NTFN

Northern Territory Naturalist

Number 19
June 2007

The Journal of the NT Field Naturalists' Club

NT FIELD NATURALISTS CLUB Inc.

NORTHERN TERRITORY FIELD NATURALISTS' CLUB

Founded 1977

ISSN 0155-4093

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Front Cover: The Gove Crow *Euploea alcathoe enastri* from north-eastern Arnhem Land is a listed threatened butterfly in the Northern Territory. (Michael Braby)

Rear Cover: Striated Heron (*Butorides striatus*) chick at Nightcliff reef, estimated age nine days post-hatching. The nestling of the race (*stagnatilis*) found in the Darwin region is described for the first time in this issue. (Richard Noske)

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Population estimate of Asian Water Buffalo and wild cattle in the Arafura Swamp, central Arnhem Land

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Abstract

An aerial survey of Asian Water Buffalo *Bubalus bubalis* and wild cattle *Bos taurus* was undertaken in the Arafura Swamp region of central Arnhem Land in September 2005. The survey covered 3 089 km² and included the Arafura Swamp, nearby Blyth River, Glyde River floodplains, Goyder River and the floodplains of the Gulbuwangay River. A total of 812 individuals was recorded during the survey, 40% being Asian Water Buffalo and 60% wild cattle. The survey area was estimated to have a buffalo population of 5 187 (95% CI, 2 108 - 8 266) and a wild cattle population of 4 333 (95% CI, 1 827 - 6 839). These estimates are corrected for perception and availability bias. The traditional owners' objective is to manage the buffalo population for subsistence and commercial use. The data presented in this paper will be useful in planning for this development and as a basis for future management and monitoring of both buffalo and wild cattle populations.

Introduction

The Asian Water Buffalo *Bubalus bubalis* was introduced into northern Australia from South-east Asia between 1826 and 1866 (Letts *et al.* 1979). They became wild when some of the early British settlements were abandoned and have since occupied all major habitat types in the Northern Territory north of latitude 16° S (Skeat *et al.* 1996). An industry utilising buffalo hides started in the 1880s and this kept buffalo populations in check until the industry collapsed in 1956. After this buffalo numbers grew exponentially until they were declared an environmental nuisance in 1978 (Letts *et al.* 1979, Tulloch & Cellier 1986). In 1985 there were approximately 340 000 buffalo (mainly feral) spread over an area of 223 672 km² (Bayliss & Yeomans 1989). In an attempt to eliminate bovine tuberculosis (*Mycobacterium bovis*) from Top End feral and domestic bovids, a control campaign was undertaken between 1985 and 1989 as part of the national Brucellosis and Tuberculosis Eradication Campaign (BTEC) (Boulton

& Freeland 1991). This program significantly reduced buffalo numbers, especially in western Arnhem Land.

Cattle were introduced to Australia during the latter half of the 19th century and the early 20th century owing to a period of broad-scale pastoral settlement. The three species of cattle in Australia are the European breeds of *Bos taurus*, the humped cattle or Zebu breeds of *Bos indicus* and the Banteng *Bos javanicus*. All three are closely related and interbreed freely, although Banteng are restricted to the Cobourg Peninsula where they were first released in 1849 to provide meat for the fledgling British military outpost of Port Essington (Letts *et al.* 1979). Only the European and Zebu breeds are used for commercial beef production and some of these are wild because they have escaped from pastoral properties or have been left unmanaged on large stations. Many such wild cattle were shot in northern and central Australia as part of the BTEC.

The Arafura Swamp is situated in central Arnhem Land, approximately 550 km east of Darwin in the catchments of the Gulbuwangay and Goyder Rivers and is drained by the Glyde River (Figure 1). The area of the Arafura Swamp is 70 000 ha^2 in the dry season and can extend to 130 000 ha^2 in the wet season. It is an extensive permanent wetland which is significant as a breeding and refuge site for waterfowl and other wetland biota (Brennan *et al.* 2003, Williams *et al.* 2003). This is an internationally recognised wetland site listed under the RAMSAR Convention (Wetlands International 2006).

Although generally in good condition, wetland conservation values of the Arafura Swamp are becoming degraded through the increasing abundance and distribution of feral animals (particularly pigs and buffalo, but also horses, donkeys, cats and cane toads), localised planting of highly invasive exotic pasture grasses, and some incursions by livestock (Brennan *et al.* 2003, Williams *et al.* 2003). A recently published report, Arafura Swamp Water Resources Study (Williams *et al.* 2003), identified salt water intrusion as being the greatest threat to the integrity of the swamp; salt water is moving landward into the swamp at an average rate of 200 m $year^{-1}$ following a preferential path created by cattle *Bos taurus* tracks. At this rate it has been estimated that many of the large freshwater pools will be salinised within 10 years (Williams *et al.* 2003).

There has been a history of pastoralism in the area since the early 1970s when the Murwangi Pastoral Company was formed with a proposed lease covering all of the Arafura Swamp and most of the catchments. This was funded through the Aboriginal Development Corporation and the Methodist Overseas Missions with the aim of eventually transferring full control to local Yolngu people (Brennan *et al.* 2003). Murwangi Station officially commenced operation in 1975 but folded in 1982 through a lack of local interest. It then reopened in 1986 and was run by traditional land owners through the Murwangi Community Development Corporation (MCDC) which appointed an operations manager and ground staff. It had an operating abattoir until 2000 and supplied meat to Ramingining, Milingimbi and Elcho Island (Brennan *et al.* 2003). Since then the abattoir has not been used commercially and Murwangi Station only supplies small amounts of meat to Ramingining. The MCDC Board have discussed the idea of destocking the northern plains of the Arafura Swamp of cattle and changing their focus to the harvest of wild cattle and buffalo in and around the swamp. In order to determine the feasibility of this option it is necessary to know the extent and distribution of the buffalo resource throughout the area. Therefore, the aim of this study was to estimate the number of Asian Water Buffalo and wild cattle in the Arafura Swamp.

