainforest ecotone communities was significantly greater than that in unfenced plots. These results indicate that eucalypt savanna and rainforest ecotone communities are an important food source for large herbivores, and that the previously observed high density of Banteng signs on the coastal plains may be unrelated to total food supply.

Introduction

Banteng *Bos javanicus*, a south-east Asian bovine, became feral on the Cobourg Peninsula following the failure of a British settlement in the late 1840s. Unlike buffalo *Bubalis bubalus*, the Banteng populations have grown slowly with an estimated current population of about 3,500 beasts on Cobourg Peninsula, although they occur at density greater than that reported from native habitats (Freeland 1990). For unknown reasons the Banteng have never spread far from their point of introduction (Bowman 1993a).

A previous survey of twelve habitats on Cobourg Peninsula revealed that signs and impacts of Banteng are focused on treeless coastal plains and monsoon rainforests (Bowman & Panton 1991). Banteng are thought to graze preferentially the treeless plains at night and retreat to the cover of the rainforest during the day (Calaby & Keith 1974). Bowman & Panton (1991) found that Banteng signs were least conspicuous in *Eucalyptus* savanna which comprises over 95% of the vegetation coverage on the Peninsula.

Bowman & Panton (1991) noted that their interpretations were based on correlative evidence and suggested that firmer conclusions would require experimental

studies. Here I report the results of two field experiments. I describe the effect of exclusion of large herbivore on: (1) herb biomass on treeless coastal plains; and (2) herb biomass across the boundary between monsoon rainforest and eucalypt savanna. Spotlight surveys and field traverses demonstrated that the primary large herbivores at Cobourg Peninsula were Banteng, the remainder being macropods.



PLATE 1 *Dead Banteng in late dry season, Cobourg Peninsula (D Bowman)*

Methods

Cover estimates were made at the start of the experiments because they are non-destructive, albeit less accurate than direct measurement of biomass. At the conclusion of the experiment biomass was harvested from the plots for which cover estimates had been made three years earlier. No attempt was made to determine floristic changes because many species were unrecognisable at the time of sampling.

Large herbivore exclusion on coastal plains

The vegetation on the coastal plains was dominated by the sedges *Bulbostylis barbata* and *Fimbristylis* sp., the grasses *Sorghum plumosum* and *Perotis rara* and the forbs *Ptilotus conicus* and *Borreria* sp. (see Bowman *et al.* 1990 for a description of

this community). In an area of homogeneous vegetation on the coastal plains, near the airstrip on Cobourg Peninsula, two 50 m x 50 m plots were established spaced 50 m apart from each other. One plot was fenced with pigmesh wire to exclude large herbivores. Fire breaks were graded around the perimeter of the plots.

In June 1988 the percentage cover of vegetation was estimated for 25 0.5m x 1.0m quadrats, using a modified cover abundance scale. The quadrats were systematically set out 5m apart in a permanently marked 20m x 20m grid located in the centre of each plot. In May 1991 the herb layer at each quadrat was harvested to determine total herb biomass following oven drying of the samples for 24 hours at 60°C.

Herbivore exclusion on a fire protected Eucalyptus savanna boundary

In 1988 two parallel 150m transects, spaced 100m apart, were established at right angles to a monsoon rainforest boundary. The plant communities along these transects comprised *Eucalyptus* savanna, rainforest ecotone and dry monsoon rainforest as defined by Bowman (1993b). The herb layer in the *Eucalyptus* savanna and rainforest ecotone was dominated by a variety of perennial grasses including *Sorghum plumosum*, *Heteropogon contortus*, *Chrysopogon latifolius*, and *Setaria uerwosa*. Numbered steel pickets were placed every 5m along both transects. A rectangular pigmesh fence was built around one transect. In June 1988 the total percentage cover of herbaceous vegetation was assessed in two contiguous 1m x 4m quadrats located at each 5m mark along the transects. In June 1991 the herb layer from three 0.5m x 1.0m quadrats was harvested at each 5 m mark on each transect to determine the herb biomass following oven drying at 600 C for 24 hours.

Data analysis

Non-parametric Wilcoxon tests were used to test the following null hypotheses: (1) that there were no differences between cover of herbs on the two plots on the coastal plains at the time of establishing the fencing experiment; (2) that three years of large herbivore exclusion caused no difference in the herb biomass on these plots; (3) that there was no difference in the cover of herbs in (savanna and ecotone communities) on the rainforest boundary at the time of establishing the fencing experiment. No comparison was made for the rainforest community as there are no herbs on the forest floor; and (4) that three years of herbivore exclusion caused no difference in the herb biomass in the savanna and ecotone.

Results

There was no significant difference ($P > 0.05$) between the fenced and unfenced plots in the mean herb cover at the time of establishing the experiment (Table 1).

After three years the mean herb biomass was not significantly different ($P > 0.05$) between the unfenced and fenced plots (Table 1). There was no significant difference ($P > 0.05$) between fenced and unfenced plots in the mean total cover of herbs of either the eucalypt savanna or rainforest ecotone at the time of establishing the experiment (Table 2). Mean total biomass was significantly greater on the fenced transect than the unfenced transect after three years of herbivore exclusion (Table 2).

Discussion

This study shows that large herbivores have a significant impact on herb biomass in eucalypt savanna and rainforest ecotone. One positive consequence of this biomass removal may be a reduction of fire intensities on the rainforest boundary.

TABLE 1 Mean (and standard error) of percentage herb cover in fenced and unfenced plots on treeless coastal plains in 1988; and total herb biomass in 1991. Significance of differences between plots for each year of measurement are determined by Wilcoxon tests.

	Fenced	Unfenced	Significance
Herb cover (%)	34 (1.9)	36 (1.5)	$P > 0.05$
Herb biomass (gm^{-2})	100 (9.3)	80* (7.7)	$P > 0.05$
n	25	25	

The greater occurrence of Banteng signs on the coastal plains compared to the eucalypt savanna (Bowman & Panton 1991) may be unrelated to total food supply given that herbivore exclusion had no significant effect on herb biomass on the plains. An alternative explanation for the conspicuous sign of Banteng on the coastal plains, yet the apparent minimal impact of herbivory, is that grazing has a stimulatory effect on herb growth on the plains, or stimulates the growth of unpalatable species. Data on changes to species composition are required to explore these ideas.

TABLE 2 Mean (and standard error) of percentage herb cover in fenced and unfenced eucalypt savanna and ecotone on a monsoon rainforest boundary in 1988 (upper), and herb biomass in 1991 (lower). Significance of differences between fenced and unfenced communities are determined by Wilcoxon tests.

	Savanna			Ecotone		
	Fenced	Unfenced	Sig	Fenced	Unfenced	Sig
Herb cover (%)						
Mean	36	26	$P > 0.05$	13	9	$P > 0.05$
SE	5.1	4.4		2.2	0.9	
n	34	24		12	26	
Biomass (gm^{-2})						
Mean	132.9	76.8	$P < 0.001$	46.4	2.7	$P < 0.01$
SE	11.7	23.2		24.8	1.9	
n	51	36		18	39	

Assuming that the results demonstrate a large off-take (56 gm^{-2}) of *Eucalyptus* savanna by Banteng then the biogeographic puzzle of why Banteng have not exploited more of the Top End's savannas is further underlined (Bowman 1993a). One possible reason for the geographic restriction of Banteng is that they must supplement their diet of savanna herbs with minerals acquired from seawater.

The results presented here caution against extrapolation of herbivore impacts from simple correlative studies of animal sign such as those of Bowman & Panton (1991). More detailed studies are required to determine what the effect of Banteng herbivory is on the ecology of Gurig National Park. These studies should ensure that they overcome the deficiencies of this study such as the lack of replication of enclosures and lack of data on the changes to different herb species biomass.