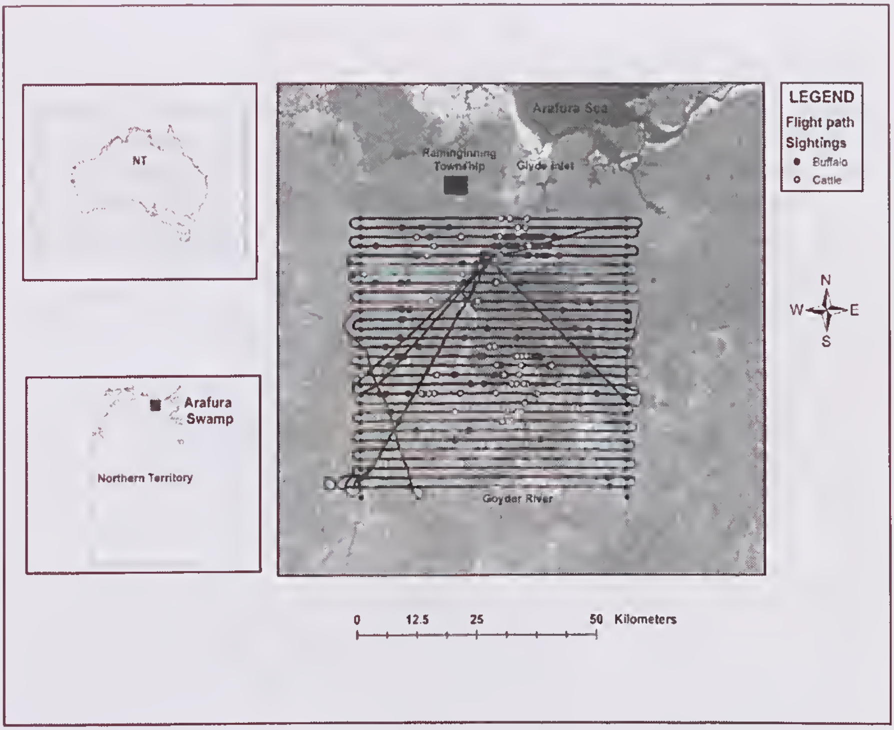

Figure 1. Map of the Arafura Swamp survey area showing its position, transect flight path and sighting of individuals/groups of buffalo and cattle.

Methods

Study area

A broad-scale aerial survey was conducted on the 8th and 9th of September 2005 to ascertain the distribution and abundance of Asian Water Buffalo and wild cattle in the Arafura Swamp region. The survey area was 3 089 km^2, and falls mainly within the Central Arnhem bioregion (Connors *et al.* 1996), and included the Blyth River to the west, Glyde River floodplains to the north, Goyder River to the south, and the floodplains of the Gulbuwangay River to the east (Figure 1).

Survey design

The survey methodology was based on established techniques for aerial survey of wildlife populations (Bayliss & Yeomans 1989, Caughley 1974, Caughley 1977, Caughley & Grigg 1982, Caughley *et al.* 1976). The sampling platform was a Cessna 206 high-wing aircraft equipped with a radar altimeter and Global Positioning System (GPS). The aircraft was flown at a mean altitude of 61 m (200 ft) above ground level and an average ground speed of 185 km h^{-1} (100 knots). The survey area was systematically sampled by east-west transects at 1.85 km spacing. A total of 30 transects was flown with a mean length of 55.6 km. Transect width was 200 m on each side of the aircraft. This represents a survey intensity of 21.6% of the total survey area. The transect width was delineated by fibreglass rods attached to the aircraft wing struts. The flight crew consisted of a pilot and three observers seated in the starboard front, port rear and starboard rear of the aircraft. Observers were able to communicate with each other via aircraft intercom and the number of animals in each group sighted was recorded by each observer on a COMPAQ iPAQ pocket computer (Hewlett-Packard Co.) that had been programmed as a data logger. All pocket computers were synchronised to the nearest second to the Universal Time Coordinate (UTC) and the time was automatically recorded when sightings were entered. Flight paths were logged using a GPS100AVD (Garmin International), recording latitude, longitude, UTC date and time every two seconds. The latitude and longitude of each sighting was determined by matching the observer sighting log with the GPS position log using UTC date and time. Sighting locations determined in this way incorporate an error due to the time lag between the sightings of the animals by the observer and the recording of the data on the pocket computer. This error was in the order of 120 m (i.e. the distance travelled in 2 seconds at 185 km h^{-1}).

Population estimates were calculated using the ratio method (Caughley 1979). Aerial survey data potentially incorporates two types of bias that lead to underestimates of the true population size: perception bias and availability bias. Perception bias is a result of observers missing animals that are potentially visible, while availability bias arises when some animals are concealed from the observers (Marsh & Sinclair 1989). To account for perception bias we used the double-count method whereby data is obtained by two starboard observers counting the same area simultaneously and is an adaptation of the Peterson mark-recapture estimate. The count of one observer is equivalent to the first capture and the count of the other observer is equivalent to the recapture/resighting (see Edwards *et al.* 2004 for a detailed description of methods). To account for availability bias, we used correction factors developed by Bayliss and Yeomans (1989).

Results

Due to significantly higher sighting rates by the single port observer compared with either starboard observers, the starboard team correction factor has been used to correct port observations rather than the individual starboard front or rear seat observer correction factors as per Edwards *et al.* (2004).

A total of 812 individuals were recorded during the survey, 322 (40%) being buffalo and 490 (60%) being wild cattle. Buffalo were observed in smaller groups (average size 3.6) but numerous groupings (90 groups sighted) compared to cattle which had larger groups (average size 8) but less numerous groups (61 groups sighted).

Buffalo were observed at highest densities in the paperbark swamps north-east of Murwangi Station in the northern part of the swamp where the swamp drains into the Glyde River (Figure 1). Cattle were also concentrated in this area but there seemed to be a greater concentration at the southern end of the Arafura Swamp in the paperbark swamps just west of where the Goyder River enters the swamp (Figure 1).

The population estimates (corrected for perception bias but not for availability bias) of buffalo and wild cattle in the Arafura Swamp survey area were 2 702 (S.E.± 802) and 2 642 (S.E.± 764) individuals, respectively. Using this population estimate (uncorrected for availability bias) and the standard error based on the variation between transects it is possible to state with 95% confidence that the buffalo population in the survey area is between 1 098 and 4 303 individuals in size. Similarly, the wild cattle population could vary from 1 114 to 4 170 individuals.

The availability bias multiplier varies with habitat type and a multiplier of 1.27 and 2.57 has been recommended for buffalo and 1.40 and 1.89 for cattle in floodplain and woodland habitats respectively (Bayliss & Yeomans 1989). Our survey area was predominantly made up of these two habitat types so it would be reasonable to use an averaged multiplier of 1.92 for buffalo and 1.64 for cattle. Using the upper and lower confidence levels of the population estimate and the averaged multipliers for habitat type, the corrected buffalo population estimate is 5 187 (95% CI, 2 108 - 8 266) while the wild cattle population estimate is 4 333 (95% CI, 1 827 - 6 839). Using these corrected population estimates the density of buffalo and wild cattle in the Arafura Swamp survey area is 1.7 km^{-2} (95% CI, 0.7 - 2.7 km^{-2}) and 1.4 km^{-2} (95% CI, 0.6 - 2.2 km^{-2}), respectively. Note that these ranges do not account for the uncertainty associated with the estimate of availability bias; actual 95% confidence intervals including this uncertainty would be larger.

Discussion

The extent and intensity of environmental impacts from buffalo varies greatly, depending on the landform type (upland, lowlands, floodplain and flood basin) of a region and the unique set of characteristics (combination of soils, topography, drainage and vegetation) associated with these areas (East 1990). Much of the research that has quantified environmental impacts of buffalo has been in the Kakadu region (East 1990, Skeat *et al.* 1996, Werner 2005), and the impacts include the reduction and removal of vegetation, changes in plant composition due to overgrazing and trampling, soil compaction, and damage to soil structure contributing to soil erosion (Skeat *et al.* 1996). Other longer term studies have found correlations with buffalo presence, fire patterns and tree growth and survival (Werner 2005). It must be noted that buffalo density was extremely high in certain areas of the Kakadu region and at their peak in the 1980s the mean density of buffalo at Kapalga research station was estimated as being 15 km^{-2} in open forest compared with 34 km^{-2} at the edge of the floodplain (Ridpath & Waithman 1988). It appears that buffalo are responsible for adverse and long-term environmental damage but management options are limited due to the expense of controlling their numbers in remote and inaccessible habitats.

The buffalo density (when corrected for perception bias only) in the Arafura Swamp was calculated at 0.87 ± 0.26 km^{-2}, which is similar to the buffalo density estimates of 0.74 ± 0.08 km^{-2} from a survey of the nearby Mann River district in 2001 (Koenig *et al.* 2003) and a 1998 survey for a similar area of 0.85 km^{-2} (K. Saalfeld, unpubl.). The landform types in the Arafura Swamp survey area are predominantly a mixture of floodplain and open woodland and the estimated buffalo densities are relatively low in comparison to the pre-BTEC population mean density in Kakadu National Park of 5.6 km^{-2} (Skeat *et al.* 1996).

Wild cattle estimates made during a survey of the Mann River district (Koenig *et al.* 2003) were much lower (0.10 ± 0.04 km^{-2}) compared with those of the Arafura Swamp area (0.86 ± 0.25 km^{-2}). The density estimates of wild cattle in the Mann River District were similar to those reported in the 1998 Arnhem Land feral animal survey (Saalfeld 1998). The higher densities around the Arafura Swamp are most likely to be caused by breakaways from Murwangi Station which operated as a pastoral lease between 1975 and 2000 (Brennan *et al.* 2003).

The Arafura Swamp is an internationally recognised wetland and as such has environmental qualities that need protecting. This area is on Aboriginal freehold land and has spiritual and cultural significance to the traditional owners. Cattle and buffalo are of great subsistence value to Aboriginal people in Arnhem Land (Altman 1987, Vardon *et al.* 1996) with the latter providing a commercial income through 'safari' and tourism ventures (Johnson 2000). The Aboriginal resource centre in this area, MCDC, is looking at a number of economic opportunities that match the expectations and skills of the people in this region, and commercial utilisation of buffalo is one of these options. Managing feral pest populations is both time consuming and expensive (Boulton & Freeland 1991, Ridpath & Waithman 1988) and if there is any opportunity to create sustainable enterprise through careful monitoring and harvest of feral pests it should be encouraged and supported. The Aboriginal people from this area are well aware of the impacts that cattle and buffalo are having on the hydrology, flora and fauna of the swamp through recent research (Brennan *et al.* 2003, Williams *et al.* 2003) and this survey has provided additional information to assist them in their future management decisions.

Acknowledgements

Many thanks to the National Landcare Program who funded this survey and also to Andrew Martin, the manager of Murwangi Station, who was actively involved in the survey and provided a place for the survey team to stay.

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Asian Water Buffalo *Bubalus bubalis* (two animals on left of photograph) mixing freely with a herd of domestic cattle in central Arnhem Land, northern Australia. (Clive R. McMahon)

Northern Territory Naturalist (2007) 19: 9-14

Dry season observations of butterflies in the "Gulf country" of the Northern Territory and far north-west Queensland

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Abstract

Land south of the Gulf of Carpentaria appears to be either a bridge or semi-arid barrier between butterfly populations of the higher rainfall areas of the Top End and north Queensland, but there have been few surveys to shed light on the issue. I surveyed butterflies in two "Gulf country" regions in July 2006, recording 25 species in far north-west Queensland and 27 species in the Borroloola region of the Northern Territory; 36 species in total. Of these, one and seven species respectively are additions to the known faunas for the regions, and records of 11 and seven species respectively provide corroboration for isolated previous records. These mostly represent a diminution of the gap in records between populations in Queensland and the Northern Territory, but exceptions are noted including three species that are at home in semi-arid environments.

Introduction

The relatively dry country along the southern shore of the Gulf of Carpentaria is a barrier separating many butterfly populations associated with the higher rainfall areas, and rainforest patches in particular, in the Top End of the Northern Territory and Cape York Peninsula in north Queensland (Kitching & Dunn 1999). Populations of several species have differentiated geographically, with different subspecies across this barrier; striking examples include the Small Brown Crow *Euploea darchia* and the Red-banded Jezebel *Delias mysis* (Braby 2000). However, the synoptic distributions maps in Braby (2000, 2004) indicate apparently isolated populations on either side of this barrier for a large number of butterfly species, many of which show no sign of differentiation across the Gulf. There are a number of possible explanations for this, amongst them the possibility that the counter-clockwise winds associated with high-pressure systems in central Australia during the dry season (Tapper *et al.* 1994), and cyclonic and monsoonal winds during the wet season (McDonald & McAlpine 1991), may trigger dispersal among apparently isolated populations.

Another possibility is that some of the distributional gaps are apparent rather than real, reflecting little survey effort in the southern "Gulf country" (Figure 1). The maps and distribution notes of Braby (2000) indicate that 22 species range into far north-west Queensland (here defined as north and west of the road from Camooweal to Burketown) whilst a further 23 species are recorded there as isolated records. Published surveys (Puccetti 1991, Daniels & Edwards 1998) detail a further 12 species, not including Puccetti's possible record of the Yellow Migrant *Catopsilia gorgophone*, bringing the known butterfly fauna for far north-west Queensland to 57 species.

In the Northern Territory section of the southern "Gulf country", knowledge of the butterfly fauna appears even less satisfactory. To my knowledge, there are no published surveys south of, nor more recent than Tindale's (1923) list of species for Groote Eylandt. Records in Braby (2000), many derived from other general works such as Dunn and Dunn (1991), indicate limited and otherwise unpublished collecting activities in the Borroloola area, with the documented fauna within about a 100 km radius comprising 21 wide-ranging species and isolated records of a further 19 species. Franklin *et al.* (2005) added three species, bringing the total known fauna of the Borroloola area to 43 species.

In this note, I provide details of species identified in these two regions of the "Gulf country" in July 2006.

Methods

Surveys were conducted: *a,* over a 10-day period in far north-western Queensland (sites 1–7), and *b,* during a two-day period in the Borroloola area (sites 8-9) (Table 1, Figure 1). Butterflies were identified by sight, by close examination of netted individuals, and examination of high-resolution photographs, using Braby (2004) and a key to the lycaenid butterflies of north-western Australia (Franklin & Bisa, in prep.). Only species readily identifiable in the field were recorded without closer examination – some sightings were not listed because their identity could not be adequately established. Surveys in Lawn Hill National Park (Qld) and Limmen National Park (proposed, NT) were limited to sightings and photography, the latter employed extensively at Lawn Hill. Many of the records which are from noteworthy locations were substantiated by photographs (indicated by "P" in Table 2), a CD of which is available upon request.