Acknowledgments

The Gurig Board is thanked for permission to conduct this research. Craig Martin, Leonie McDonough, Bill Panton and Bruce Wilson are thanked for their field assistance. Funding from the Endangered Species Unit, ANPWS and the National Rainforest Conservation Programme supported some aspects of this research and is gratefully acknowledged.

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PLATE 2 Coastal calcareous plains typical of study site (D. Bowman)

Assessment of Banteng Grazing on Coastal Plains, Cobourg Peninsula: an Update on Bowman (1994)

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Abstract

Late 1993 dry season herbage cover was found to be significantly different between fenced and unfenced plots on the coastal plains at Smith Point, Cobourg Peninsula. These findings contrast markedly with the results of Bowman (1994) who found that at the same site there was no significant difference in the biomass of herbs between the fenced and unfenced plots over the three years (1988-1991) of his study. Comparison of Banteng *Bos javanicus* scat counts on the plains for 1988 and 1993 indicate that there had been a marked increase in the local density of Banteng at this site.

I report these data to make the simple point that experimental studies must be run for a sufficiently long time period to capture extreme or infrequent events, which may be of greater ecological significance than results recovered for "normal" years.

Introduction

Little is known about the impact of introduced ungulates (both feral and domestic) on the Northern Territory savanna environment. Even basic data on the removal of herbage is largely unquantified. Bowman (1994) found that, after three years of exclusion of Banteng *Bos javanicus* from fenced plots on the coastal calareous plains of Cobourg Peninsula, herbage biomass did not differ significantly from that in adjacent unfenced plots, to which Banteng had access. However, over the same time period, in the savanna-monsoon rainforest ecotone, significant differences in herbage biomass were recorded.

Here I report differences in the cover of herbs between the fenced and unfenced plots on the coastal plains at the end of the 1993 dry season. I undertook this study because of the concerns expressed by Gurig National Park rangers that utilisation of these plains by Banteng had increased significantly. Unfortunately I could not examine the impact of Banteng grazing at the monsoon rainforest boundary site because the enclosure used by Bowman was destroyed by cyclone "Neville" in 1992.

Methods

In December 1993 a reassessment of herbage cover was undertaken for 25 pairs of fenced and unfenced permanent subplots on the coastal sand plains at Smith Point, Cobourg Peninsula. The percentage cover of herbs by species was visually estimated by Braun-Blanquet cover classes. The plots had been harvested in 1991 by Bowman (1994), so cover reported here represents growth occurring over a 30 month period since harvesting. The cover scores were converted to percentage mid-points and means and standard errors were calculated for the fenced and unfenced plots. The effect of herbivore exclusion was determined by non-parametric Wilcoxon Rank Sum tests.

Counts of scats on the sandplains were made to determine if the density of Banteng scats was significantly different to 1988 densities (Bowman & Panton 1991). Scat density was determined from 25 quadrats, each measuring 10m x 20m, placed 50m apart on two parallel transects. These transects were in approximately the same location as those used by Bowman & Panton (1991). Wilcoxon tests were used to compare the 1988 and 1993 Banteng scat data for these transects.

Results

The Wilcoxon test revealed a highly significant difference between the herbage cover in the fenced and unfenced plots ($P > 0.0001$). The fenced plot had a mean herbage cover of 9.2% (SE, 1.7%) and the unfenced plots had a mean cover of 0.7% (SE, 0.18%) cover. Only six non-grass species were encountered in sampled plots and all except one, *Cassytha filiformis*, were common to both fenced and unfenced treatments.

Wilcoxon tests also revealed a highly significant ($p > 0.0001$) increase in the density of scats from 162 (SE, 33) ha⁻¹ in 1988, to 526 (SE, 42) ha⁻¹ in 1993. It is probable that the scats recorded on this survey were less than one year old, as seasonal changes between wet and dry season and the extent of Banteng trampling (Bowman & Panton 1991) on the sandplains would be conducive to the breakdown rather than preservation of scats.

Discussion

The results of this study are at variance with those of Bowman (1994) who concluded that there was no significant difference between the unfenced and fenced plots, after three years of Banteng exclusion from the latter, on the coastal plains at Smith Point. One likely explanation for these disparate findings is increased grazing pressure on the plains from Banteng since Bowman's (1994) study, as suggested by the greater density of scats in 1993. Aerial surveys in 1985 and 1989 (Bayliss & Yeomans 1989) detected some decrease in Banteng population, accounted for by off-take for disease control and trophy hunting; while

subsequent surveys in 1991, 1992 and 1993 (Saalfield & Chatto 1994) indicating a levelling of the population at around 1,200 to 1,800 head. These surveys detected no change in the distribution of Banteng between broad scale sampling areas.

The scat results, however, suggest that Banteng density has been subject to a substantial local fluctuation (assuming a direct relationship between herd size and density of scats). The perception by the Gurig National Park Board of an increased Banteng population in the Smith Point area, independent of this study, was such that the Board allocated funds to fence the airstrip due to the increased risk of light aircraft striking these animals when landing.

One possible cause of major fluctuations in Banteng numbers is movements due to changes in food supply. Bowman (1994) reported significant changes in herbage cover in the eucalypt savanna and savanna-monsoon rainforest ecotone communities following Banteng exclusion, suggesting the importance of these habitats in providing suitable forage for these mammals. Eucalypt savanna is the dominant vegetation community of the peninsula (Wilson *et al.* 1992), and is capable of supporting annual fires. R. Chatto and K. Saalfield (pers. comm.) observed extensive areas of intensely burnt savanna in the southern portions of the peninsula during their aerial surveys of October 1993. These observations contrasted with their impressions of a discontinuous fire pattern from previous surveys. It is probable that many of the Banteng from these burnt areas of the park were displaced to the unburnt north (e.g. Smith Point) in search of food.

This survey provides a cautionary note for the interpretation of studies on plant/feral animal interactions. It is possible that occasional extreme events, like that reported here, have greater deleterious effects on natural ecosystems than does the low to moderate continuous pressure that occurs normally. Extreme, and probably, irregular events of this type may help to explain rapid increases in soil erosion or weed invasion within otherwise stable environments.

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Seasonal Patterns of Wader Populations in Darwin, Northern Territory, 1974-1987

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Abstract

Counts of waders (Aves: Charadriiformes) were made several times each month from 1974 to 1987, in the Darwin vicinity, Northern Territory. Four species, all breeding in Australia, were present year-round or were most numerous during the dry season months. Most species (at least 28) were wet season migrants, arriving and reaching maximum numbers in September or October. Approximately half of these species showed a second influx in numbers during December and January. Only a limited number of species showed a return passage through the study area. Seasonal patterns shown by the Darwin waders differ from those emerging from other parts of northern Australia (e.g. Lane 1987), indicating that distinct regional differences occur.

Introduction

Darwin, on the north coast of the Northern Territory, is one of the 20 most important sites for aggregations of waders (Aves: Charadriiformes) within Australia (Lane 1987). It is the closest of these sites to south-east Asia and the Indonesian archipelago, and thus studies of waders near Darwin could play a prominent role in increasing our understanding of wader migration throughout this part of the world. Published records to date for this area are based upon limited sampling, such as reported in Lane (1987), or mostly unquantified observations, such as reported by Crawford (1972) for the period 1967-71.

Darwin has a marked wet-dry monsoonal climate, with rainfall between years being highly variable (Ridpath 1985). The wet season usually extends from December-March, the dry from June-September, with short intervening transition periods. The studies reported here commenced in 1974 and continued until mid-1987. They form part of more extensive records kept for all bird species in the area. Previous reports for the study area have been made for other groups of birds (McKean 1981, 1986; Thompson 1982, 1984).