Results and Discussion

In total, 36 butterfly species were identified during the survey period (Table 2). In far north-west Queensland, 25 species were identified, of which one is an addition to the known fauna and 11 provide corroboration for isolated records. In the Borroloola area of the Northern Territory, 27 species were identified, of which seven are additions to the known fauna and seven provide corroboration for isolated records.

A number of the noteworthy records involved numerous individuals or repeat sightings, suggesting that occurrences of these species may not be isolated. The Tailed Emperor *Polyura sempronius* was added to the known fauna for both regions based on three individuals including two at well-separated locations in north-west Queensland. In far north-west Queensland, the Blue Argus *Junonia orithya* and Black-spotted Grass-blue *Famegana alsulus* were both widespread and locally common, and the Jewelled Grass-blue *Freyeria putli* was recorded at two locations and was moderately common at one of these (Hedleys Gorge), though the only previous regional records of these species are those of Daniels and Edwards (1998). The Two-spotted Line-blue *Nacaduba biocellata* and Long-tailed Pea-blue *Lampides boeticus* were both widely dispersed in far north-west Queensland and were repeatedly observed associated with their larval food plants (*Acacia* flowers and Rattlepods *Crotalaria* spp. respectively) (Braby 2000), and many hundreds of individuals of the former were present in the Lawn Hill Gorge area. In the Borroloola area, the Chocolate Argus *Junonia hedonia* was abundant along a swampy watercourse at Lorella Springs, whilst the Small Dusky-blue *Candalides erinus* was recorded at both Lorella Springs and Butterfly Springs.

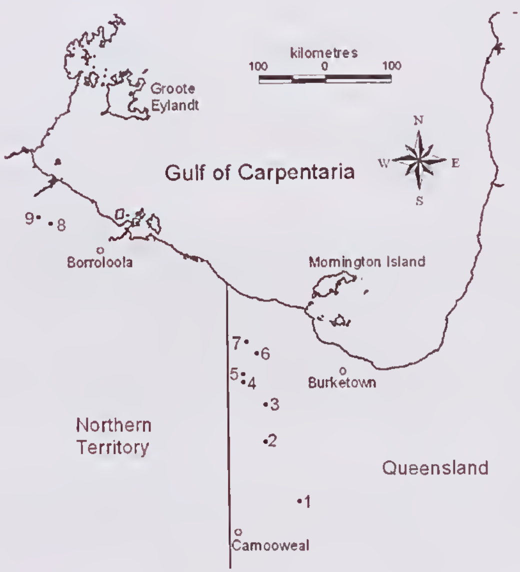

Figure 1. The southern "Gulf country" of the Northern Territory and Queensland. Numbers are survey sites (Tables 1, 2).

Table 1. Location and detail of butterfly surveys of the "Gulf country" in July 2006.

Location	Dates	Details
1. Qld: tributary of Thorntonia River 19°30'S, 138°56'E	15	0.7 hrs; riparian flat
2. Qld: main gorge area, Lawn Hill Nat. Pk 18°42'S, 138°29'E	16-21	± incidental; various habitats
3. Qld: Elizabeth Creek 18°12'S, 138°30'E	21	0.8 hrs; creekside savanna
4. Qld: Kingfisher Camp, Nicholson River 17°47'S, 138°12'E	22	5 hrs; various habitats
5. Qld: Hedleys Gorge 17°47'S, 138°12'E	23	4 hrs; sandstone gorge, creek
6. Qld: Hells Gate Roadhouse 17°30'S, 138°23'E	24	incidental; garden
7. Qld: Lagoon Creek 17°21'S, 138°15'E	24	0.8 hrs; riparian flat
8. NT: Lorella Springs 15°43'S, 135°38'E	26	5 hrs; various habitats
9. NT: Butterfly Springs, Limmen Nat. Pk 15°38'S, 135°28'E	27	incidental; various habitats

Most of the new regional records or the isolated records that these observations corroborate represent a diminution of the recorded gap between Top End and northern Queensland populations. However, there are four exceptions. The Two-spotted Line-blue and Long-tailed Pea-blue records are northern outliers of southern/arid zone species. The Spotted Dusky-blue *Candalides delospila* is a species of dry subcoastal and inland areas of northern Australia recorded from a series of disjunct locations (Braby 2000). The Northern Pencil-blue *Candalides gilberti* population at Lawn Hill is an eastern extension of a population restricted to north-western Australia, as previously noted by Puccetti (1991) and Daniels and Edwards (1998).

The number of noteworthy records obtained and the ease with which they were obtained in a short period of survey may in part reflect that the previous wet season in the areas surveyed finished late, with rainfall 50 to 100% above average (Bureau of Meteorology web-site, www.bom.gov.au, 1 Aug. 2006). However, it also demonstrates how poorly surveyed the lower "Gulf country" is, and suggests that further surveys of these areas are likely to be fruitful.

Acknowledgements

Viola Barnes and Kerstin Maas Enriquez joined me on several of the surveys. Michael Braby and Helen Larson commented helpfully on a draft of this manuscript.

Table 2. Butterflies observed in the "Gulf country" of far north-west Queensland and the Northern Territory, July 2006. Location numbers correspond to those in Table 1 and Figure 1. Notes: "xx" indicates a new record for the region; "x" corroboration of a spot record; and "P" that the record is supported by a photograph. Nomenclature follows Braby (2004) updated by Lushai *et al.* (2005).

Family Species	Locations	Notes N-W Qld		Notes Borroloola	
Hesperiidae					
Lyell's Swift *Pelopidas lyelli*	8			xx	P
Papilionidae					
Chequered Swallowtail *Papilio demoleus*	1 2 7				
Pieridae					
Lemon Migrant *Catopsilia pomona*	2 3				
Lined Grass-yellow *Eurema laeta*	7				
Pink Grass-yellow *Eurema herla*	3 4 7 8				
Small Grass-yellow *Eurema smilax*	2 3 7 8				
Large Grass-yellow *Eurema hecabe*	3 4 5 7 8				
Narrow-winged Pearl-white *Elodina padusa*	2				
Caper White *Belenois java*	1 2 5				
Caper Gull *Cepora perimale*	2	x	P		
Scarlet Jezebel *Delias argenthona*	8 9			xx	
Nymphalidae					
Evening Brown *Melanitis leda*	8				
Dusky Knight *Ypthima arctous*	8				
Orange Ringlet *Hypocysta adiante*	8 9			x	
Tailed Emperor *Polyura sempronius*	5 6 9	xx	P	xx	
Glasswing *Acraea andromacha*	2 3 4 5 7 8 9				
Varied Eggfly *Hypolimnas bolina*	8				
Blue Argus *Junonia orithya*	1 2 4 5 8 9	x	P		
Meadow Argus *Junonia villida*	8				
Chocolate Argus *Junonia hedonia*	8 9			x	
Blue Tiger *Tirumala hamata*	9			xx	
Australasian Lesser Wanderer *Danaus petilia*	4 5 8 9				
Common Crow *Euploea core*	2 4 5 7 8 9				
Lycaenidae					
Northern Pencil-blue *Candalides gilberti*	2	x	P		
Small Dusky-blue *Candalides erinus*	8 9			x	
Spotted Dusky-blue *Candalides delospila*	5 9	x	P	x	P
Two-spotted Line-blue *Nacaduba biocellata*	2 3 4 8	x	P	xx	
Speckled Line-blue *Catopyrops florinda*	5 8	x	P	x	
Wattle Blue *Theclinesthes miskini*	1 2 7 8				
Long-tailed Pea-blue *Lampides boeticus*	1 2 3 8	x	P	x	
Spotted Grass-blue *Zizeeria karsandra*	4	x			
Common Grass-blue *Zizina labradus*	3 4 7 8				
Black-spotted Grass-blue *Famegana alsulus*	3 4 5 7 8	x	P	x	
Dainty Grass-blue *Zizula hylax*	4	x	P		
Spotted Pea-blue *Euchrysops cnejus*	8			x	
Jewelled Grass-blue *Freyeria putli*	3 5 8	x	P	xx	

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The Two-spotted Line-blue *Nacaduba biocellata* at the flowers of Apple Bush (*Pterocaulon* sp.) in Lawn Hill National Park. (Don Franklin)

Northern Territory Naturalist (2007) 19: 15-24

Short-term effects of a Category 5 cyclone on terrestrial bird populations on Marchinbar Island, Northern Territory

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Abstract

On 24th April 2006, Category 5 Tropical Cyclone Monica severely damaged nearly all vegetation communities on the 20 600 hectare Marchinbar Island. This study documents the immediate effects of this cyclone on terrestrial bird populations for the hummock grassland community on the island, by comparing systematic baseline data collected in 1993 to surveys conducted during June 2006 (6 weeks after the cyclone). Conservative analysis of the combined data sets identified significant reductions in a number of bird species, total bird species richness and total abundance. Opportunistic bird observations recorded in 1972 and 1993 were also compared to the June 2006 opportunistic bird observations and highlight some notable omissions. Cyclones of this magnitude may be an important factor influencing species composition and some aspects of ecosystem dynamics on north Australian islands.

Introduction

Cyclones (hurricanes and typhoons) or tornadoes may directly and indirectly influence the characteristics of the local bird fauna (Wunderle 1995, Wiley & Wunderle 1994, Tanner *et al.* 1991). Strong winds and high rainfall associated with severe storm events can cause the death of some birds (Wunderle 1995). Indirect effects may have profound or long-lasting consequences on bird populations including loss of food resources and foraging substrates, loss of nests and roost sites and increased vulnerability to predators (Wunderle 1995).

Moreover, through their effects on ecosystem structure hurricanes can ultimately influence the kinds of habitats available to birds on islands and potentially provide clues about the selective forces that affect island avifauna (Waide 1991). In the Caribbean, hurricanes may be the most important factor controlling species composition and some aspects of ecosystem dynamics (Tanner *et al.* 1991). A number of studies have examined the effects of hurricanes on bird populations, using pre- and post-impact data (Lynch 1991, Waide 1991, Wunderle *et al.* 1992, Wunderle 1995).

However, for northern Australia there is no information on the effects of cyclones on island avifauna.

Marchinbar Island is the largest island in the Wessel Islands chain off north-east Arnhem Land (Figure 1). During the 1960s and 1970s, the Wessel Islands experienced seven Category 1 tropical cyclones (T. Smith, pers. comm. Darwin Bureau of Meteorology), but from the 1980s to 2005 there was almost no recorded cyclone activity in the area. However, in March 2005, Category 5 Cyclone Ingrid passed approximately 100 km to the south of the Wessel Islands chain and on 24th April 2006, Category 5 Cyclone Monica passed directly over Marchinbar Island. Cyclone Monica was the most intense storm ever observed in the Northern Territory (Bureau of Meteorology 2006). At Cape Wessel, the most northerly point in the Wessel chain, 130 km/h winds were reported before the wind instrument failed, but wind gusts were predicted to be in the order of 360 km/h (Bureau of Meteorology 2006).

Six weeks after Cyclone Monica, a field trip to Marchinbar Island was undertaken to sample for the endangered Golden Bandicoot *Isoodon auratus*. As such, bird surveys were a secondary objective and the systematic bird surveys only focussed on *I. auratus* trapping transects in the hummock grassland community. Additional general bird observations were also recorded regularly but opportunistically from a range of habitats across the island.

This study presents and compares two types of terrestrial bird data:

1) Opportunistic observations from 1972, 1993 and June 2006, and

2) Systematic hummock grassland bird surveys in 1993 and June 2006 (six weeks after Cyclone Monica).

Methods

Study area

Marchinbar Island (11°10' S 136°42' E) extends almost 100 km from the mainland off north-east Arnhem Land (Figure 1). Marchinbar Island is of gentle relief with low dune fields on the west coast to steep rocky cliffs on the eastern side. Rugged sandstone blocks form the dominant surface geology and lenses of laterite occur on some crests (Plumb 1965, Woinarski *et al.* 2001). Vegetation communities include shrubland or low open woodland with a hummock grass understorey, and extensive dry coastal vine thickets often forming a mosaic with dune grasslands and herbfields. Woodlands and open forest of *Melaleuca* are found along drainage lines or areas of impeded drainage. Mangroves and wet rainforests occur in very limited areas (Woinarski *et al.* 2001). The hummock grassland community (vegetation group 2 in Woinarski *et al.* (2001)) is dominated by *Triodia microstachya*, often with a diverse heathland community with occasional low trees, and grows on sand with moderate rock cover.

Figure 1. Wessel Islands off north-east Arnhem Land.

Data collection

Opportunistic observations

The following sources were used to track records of terrestrial birds on Marchinbar Island between 1972 and 2006:

i) An unpublished species list following a visit by D. Howe and D. Lindner in 1972 (as reported in Fisher *et. al.* 1996);

ii) Field surveys in 1993 including both quadrat sampling (see details below) and opportunistic bird observations from a range of habitats;

iii) Field surveys in 2006, including transect sampling (see below) and opportunistic observations from a range of habitats across the island.

Systematic hummock grassland bird surveys

Surveys in 1993 were undertaken from 5th to 16th July, centred on four sites located along the western side of Marchinbar Island. Surveys in 2006 were undertaken from 3rd to 23rd June and centred on three sites which were less than 5 km from three of the 1993 survey sites (Figure 2).