Methods

Surveys were made several times each month, at each of six habitat types: beach and intertidal mudflat (Lee Point and Buffalo Creek), mangroves (Buffalo Creek,

Palmerston and Sanderson sewage ponds), sewage ponds (Sanderson, Palmerston), saltflats (Leanyer), estuarine swamp merging into freshwater swamp (Holmes Jungle Swamp), and open grassland (Holmes Jungle, Lee Point road). A total of 1,330 surveys were made. The maximum count for a species for any given month was used in the data analysis. This was used rather than all the individual counts per month, as variations across surveys were high due to differences in time and stage of tide, observers and length of time per survey. The time period spent on each survey was usually about 60 minutes, but varied between 30 and 180 minutes.

Because the data were not standardised, it is assumed that the numbers represent relative data only; therefore, non-parametric tests of statistical significance were applied. To test whether the population samples were significantly different from month to month, the data were analysed using the non-parametric Friedmann two-way analysis of variance. The monthly figures were ranked within a given year from lowest to highest. The test determines whether the rank totals for the months over the 14 years differ significantly.

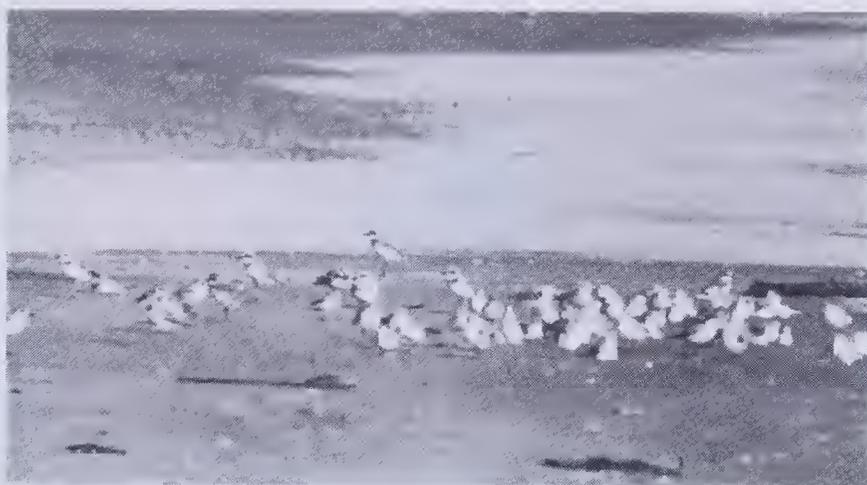


PLATE 3 *Large Sand Plovers and Sanderlings, Darwin* (A. Hertog)

Results

Thirty-three wader species were recorded regularly during the study. There were also several records of vagrant species, but as these have been documented elsewhere (e.g. McKean *et al.* 1976; McKean & Hertog 1981), and do not show population trends, they are not dealt with in this paper. Twenty-six species occurred frequently enough to test for significant changes in population levels.

These fell into three groups based on patterns of abundance through the year: those which were present year-round without marked seasonal changes (one species), those which showed dry season peaks (three species), and the remainder which showed wet season peaks (22 species).

The only species that showed no significant seasonal changes in population was the Red-capped Plover *Charadrius ruficapillus*, although January showed consistently larger numbers (Fig. 1). The three species which were most numerous during the dry season months of June-September were the Australian-breeding Masked Lapwing *Vanellus miles*, Black-winged Stilt *Himantopus himantopus*, and Australian Pratincole *Stiltia isabella* (Fig. 1). The remaining species were long-distance migrants from the Palaearctic region which showed highest numbers during the wet season, or wet season transition months (October-November) (Fig. 2).

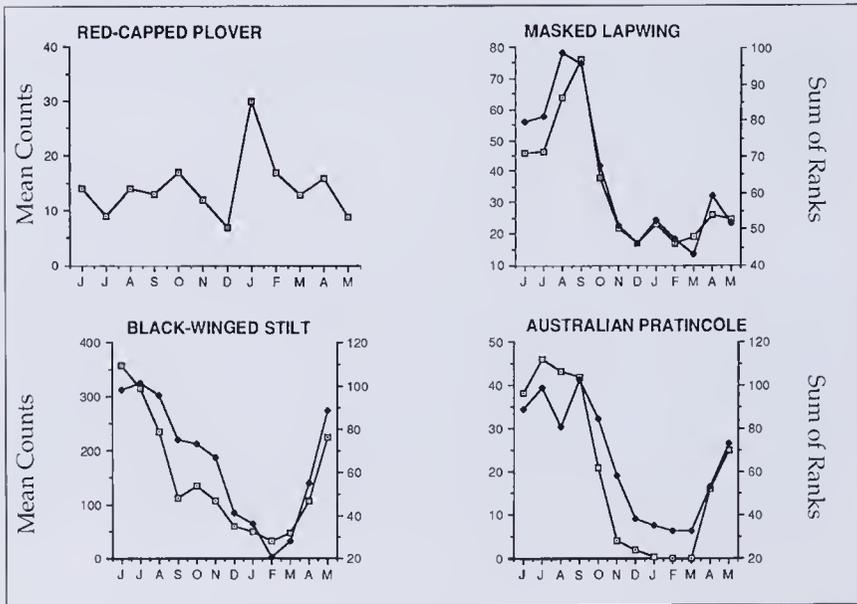


FIGURE 1. Mean counts of individuals per month for four Australian-breeding species. Except for Red-capped Plover, graphs show both mean counts of individuals (\square) and sum of monthly ranks (\bullet) over the full study period, 1974-87.

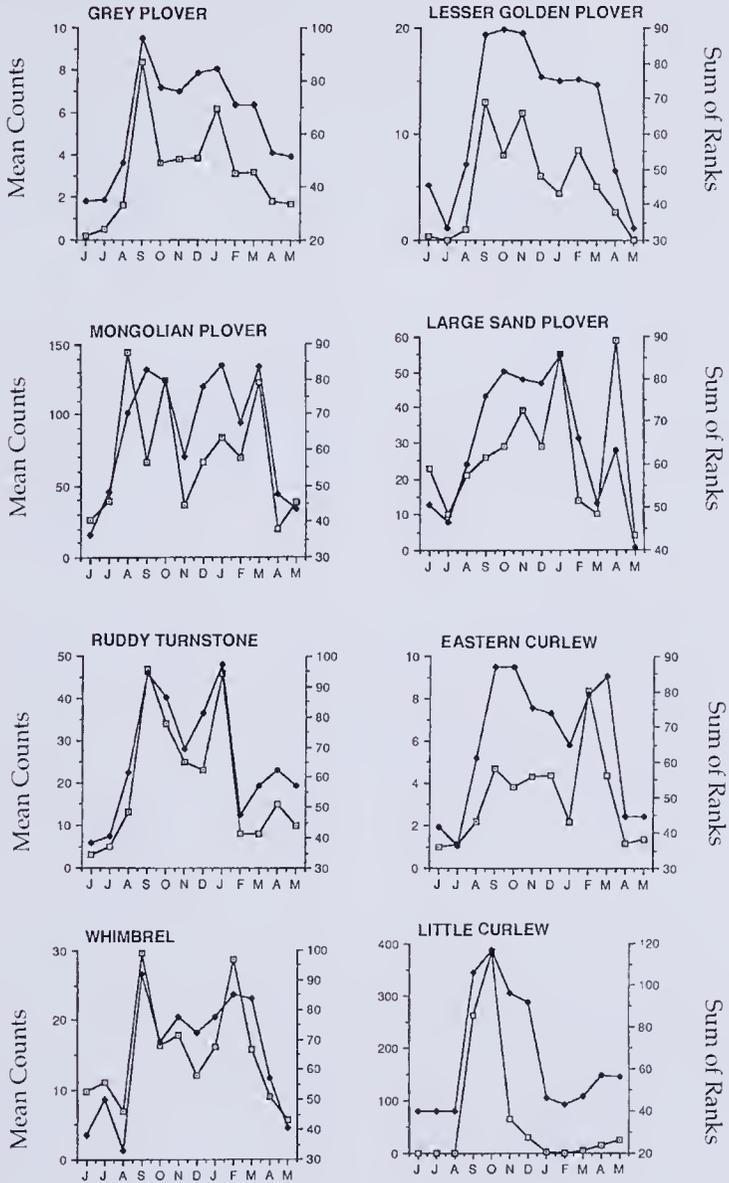


FIGURE 2 Mean counts of individuals (□) and sum of monthly ranks (●) over the full study period, 1974-8 for wet season migrant waders.