During 1993, twenty 50 x 50 m quadrats in the hummock grassland community were sampled. Each quadrat was censused by eight instantaneous counts (Woinarski *et al.* 2001) of all bird species seen and/or heard over a three day trapping period (12 days in total at four sites) with the majority of counts made in the first four hours after dawn. Although quadrats were also visited twice at night and records made of birds heard or seen by spotlight, these are not included in the comparison as similar records were not available for 2006. Similarly, quadrat data from other habitats not sampled in 2006 are not included.

During 2006, 24 transects approximately 400 m long and 10 m wide were sampled in the hummock grassland community. As traps (for the Golden Bandicoot) were checked along each transect, birds were censused by eight instantaneous counts of all bird species seen and heard over a six day trapping period (18 days in total at three sites), with the majority of counts in the first four hours after dawn.

Figure 2. Survey sites on Marchinbar Island 1993 and 2006.

We recognize that the data analysis is compromised due to the two different sampling techniques. However, the 2006 bird census effort included: i) more time spent at each site (six days in 2006 compared to three days in 1993) and ii) the larger area covered by the transects (24 x 4 000 m^2 transects in 2006 - total 96 000 m^2 and 20 x 2 500 m^2 quadrats in 1993 - total 50 000 m^2).

Analysis

Using pooled quadrat data from 1993 and the transect data from 2006 differences between individual bird species abundance, species richness and total abundance were compared with Mann-Whitney U tests. Only species that were recorded three or more times in either survey were used in the analysis.

Results

There was massive damage to all vegetation types on Marchinbar Island, with most trees and shrubs stripped of flowers, fruit and many branches. At one site bird skeletons were observed in the vegetation debris. Nevertheless, six weeks after Cyclone Monica, coppicing was starting to take place on many of the defoliated trees and shrubs.

The visit to Marchinbar Island in 2006 revealed the lowest species richness for terrestrial birds of any opportunistic observations on the island. In 1972, 46 terrestrial bird species were recorded; in 1993, 57 species were recorded; and in 2006, only 23 species were recorded (Table 1). There was a noticeable lack of frugivores, nectarivores and insectivores. Of eight nectarivores and frugivores recorded in 1993, only two were found in 2006.

Table 1. Terrestrial opportunistic (opp) bird observations recorded in 1972, 1993 and 2006 (+ indicates species present) and systematic hummock grassland bird surveys (1993 mean and 2006 mean) for Marchinbar Island. The 1993 and 2006 means are the average of counts for species recorded ≥3 times in either survey, otherwise x signifies present but < 3 records. z = Mann-Whitney U, P = * < 0.05, ** < 0.01, *** < 0.001.

Species	1972 opp	1993 opp	2006 opp	1993 mean	2006 mean	z	P
Orange-footed Scrubfowl *Megapodius reinwardt*	+	+	+				
Brown Quail *Coturnix ypsilophora*		+		x			
Black-necked Stork *Ephippiorhynchus asiaticus*	+	+					
Osprey *Pandion haliaetus*	+	+	+				
Pacific Baza *Aviceda subcristata*		+					
Whistling Kite *Haliastur sphenurus*	+						
Brahminy Kite *Haliastur indus*	+	+	+	0.000	0.208	1.890	

Table 1 continued

Species	1972 opp	1993 opp	2006 opp	1993 mean	2006 mean	z	P
White-bellied Sea-eagle *Haliaeetus leucogaster*	+	+	+	0.000	0.125	1.618	
Spotted Harrier *Circus assimilis*							
Swamp Harrier *Circus approximans*	+	+					
Brown Goshawk *Accipitar fasciatus*		+					
Collared Sparrowhawk *Accipiter cirrhocephalus*			+		x		
Wedge-tailed Eagle *Aquila audax*		+					
Brown Falcon *Falco berigora*	+	+	+		x		
Australian Hobby *Falco longipennis*	+						
Peregrine Falcon *Falco peregrinus*		+					
Nankeen Kestrel *Falco cenchroides*	+	+					
Brolga *Grus rubicunda*	+						
Red-backed Button-quail *Tumix maculosa*	+						
Bush Stone-curlew *Burhinus grallarius*	+	+	+				
Australian Pratincole *Stiltia isabella*		+					
Emerald Dove *Chalcophaps indica*	+	+	+				
Common Bronzewing *Phaps chalcoptara*	+	+					
Peaceful Dove *Geopelia striata*	+	+	+	x	x		
Bar-shouldered Dova *Gaopelia humeralis*		+	+	0.350	0.208	1.035	
Rose-crowned Fruit-dove *Ptilinopus regina*		+		x			
Pied Imperial Pigeon *Ducula bicolor*	+						
Red-tailed Black-cockatoo *Calyptorhynchus banksii*							
Little Corella *Cacatua sanguinea*	+	+	+	0.000	3.240	1.305	
Rainbow Lorikeet *Trichoglossus haematodus*	+	+	+				
Fan-tailed Cuckoo *Cacomantis flabelliformis*		+					
Horsfield's Bronze-Cuckoo *Chrysococcyx basalis*		+					
Little Bronze-Cuckoo *Chrysococcyx minutillus*	+	+					
Pheasant Coucal *Centropus phasianinus*	+	+	+	x	x		
Boobook Owl *Ninox novaaseelandiae*	+	+	+	x			
Spotted Nightjar *Eurostopodus argus*	+	+		0.250	0.000	2.269	*
Azure Kingfishar *Alcedo azurea*	+	+					
Forest Kingfisher *Todiramphus macleayii*	+						
Sacred Kingfisher *Todiramphus sanctus*	+	+	+	x	x		
Collared Kingfisher *Todiramphus chloris*	+	+					
Rainbow Bee-eater *Merops ornatus*	+	+	+	0.650	0.000	3.625	***
Rainbow Pitta *Pitta iris*	+	+					
Silver-crowned Friarbird *Philemon argenticaps*	+	+	+	1.050	0.583	1.604	