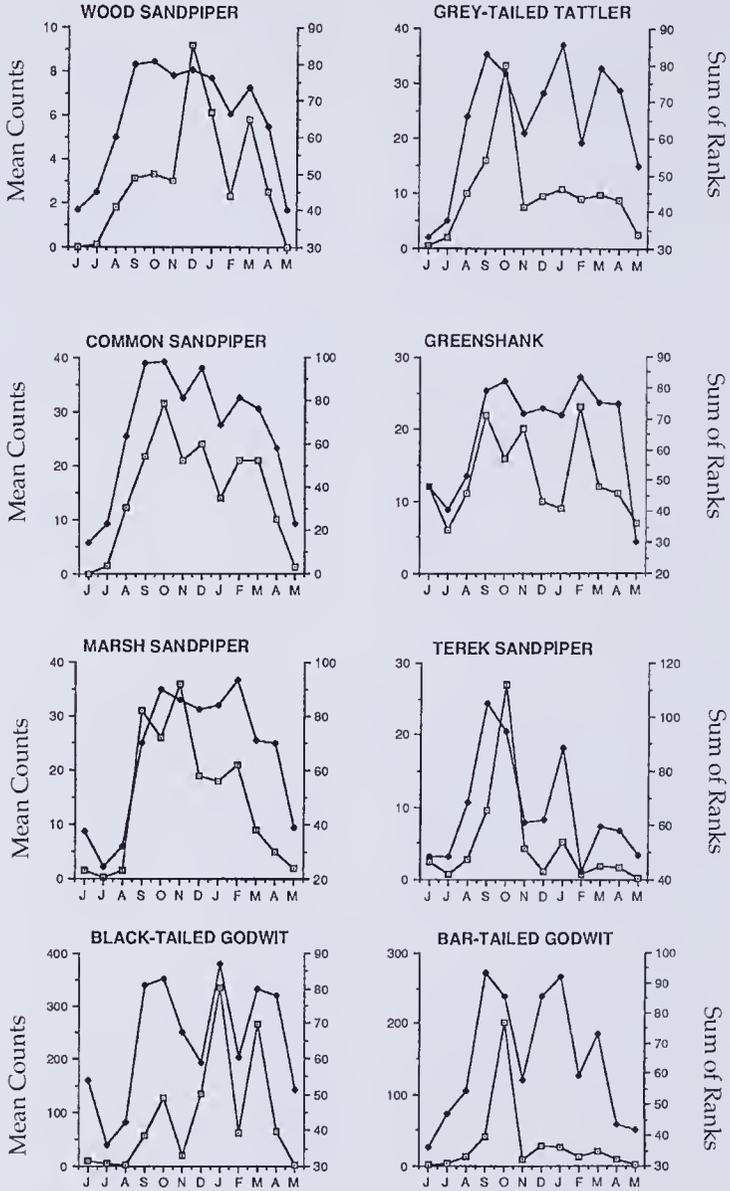


FIGURE 2 (continued)

Arrival of Long-distance Migrants

Long-distance migrant species generally arrived in Darwin during September, but maximum numbers were in either September or October, with the exception of Oriental Pratincole *Glareola maldivarum* (Fig. 2). Based on the measure of the total ranks, those species with initial peak numbers in September (Group 1) were Grey Plover *Pluvialis squatarola*, Mongolian Plover *Charadrius mongolus*, Ruddy Turnstone *Arenaria interpres*, Whimbrel *Numenius phaeopus*, Grey-tailed Tattler *Tringa brevipes*, Terek Sandpiper *T. terek*, Bar-tailed Godwit *Limosa lapponica*, Great Knot *Calidris tenuirostris*, Curlew Sandpiper *C. ferruginea* and Sanderling *C. alba*.

Other long-distance migrant species, although they commenced arriving in September or earlier, peaked later, in October (Group 2). These included Large Sand Plover *Charadrius leschenaultii*, Little Curlew *Numenius minutus*, Greenshank *Tringa nebularia*, Marsh Sandpiper *T. stagnatilis*, Black-tailed Godwit *Limosa limosa*, Sharp-tailed Sandpiper *Calidris acuminata* and Red-necked Stint *C. ruficollis*. Other species (Group 3) were not consistent in their arrival month, including Lesser Golden Plover *Pluvialis dominica*, Eastern Curlew *Numenius madagascariensis*, Wood Sandpiper *Tringa glareola* and Common Sandpiper *T. hypoleucos*.

December-January influx

About a half of the long-distance migrants showed a second influx during the months of December and January. After building up numbers during September and October, these species showed substantial decreases during November and early December, but subsequently increased again in late December and January. Their numbers characteristically declined again in February. This December-January influx was found in all the species of Group 1 (September maxima), as well as for the Large Sand Plover, Common Sandpiper, Black-tailed Godwit and Red-necked Stint. Two other species, the Greenshank and Marsh Sandpiper, showed a similar pattern, but with the increase in February.

Departure and return passage of long-distance migrants

Most long-distance migrants (16 species) departed during March and early April, though three species departed in late April-May. Only one species, the Large Sand Plover, showed strong evidence of a return passage through the study area (presumably from southern Australia), with substantial increases in the study area during February-April. Other species showing minor increases during this period include Mongolian Plover, Sanderling, Whimbrel, Eastern Curlew, Ruddy Turnstone and Greenshank.

Several long-distance migrants were present in limited numbers throughout the northern hemisphere breeding season, June-July. These were Great Knot, Greenshank, Whimbrel, Large Sand Plover, Mongolian Plover, Red-necked Stint and Eastern Curlew.

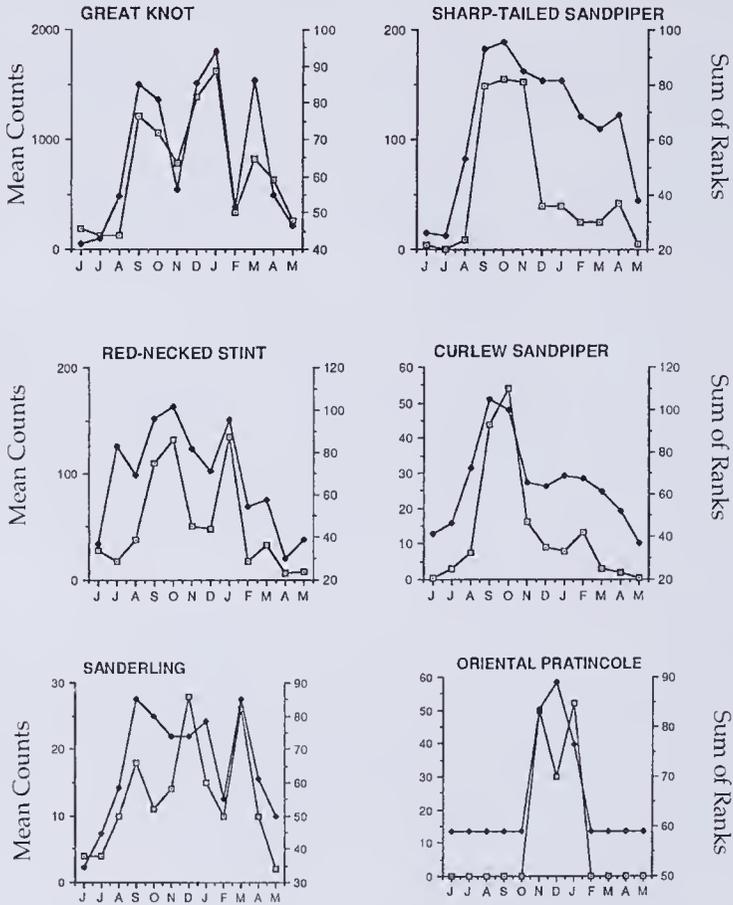


FIGURE 2 (continued)

Restricted Season Species

Little Curlew *Numenius minutus* and Oriental Pratincole showed discrete, restricted seasonal patterns, occurring only from September to January (Fig. 2). Oriental Plover *Charadrius veredus*, which occurred in very small numbers (see below), showed a similar trend. All three species feed on open grasslands but move out of the study area after the start of the wet season, when local feeding grounds become flooded and alternative areas become suitable due to widespread rains. Little Curlew disperse inland after the onset of rains flood their feeding grounds and do not show a return passage through the study area (McKean *et al.* 1986), probably due to lack of suitable feeding grounds at that time.

Uncommon Species

The remaining species occurred in numbers too low to show statistically significant population patterns. A few Beach Thick-knees *Burhinus neglectus* were regularly recorded, except from April to July. Pied Oystercatcher *Haematopus longirostris* and Sooty Oystercatcher *H. fuliginosus* were found in every month. Several other species that breed within Australia were absent during at least part of the wet season. Black-fronted Dotterel *Charadrius melanops* and Red-kneed Dotterel *Erythrogonys cinctus* were absent from November and December respectively, to February. Red-necked Avocet *Recurvirostra novaehollandiae* was never recorded from November to April. These absences could coincide with breeding elsewhere. Their abundance in the study area varied substantially from year to year.

Other uncommon species showed patterns similar to the more common wet season migrants. Swinhoe's Snipe *Gallinago megala* was present from October to April, while Little Ringed Plover *Charadrius dubius* occurred only from September to March. A few species apparently disappeared, and then reappeared later during the wet season. Oriental Plover was found from August to January, and subsequently in April, on return passage. Red Knot *Caladris canutus* was present in September-October, December-January, and March-May.

Discussion

Australian breeding species were the only ones which showed higher numbers during the dry season, possibly representing influxes of birds from further south, where conditions would be drier and colder. The large numbers of Red-capped Plover recorded during January in Darwin conflict with the data of Crawford, as reported in Lane (1987), which indicated that highest numbers occurred during the dry season on saline plains. This pattern clearly does not hold for the range of habitats surveyed in this study.

Most migrants arrived during the period August-October; 17 species being very consistent in their arrival month. Approximately 50% of maximum counts occurred during September, 30% in October and 20% in August, with one species (Oriental Pratincole) having maximum numbers in December. This timing appears to be slightly later than the maximum counts found for north-western Australia (see Lane 1987). It suggests that the migrants landing in the north-west may originate from separate places in Asia to those landing in Darwin; or that Darwin birds have moved east after first arriving in north-west Australia, as has been suggested by Lane.

This study found a second influx in numbers for several long-distance migrants during December and January. Two waves of migration had previously only been reported for Red-necked Stint (Lane 1987). The second influx could represent birds newly arriving from overseas (perhaps juveniles, M. Barter pers.comm.) or

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1. On p 7 and back cover:

Assessment of Banteng Grazing on Coastal Plains, Cobourg Peninsula: an Update on Bowman (1994)
should read:

Assessment of Banteng Grazing on Coastal Plains, Cobourg Peninsula: an Update on Bowman (1993)

2. On pp 7, 8, 9

Bowman (1994) *should read:* Bowman (1993)

3. On p 9 in References

Bowman, D.J.M.S. (1994) Effect of large herbivore exclusion on understorey biomass in three plant communities.....
should read:

Bowman, D.J.M.S. (1993) Effect of large herbivore exclusion on understorey biomass in three plant communities.....

4. On back cover (contents)

Seasonal patterns of wader populations in Darwin, Northern Territory, 1974-1987. K.S. SHURCLIFF and H.A.F. THOMPSON
should read: K.S. SHURCLIFF

internal migration, especially from the north-western Australia. Unfortunately no data are available on the age of birds in this study. Many of the species involved are those which spend most of their time in Australia in the north (e.g. Large Sand Plover, Great Knot, Black-tailed Godwit), but also include some predominantly southern species according to Lane (1987), e.g. Red-necked Stint and Curlew Sandpiper.

Only seven long-distance migrant species showed evidence of a return passage through the area. As individuals or groups of only seven Palaearctic-breeding species remained through their breeding season, the Darwin area does not appear to be an important overwintering site, such as the Gulf of Carpentaria.

Acknowledgements

Most (90%) observations reported in this paper were made by the author, H. Thompson and J. McKean. Other observers included K. Fisher, L. Fisher, J. Estbergs, F. van Gessel and A. Hertog. Very constructive suggestions on an earlier draft of this paper were made by M. Barter, R. Jaensch and R. Noske.

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Temporal Dynamics of two Tropical Ant Species, *Iridomyrmex sanguineus* and *Oecophylla smaragdina*, in relation to Temperature and Humidity

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Abstract

The activity of the tropical meat ant *Iridomyrmex sanguineus*, in the Darwin region, is strongly affected by environmental temperature and relative humidity. Activity peaked at air temperatures 3mm above the soil surface between 30° and 35°C and was limited at temperatures exceeding 38°C with a relative humidity less than 62%. By contrast, the green weaver ant *Oecophylla smaragdina*, did not adjust its activity in response to changing air temperatures experienced in the months March to May. It did, however, appear to respond to light, being more active at night than during daylight over the study period. It is unlikely that weaver ants in their preferred habitat would ever experience temperatures high enough to cease activity.

Introduction

Ants often follow distinct daily cycles of activity, and operate within limits of temperature and humidity (Hölldobler & Wilson 1990). They tend to be strongly thermophilic, with few species foraging at all below 10°C (Hölldobler & Wilson 1990). Some species can tolerate extremely high temperatures: for example, the central Australian ant *Melophorus bagoti* remains active during the hottest period of a summer day when ambient temperature exceeds 50°C (Christian & Morton 1992). Many species adjust their foraging activity in response to several factors including ambient and surface temperatures. In tropical habitats, daily and seasonal changes in foraging activities of ants are related to both temperature (Torres 1984) and moisture (Levings 1983). This study uses field observations to assess the effects of ambient and surface temperatures, and relative humidity, on foraging activity in two species of tropical ants, *Iridomyrmex sanguineus* and *Oecophylla smaragdina*.

Materials and methods

The northern meat ant, *Iridomyrmex sanguineus* (Formicidae: Dolichoderinae), is a relatively large (length 6-8 mm), dominant, diurnal ant species (Greenslade

1976; Andersen 1992), very common in open vegetation in tropical Australia. Meat ants generally live in large colonies in underground nests (Barker & Greenslade 1982), with each nest having one to many entrance holes, each of which leads to a separate system of galleries and chambers (Greenslade 1979). A nest may be occupied by the same population for many years (Greenslade 1975).

The green weaver ant, *Oecophylla smaragdina* (Formicidae: Formicinae), is common throughout tropical Australia and South East Asia. It typically lives in large colonies and constructs nests by weaving the leaves of trees, which are bound by silk produced by the larvae. Green ants are one of the most successful ant species due to their ability to form large colonies and their aggressive and territorial behaviour. A colony may dominate several trees at one time and populations of half a million often occur (Hölldobler & Wilson 1990).