Table 1 continued

Species	1972 opp	1993 opp	2006 opp	1993 mean	2006 mean	z	P
Little Friarbird *Philemon citreogularis*							
Blue-faced Honeyeater *Entomyzon cyanotis*	+						
Brown Honeyeater *Lichmera indistincta*	+	+		0.500	0.000	2.847	**
Red-headed Honeyeater *Myzomela erythrocephala*	+	+					
Leaden Flycatcher *Myiagra rubecula*	+	+	+	0.500	0.041	2.016	*
Shining Flycatcher *Myiagra alecto*	+	+	+				
Restless Flycatcher *Myiagra inquieta*		+					
Magpie-lark *Grallina cyanoleuca*	+	+					
Grey Fantail *Rhipidura fuliginosa*		+					
Mangrove Grey Fantail *Rhipidura phasiana*		+					
Northern Fantail *Rhipidura rufiventris*	+	+		x			
Spangled Drongo *Dicrurus bracteatus*	+	+					
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	+	+		0.125	0.000	1.943	
White-bellied Cuckoo-shrike *Coracina papuensis*		+					
Cicadabird *Coracina tenuirostris*	+	+					
White-winged Triller *Lalage sueurii*	+	+		0.150	0.000	1.567	
Varied Triller *Lalage leucomela*	+	+	+	0.200	0.000	1.942	***
Olive-backed Oriole *Oriolus sagittatus*		+		x			
White-breasted Woodswallow *Artamus leucorynchus*	+	+		0.300	0.000	1.567	
Torresian Crow *Corvus orru*		+	+	0.050	0.668	1.869	
Great Bowerbird *Chlamydera nuchalis*	+	+	+	x	x		
Richard's Pipit *Anthus novaeseelandiae*		+					
Mistletoebird *Dicaeum hirundinaceum*	+	+		0.750	0.000	3.863	***
Tree Martin *Hirundo nigricans*	+	+	+	0.150	0.000	1.567	
Yellow White-eye *Zosterops luteus*	+	+		x			
Total	**46**	**57**	**23**	**22**	**13**		

During the 1993 survey 23 bird species were recorded from twenty quadrats in the hummock grassland community but only 12 were recorded ≥ 3 times. During the 2006 census in the hummock grassland community, 13 species were recorded from 24 transects but only seven were recorded ≥ 3 times. One species recorded in 2006, the Collared Sparrowhawk *Accipiter cirrhocephalus,* had not been recorded in previous surveys (Table 1).

Nine species recorded from the quadrats in 1993 were not recorded from transects in 2006 (Spotted Nightjar *Eurostopodus argus*, Rainbow Bee-eater *Merops ornatus*, Brown Honeyeater *Lichmera indistincta*, Black-faced Cuckoo-shrike *Coracina novaehollandiae*, White-winged Triller *Lalage sueurii*, Varied Triller *Lalage leucomela*, White-breasted Woodswallow *Artamus leucorynchus*, Mistletoebird *Dicaeum hirundinaceum*, Tree Martin *Hirundo nigricans*) (Table 1). There was a significant reduction in the abundance of six species, five of which were not recorded at all on the island in 2006 (Table 1). An additional four species recorded in the quadrats in 1993 were not recorded from transects in 2006. Two species not present in the 1993 quadrats were recorded in the 2006 transects (Brahminy Kite *Haliastur indus* and White-bellied Sea-eagle *Haliaeetus leucogaster*), although these species had been included in every opportunistic survey on the island, including in 1993.

There was a significant difference in bird species richness between the 1993 and 2006 hummock grassland surveys (Table 2). Although a significant reduction in total abundance of birds was also reported, this was of a small magnitude, compared with the reduction in species richness. Declines in most species were almost entirely compensated for by increases in the abundance of Torresian Crow and Little Corella (Table 1).

Table 2. Mann Whitney U-test for systematic bird census in 1993 and 2006 in the hummock grassland community.

	mean 1993	mean 2006	z	P
Total species richness	3.85	1.54	3.858	0.0001
Total bird abundance	5.95	5.65	2.966	0.003

Discussion

We acknowledge the difficulty with interpreting our results due to sampling, i.e. comparing quadrats and transects. However, even with the overall greater survey effort and area covered in 2006, fewer species were recorded. In addition, bird abundance and species richness was significantly lower than in 1993. Potentially, some absences could be explained by seasonal differences (though all surveys were conducted in the dry season) and/or the migratory and transient nature of some species, however many terrestrial species are likely to be resident on the island.

Our results are consistent with a similar pattern at Iron Range on mainland Cape York in north Queensland where all obligate frugivores were almost completely absent or numbers very much depressed in the weeks after Cyclone Monica went through with wind gusts of 125-170 km/h (on its way to Marchinbar Island) (S. Murphy, pers. comm.). In the Virgin Islands National Park, United States, Askins and Ewart (1991) compared data on bird populations two years before and four months after Hurricane Hugo and found that many species, especially nectarivores and frugivores, showed substantial population decreases; Wunderle *et al.* (1992) found a similar pattern after Hurricane Gilbert.

It is important to note that the hummock grassland community was of low species richness in 1993 and in many respects was likely to be the habitat least affected by cyclone impacts, because there are fewer trees and generally the habitat is low to the ground and has less structural diversity. Nonetheless, the significant reduction in species richness and abundance for this habitat type is indicative of the overall pattern for all habitat types on the island. This trend is highlighted in the fewer opportunistic bird records in 2006 when compared to 1972 and 1993.

There are some indications of selectivity in species change, particularly with fewer frugivores, nectarivores and insectivorous forest birds. Indicative of this change is the Brown Honeyeater, the most widespread species in 1993 and recorded from all habitats except rainforest (Fisher *et al.* 1996). During 2006 the species was not recorded at all on the island.

Terrestrial birds may have behavioural mechanisms to prevent being blown off an island during a cyclone, by avoiding flight and seeking shelter on or near the ground (Wiley & Wunderle 1994). However, if species survive the initial cyclone impact on an island they may be affected by depletion of required resources e.g. loss of food, nesting sites and more vulnerable to predation.

Islands in northern Australia are in highly dynamic locations where species occurrence and richness may be reflected in repeated re-colonisations and such frequent extreme disturbance may be a major factor limiting species richness.

Acknowledgements

The study was undertaken as part of a Natural Heritage Trust funded project 'The Conservation of the Golden Bandicoot'. We would like to thank our partners in that project; the Gumurr Marthakal Rangers (John Gurrum Gurrum, Bruce Lirrwa, and David Garambaka) Northern Land Council's Caring for Country Unit (Lyndall McLean) and Kakadu National Park (Fred Baird, Steve Winderlich). Many thanks to Irene Rainey for communication support in Darwin and to Craig Hempel for map production. Valuable comments on an earlier draft were provided by John Woinarski, Gay Crowley and Steve Murphy.

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Vegetation damaged by Tropical Cyclone Monica, Marchinbar Island. (Carol Palmer)

Northern Territory Naturalist (2007) 19: 25-34

Flora of the Territory Wildlife Park, Berry Springs, with particular reference to the grass layer

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Abstract

The Territory Wildlife Park near Darwin is often used as a study site for ecological research. As a consequence, a detailed discussion of vegetation in the grass layer is required by present and future researchers. This study presents a comprehensive species list of grass layer plants found within the Park, compiled from published and unpublished surveys in the period 1980 to 2004. Additionally, the current composition of the grass layer vegetation was compared with a description of the Park area undertaken in 1980. There are 242 grass layer plant species present, represented by 56 families and 145 genera. The number of species at the Territory Wildlife Park is much greater than in another popular experimental site nearby (Solar Village), although the proportion of the different life-form groups (e.g. grasses, forbs, vines) is generally similar. In at least the north-western area of the Park, the dominant grass layer species have changed. *Aristida* sp. and *Sarga intrans* have decreased in abundance in areas where they were dominant in 1980. The cause of this decline may be related to the Park's unusual fire and grazing history.