The present study took place near Darwin (12°26' S, 130°55' E) during March-May 1993, the transition period between wet and dry season, when conditions are often overcast with irregular heavy rain storms. The air temperature ranges from about 22° to 35°C, and relative humidity from about 35 to 98%. The meat ant nest was located on the grounds of the CSIRO laboratories Berrimah, 10 km north east of Darwin. The nest was in bare red earth and had 11 entrances, roughly in a line with a maximum separation of 23 m. Only one hole, centrally located, was selected for monitoring. The green ant nest was located in Nightcliff, 10 km north of Darwin. The monitored nest was one of eight located in a lemon tree, and was approximately 2 m above ground level on the perimeter of the tree. It had three openings but only the main entrance hole was monitored.

Activity in both species was measured by counting the number of ants entering and leaving one entrance over five minute periods. Entry/ exit counts were combined to give a measure of activity. For *I. sanguineus* the following variables were measured at each count: air temperature at 2 m (T_a), ground surface temperature (T_g), temperature at 3 mm above ground ("ant height") (T_{ah}), nest temperature at 20 cm below surface (T_n), relative humidity at 2 m (R_h). T_g and T_{ah} readings were taken approximately 1 m from the monitored hole. For *O. smaragdina*, only air temperature (at 2 m), nest temperature and relative humidity at 2 m were measured. Temperatures were measured with thermocouples, the nest probe being left in the ground for the entire study, and relative humidity was measured with a sling psychrometer.

To determine which environmental variable most affects the activity of *I. sanguineus*, all subsets regressions of the variables against total activity were carried out, using the adjusted r^2 as the selection factor. A paired t-test was used to test the null hypothesis that the nest temperature of *O. smaragdina* was similar to ambient temperature.

Results

Iridomyrmex sanguineus

The range of air and nest temperatures were much narrower than soil surface or ant height temperatures (Fig. 1). The model of activity with the variables Rh, Tah and Tah² had the highest adjusted r^2 (Table 1) and demonstrates that *I. sanguineus* prefers high humidity and medium temperatures (Fig. 2). Activity was also significantly related to ground temperature ($r^2 = 0.5181$, $p = 0.0000$) and air temperature ($r^2 = 0.3297$, $p = 0.0000$). Activity was lowest at low air temperatures, and at high air temperatures with low humidity and generally, minimum activity occurred at the extreme temperatures in the ranges.

TABLE 1 Summary of the best model describing activity of *Iridomyrmex sanguineus* over five minute periods

Variable	Adjusted r^2	P
Rh	0.2323	0.0004
Rh - Rh ²	0.3939	0.0000
Tah	0.2479	0.0003
Tah - Tah ²	0.4304	0.0000
Rh + Tah - Tah ²	0.5272	0.0000

At the cooler temperatures, the ants adopted a crouched position, moved very slowly and stayed in close proximity to the nest. Some remained stationary for short periods of time. At higher temperatures their bodies were raised from the ground and they moved very quickly around and away from the nest.

O. smaragdina

The activity of *O. smaragdina* was unrelated to air temperature ($r^2 = 0.0392$; Fig. 3a) and relative humidity (adjusted $r^2 = 0.0270$). Time of day however, was a significant factor with an r^2 of 0.5488 (Fig. 3b). Maximum activity occurred during the dark hours (before 06:00 and after 18:00) and showed a 50% decrease during the daylight hours (after 06:00). There was no significant difference between mean air temperature and mean nest temperature ($t = 0.47$, $d.f. = 59$, $P > 0.05$).

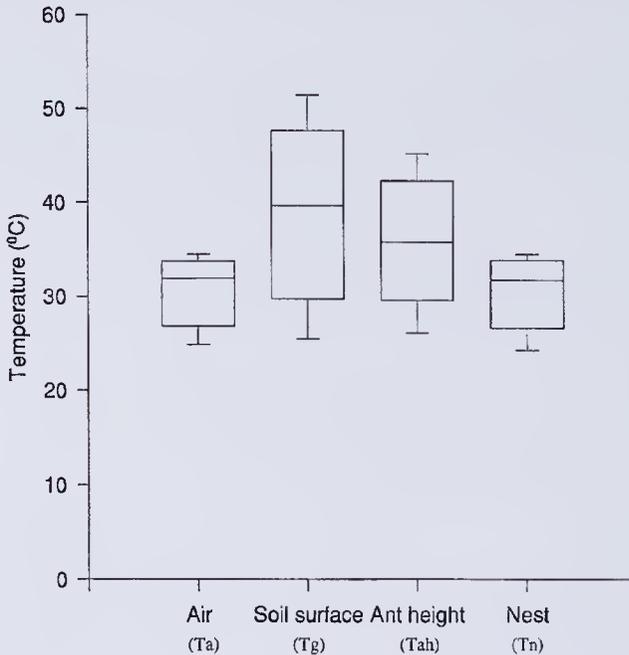


FIGURE 1 Range of the temperature, means and standard errors at different locations. The boxes indicate the range between the 25th and 75th percentiles of the data; the lines mark the 50th percentiles, and capped bars indicate the 10th and 90th percentile points.

Discussion

The results suggest that *I. sanguineus* activity is strongly affected by environmental temperature and relative humidity. The optimum foraging ant height temperature was around 35°C. The high temperatures occurred mainly after 11:30 and low temperatures occurred before 07:00 hours.

By contrast, *O. smaragdina* was not strongly affected by air temperature, at least within the range of 24° to 37°C, or relative humidity. Because these ants spend the majority, if not all, of their time in trees, they would be well shaded from direct and reflected solar radiation and would not experience the high temperatures occurring at ground level. Also, the thermal conductance of vegetation is lower than that of bare ground so the risk of desiccation induced by activity at high temperatures would be considerably reduced. The highest air temperature recorded was 37.5°C, which is above average, but the activity of green ants at this temperature was not significantly different than at some lower temperatures. The highest air temperature ever recorded in Darwin was 38.9°C in October 1991

(Bureau of Meteorology, Darwin, pers. comm.) so it seems unlikely that green ants would ever experience air temperatures sufficiently high in the Darwin region to prevent their activity. Greenslade (1972) found that this species is well adapted to tropical environments and is tolerant of variations in both temperature and humidity.

Ground temperature and temperature at ant height for *I. sanguineus* varied considerably more than air and nest temperature (Fig. 1). Both fluctuated readily with slight changes in wind speed and cloud cover. The ants were active over a large range of environmental temperatures but for a given temperature, activity was generally greater at high humidity when the risk of desiccation would be considerably reduced. It is significant that the lowest ant count of only one over a five minute period occurred at the highest ground temperature of 54.2°C when relative humidity was only 45%. Nest temperature by contrast, showed very little variation with a mean of 33.6°C, ranging from 26° to 36°C. It rarely fell below T_a , and then only slightly. Ground-dwelling insects intercept direct and reflected solar radiation as well as infrared radiation, conductive and convective heat from the ground. Therefore, they are particularly prone to desiccation (Withers 1990). When ambient temperatures are high it is imperative that they have some means of avoiding overheating and, for meat ants, a relatively cool nest environment provides a thermal refuge.

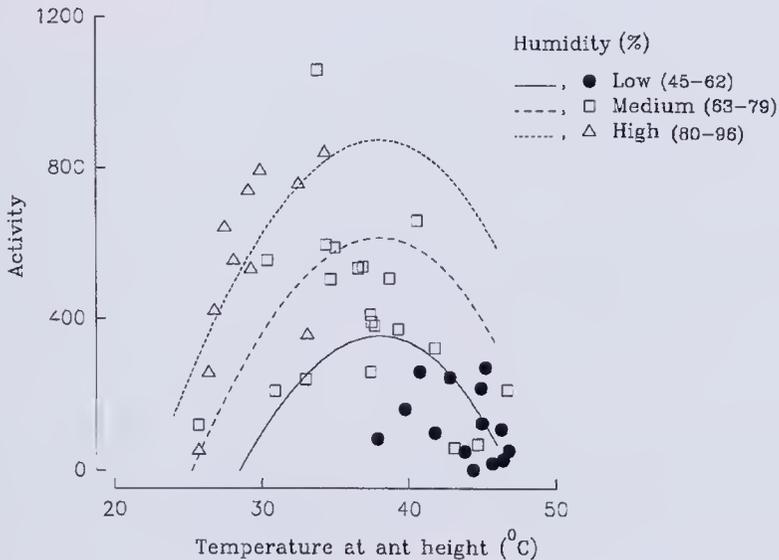


FIGURE 2 Actual and fitted values of the activity of *I. sanguineus* over five minute periods in relation to temperature 3 mm above the soil surface (T_{ah}) and relative humidity (Rh). The equation for the model is, $Activity = 14.6Rh + 314T_{ah} - 4.2T_{ah}^2 - 6350$.

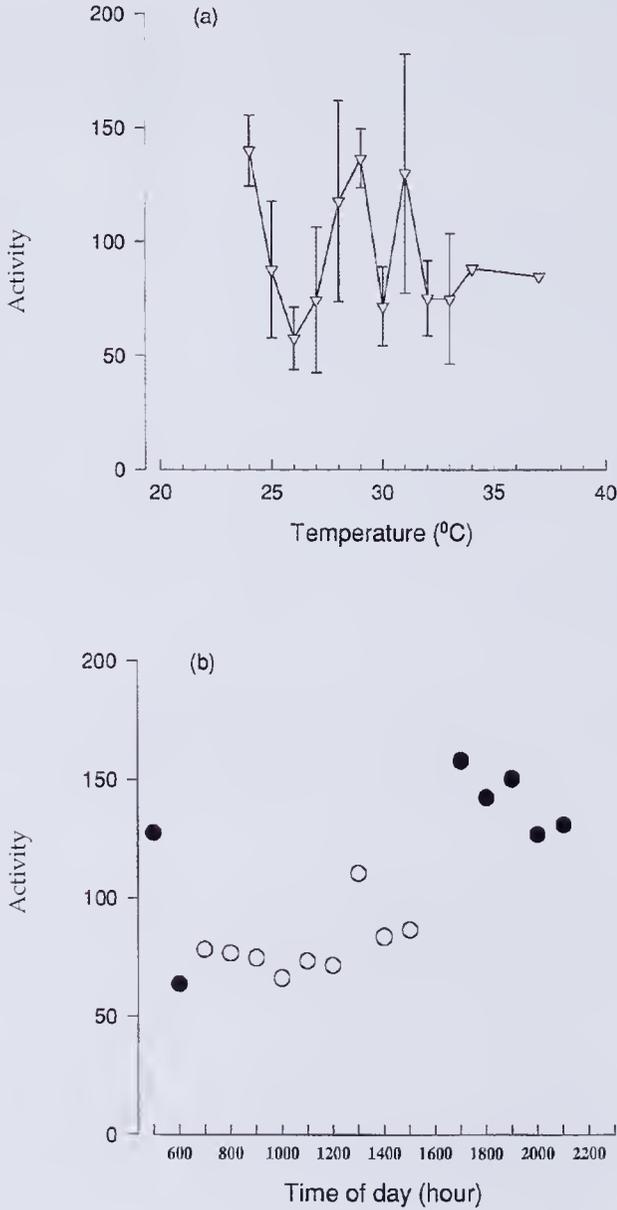


FIGURE 3 Mean activity of *O. smaragdina* over five minute periods at (a) air temperature and (b) time of day (open circles = day; closed circles = night).

It is possible that the energy available, if any, at low ambient and surface temperatures is too low for effective foraging. The low body posture adopted by *I. sanguineus* would maximise heat gain from the boundary layer of the ground surface. The elevated posture adopted at high ground temperatures would raise the ant's body into the cooler part of the thermal boundary layer and increase convective heat loss (Withers 1990). *Melophorus bagoti* spends up to 50% of the foraging time during midday in the refuge of sparse vegetation, and, despite soil surface temperatures exceeding 70°C, there is never a cessation of activity (Christian & Morton 1992). It is possible that *I. sanguineus* also uses this strategy for thermal respite. The fact that no other ant species were observed around the nest site and that meat ants are relatively large and aggressive, suggests that their foraging times are not affected by interspecific competition.

The nest temperature of *O. smaragdina* fluctuated with air temperature so it would not provide a thermal refuge as it does for *I. sanguineus*. When the sun was shining directly on the nest of *O. smaragdina*, the majority of ants spent most of their time in the shade on the underside of the nest, while at other times, particularly in the early morning, they moved over the entire nest (S. Walsh pers.obs.). No thermoregulatory behaviour in response to thermal extremes was observed. The lowest temperature recorded was 24.8°C and it was at this temperature that the highest activity occurred. This reading was taken at night. Activity appears to be limited by light, peaking at and after sunset and before sunrise. Activity decreased by approximately 50% during the daylight hours. It may have been useful to take more readings during the night to determine if this trend is consistent as not all nests or colonies may exhibit nocturnal behaviour.

This study revealed that *I. sanguineus* and *O. smaragdina* respond quite differently to changes in environmental temperature. The activity of the meat ant was limited by environmental temperature extremes and low relative humidity, while the green ant was tolerant of changes in ambient temperature, responding more to light. Further observations on other nests of *I. sanguineus* and *O. smaragdina*, and at other times of the year, are required to determine the generality of these findings.

Acknowledgements

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PLATE 4 *The northern meat ant, Iridomyrmex sanguineus* (B. McKaige)

SHORT NOTES

The Use of Small Pebbles in the Web Retreat of a Comb-footed Spider, *Achaearanea* sp. (Araneae: Theridiidae)

The comb-footed spiders of the family Theridiidae typically construct a three-dimensional tangle web, or cob-web, often in a sheltered site. A retreat where the spider resides is sometimes made towards the centre of the web. This retreat is usually conical in shape (with the point uppermost) if constructed wholly of silk, but the shape may be altered if other building materials are incorporated.

In December 1991 a number of *Achaearanea* sp. spiders were observed establishing themselves under the window-sill of a recently constructed house at Humpty Doo, Northern Territory. The window had a northerly aspect and was protected by the roof of a verandah, approximately 3.2 m wide. The webs of the spiders were similar to other theridiid webs observed by the author, albeit rather sparse. The construction of the retreat, however, was unusual. A number of tiny pebbles were incorporated into the silk of the retreat, in some cases packed quite tightly. Similar pebbles were found scattered over a section of the paved floor of the verandah, one metre below the web site. The pebbles were up to 3 mm in diameter, often larger than the spiders' abdomen.

As the months passed, and as other webs and retreats appeared, the incidence of pebbles as the major component of retreats decreased. In order to establish whether the use of the pebbles was dependant on the type of material available, two spiders were removed from their "pebblecrete" retreats, and placed in separate jars. The floor of the jars were covered in material gathered from below the web sites, mostly small pebbles, sand grains and pieces of dry leaves, presumably blown in from the yard. Within several days the reconstruction of the retreats had begun. The spiders used the smaller building materials such as the sand and leaf components rather than the larger, heavier pebbles.

Subsequently I found a new web and retreat, which was built directly over an ants' nest, and composed of sand grains deposited by the ants. Other retreats observed nearby in pot-plants were constructed from fragments of potting mix. These observations suggest that the original pebble retreats were constructed using the only material available at the time. With the availability of a wider variety of building material in the immediate area, the occurrence of the larger pebbles in the retreat decreases. Use of such heavy building

materials must have a considerable energetic cost, indicating a high premium for unreinforced retreats.

I thank Dr Mike Gray (Australian Museum) for identification of the specimen, and Drs Mark Harvey (WA Museum), Alice Wells (ABRS) and Richard Noske (NTU) for comments on the text.

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* this article was originally published in *Australasian Arachnology*, no. 45.

Observations of the Port Darwin Sea Snake *Hydrelaps darwiniensis*

The Port Darwin Sea Snake *Hydrelaps darwiniensis* (Hydrophiidae), was named from two specimens collected near Darwin (Boulenger 1896). Since then little has been added to our knowledge of the species except that it lives in mangrove areas in northern Australia and feeds on mudskippers (*Periophthalmus*) (Gow 1989; Cogger 1992). It is reported to swim along the water line of rising or falling tides investigating crab holes in compacted to relatively soft mud (Ehmann 1992). Six specimens were retrieved from the stomachs of sharks that were netted within Darwin Harbour in the Frances Bay region (Lyle & Timms 1987).

On 17 October 1992, we observed several *H. darwiniensis* from a dinghy on Sadgrove's Creek, Darwin, where the species had been recorded previously (J. Lyle pers. comm.). Four hours of careful checking of the mangrove-lined streams during low tide proved fruitless. At 15:00, however, as the tide began to rise, a single *H. darwiniensis* was seen leaving the water and crawling onto a bank of consolidated mud. It then moved into a nearby crab burrow to emerge some minutes later from a neighbouring burrow. Another three individuals were seen within 30 minutes of the first, but none in the subsequent two hours. These observations, albeit limited, indicate that the species is diurnal, and that it probably feeds out of the water.



PLATE 5 The Port Darwin Sea Snake *Hydrelaps darwiniensis* from Sadgrove's Creek (P.McGrath).

The first individual was captured and kept for 48 hours in a bucket of seawater collected at the same time. The snake was extremely adept at moving on land, and was placed in a pool in the upper tidal zone for photographing. It paused and drank for about a minute from the pool which contained water that was fresh to taste and presumably had accumulated from an overnight storm. Although sea snakes are thought to obtain their fresh water requirements by removing salt from their bodies with specialised "salt" glands near the tongue (Burns & Pickwell 1972), the closely-related sea kraits are known to drink fresh water when it is available (Guinea 1991).

The terrestrial feeding habits of this species are unique among seasnakes, and deserves further study.

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Antiphonal Song in the Black Butcherbird *Cracticus quoyi* in Darwin

Duetting, in which two birds sing simultaneously, is a common occurrence, especially among medium sized tropical passerines (e.g. Diamond & Terborgh 1968; Diamond 1972). Antiphonal singing, in which two birds sing phrases alternately to produce an integrated melody, is less commonly reported. Duetting is well known in various Australian and New Guinea species of butcherbirds (Macdonald 1973; Frith 1976; Coates 1990), but neither duetting nor antiphonal song appear to have been recorded for the Black Butcherbird *Cracticus quoyi*. This paper reports on the occurrence of antiphonal song for this species in the Darwin region.

The Black Butcherbird is common in mangroves and remnant riparian forest in the Darwin region. Between July 1988 and July 1993 I conducted an early morning census of birds on about 18 days per month. The census followed a regular route including residential streets, parkland, mangroves and riparian vegetation bordering Rapid Creek. Two pairs of Black Butcherbirds, presumed to be the

same resident individuals, were commonly recorded along sections of the route. They were frequently seen and heard calling from mangroves, and less often encountered in parkland and gardens, generally within about 50 metres of mangroves.

Though less melodious than other butcherbirds, the Black Butcherbird has a variety of rich calls. These show considerable geographic variation, at least in the New Guinea region (Beehler *et al.* 1986; Coates 1990). In Darwin, the species is particularly vocal at dawn when their loud calls may be heard up to a kilometre away.

Antiphonal songs of Darwin birds were always composed of simple phrases in two similar variants. The phrases were also commonly given by solitary individuals. When singing antiphonally, two birds usually perched one to two metres apart within the same tree, but on one occasion were in different trees, about ten metres apart. One bird (Bird 1) was always perched higher, and began each sequence of calls with a low-pitched, rather muted and slightly guttural (a) double ("croo-croo") or (b) single ("ork") note. Bird 2 followed with louder, higher-pitched, more melodious calls: (a) a disyllabic, upward-inflected "oo-wa", or (b) a trisyllabic "oodle-oo" (Fig. 1). In the latter trisyllabic call, the first and last notes were of the same pitch; the second lower, and shorter in duration. Both variants were delivered once or repeated several times, at the rate of three sequences in five seconds.

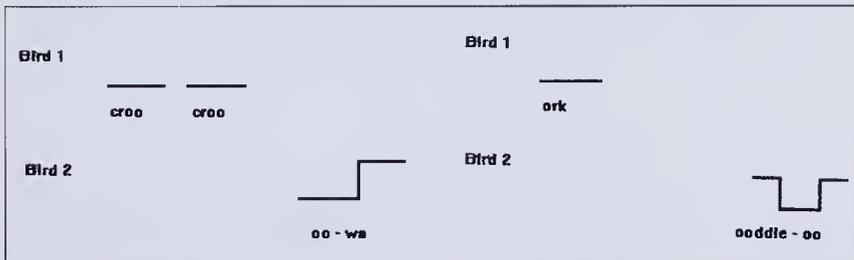


FIGURE 1. The two main song phrases of the Black Butcherbird

Antiphonal singing has only been observed clearly in the late dry season (September to November) when birds are presumably preparing to breed. It may be associated with establishing or re-affirming territories. Twice, I saw two pairs engaged in bouts of aggressive pursuit interspersed with antiphonal song at a territorial boundary. Since the species is sedentary and apparently maintains territories throughout the year, however, it is possible that pairs engage in antiphonal singing throughout the year. Further studies may clarify if this is so, and if song varies within Australian populations.

I thank Richard Noske and two anonymous referees for their comments on a draft of this note.

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First Record of the Spectacled Monarch *Monarcha trivirgatus* for the Northern Territory

The Spectacled Monarch *Monarcha trivirgatus* is found in coastal eastern Australia, New Guinea, and many islands of eastern Indonesia, including Timor (White & Bruce 1986). In far north Queensland it is sedentary, but breeding populations in southern Queensland and northern New South Wales migrate north during the winter (Blakers *et al.* 1984), probably mostly destined for the Trans-Fly region of southern New Guinea (Beehler *et al.* 1986). In Australia it inhabits rainforests and occasionally mangroves (Blakers *et al.* 1984; Boles 1988), while in Timor it occurs in lowland evergreen and semi-deciduous forests, as well as scrub (RN, pers. obs.).

During an avifaunal survey of mining leases on Groote Eylandt, we recorded this species in a patch of coastal vine forest, c 24 km south of Alyangula, on 16 September 1991. Two birds were found: an adult and an immature, the latter recognisable by the lack of black on the face, the lores being whitish-grey, the throat, dark grey (see Slater *et al.* 1986), and the base of the bill being pale yellow. Both birds were present on the following day (RN), but the site was

not re-visited until 5 January 1992, when an immature was sighted (GB). The species was not found, however, during three visits to the site in late March 1992; nor was it ever recorded at the two other vine forest patches surveyed.

These records constitute the first of the Spectacled Monarch for the Northern Territory, and the only known Australian records west of 141°E (Cape York). As the closest known locality to Groote Eylandt is Weipa on Cape York (Blakers *et al.* 1984), it seems likely that the individuals concerned originated from these populations, and were blown westward across the Gulf of Carpentaria. The presence of an immature (albeit independent) bird in September is curious given that Australian populations are purported to breed from October to February (e.g. Boles 1988). Without information on the duration of immature plumage in this species, however, the origin of these birds must remain a mystery.

The above observations were made while conducting a bird survey for Groote Eylandt Mining Company Pty Ltd, under the supervision of Mr Rob Savoury, to whom we extend special thanks.

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