Introduction

The Territory Wildlife Park (TWP) in Berry Springs, 40 km south-west of Darwin, is often used as a study site for ecological research owing to its proximity to the Northern Territory capital. A survey of the vegetation within the Park was performed in 1980 (Sivertsen *et al.* 1980), although a detailed discussion of the grass layer (e.g. grasses, sedges, forbs, etc.) was not included. Twenty-six years after that survey and with the development of the Park, the composition of the grass layer appears to have changed in some areas. Current and prospective researchers could benefit from a detailed description of the grass layer. The composition of the grass layer within the north-western corner of the TWP is described here and compared with observations from the same area in 1980, to examine whether any changes have occurred in the last 26 years. Additionally, a comprehensive species list of grass layer plants is provided.

Methods

Vegetation structure and grass layer composition

The undeveloped north-western section of the TWP is dominated by a *Eucalyptus tetrodonta/E. miniata* open forest (*sensu* Specht *et al.* 1995). A small area in the vicinity of Goose Lagoon (c. 5-10 ha, Fig. 1a) has a higher density of mid-storey plants (hereafter referred to as the *dense mid-storey* community) than the area further to the north (c. 30 ha, Fig. 1b). Much of the ground in the dense mid-storey community is shaded and covered by leaf litter, resulting in low grass density and cover, and the presence of essentially only one grass species (*Eriachne triseta*) and very few forb species.

The vegetation further to the north has a lower density of mid-storey plants (hereafter the *sparse mid-storey* community) and supports a continuous and species rich layer of grasses and forbs. The grass species in this area are typically low-growing perennials such as *Eriachne triseta* and *E. avenacea* (20-60 cm), or annuals of intermediate height such as *Pseudopogonatherum contortum* (50-100 cm). *Alloteropsis semialata*, *Sarga plumosum*, and *Chrysopogon* spp. are relatively common taller grass species, growing up to 1.5 m. The exotic grasses *Andropogon gayanus* and *Pennisetum pedicellatum* are present throughout the TWP and adjacent rural properties, although *P. pedicellatum* is more abundant.

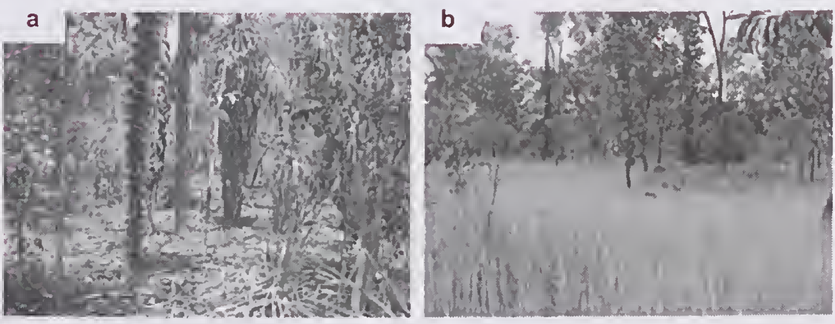

Figure 1. Open forest communities of the north-western corner of the Territory Wildlife Park. **a)** surrounding Goose Lagoon with a dense mid-storey of shrubs and **b)** further to the north, with a sparse mid-storey shrub layer.

There are differences in the composition of the grass layer between the north-western area of the TWP mentioned above and adjacent privately owned land to the west. Whilst the tree layer appears similar to that immediately inside the TWP, tall annual and perennial grasses such as *Sarga intrans* and *Heteropogon triticeus* are the dominant species in the adjacent privately owned land, yet only occur in low abundance within the Park.

A land resource survey of the TWP area provided a description of vegetation and several photographs (Sivertsen *et al.* 1980) and is used here to describe changes to the grass layer composition within the north-western corner since 1980.

Species list

A list of vascular plants found within the grass layer of the TWP is presented as a compilation of surveys undertaken by Sivertsen *et al.* (1980, 40 species contributed), Green Corps (2003, 155 species), the author's own records (82 species), and Schatz (unpubl., 15 species; Table 1). Species in the list contain superscripted letters to denote which species were contributed by the various authors. Species lists are presented in full by Sivertsen *et al.* (1980) and Green Corps (2003), while the author and Schatz (unpubl.) provide species detected during vegetation surveys.

The author used 648 permanent 1 m^2 quadrats throughout the site annually in the late wet season between 2004 and 2006, as part of a project surveying the abundance of grass layer species and their response to fire. Schatz (unpubl.) used the same quadrats, but surveyed in the late wet season on a single occasion in 2004. The plants in the author's list were identified by experienced field personnel or plant taxonomists. Voucher specimens in the author's collection and Schatz (unpubl.) are stored at the CSIRO Tropical Ecosystems Research Centre, Darwin. The authors of the remaining sources of data used to compile the species list have not lodged voucher specimens at a particular location, and as such the identification of their specimens should be treated with an element of caution.

Plants were included in the list if noted as forbs (FO), vines (VN), sedges (SE), grasses (G), ferns (F), or a combination of those life-forms (e.g. shrub/forb, SH/FO) by Brennan (1996). The few remaining species not listed by Brennan (1996) were assigned life-form classifications which are present in the literature or from photographs. Trees, shrubs, epiphytes, hydrophytes and mangrove species were excluded from the list. To avoid possible duplication, specimens identified to generic level were only included if no other plants from that genus were represented. Plant families are arranged alphabetically under the headings of Pteridophyta (Ferns and fern allies) followed by Angiospermae (Flowering plants). Exotic species are indicated by an asterisk (*).

Results

Grass layer composition

The dense mid-storey community currently surrounding Goose Lagoon was described by Sivertsen *et al.* (1980) as having a grass layer dominated by *Aristida* sp. This area is now dominated by *Eriachne triseta*, and *Aristida* sp. is uncommon both within this vegetation type and within the TWP generally. Descriptions of open eucalypt woodlands by Sivertsen *et al.* (1980) often note that the grass layer is dominated by

Sarga intrans. This species now has a very low abundance within the Park, but is very common immediately adjacent to the TWP.

Species list

The list (Table 1) contains a total of 242 grass layer species, represented by 56 plant families and 145 genera. Half of the families (28) contain only one species. Not included in the list are 19 species from the author's records and 11 species from Sivertsen *et al.* (1980) which are identified to generic level only. The Poaceae contain the highest number of species (57), followed by the Cyperaceae and Fabaceae (29 and 21 species respectively). The genus with the most species is *Fimbristylis* (12 spp., Cyperaceae), followed by *Eriachne* (8 spp., Poaceae), and *Ipomoea* (7 spp., Convolvulaceae). Forbs are the most common life-form with 117 species, followed by the grasses (57 species), vines (32 species), sedges (30 species), and ferns (6 species). Exotic species comprise 5.4% of the flora (13 species).

Discussion

Grass layer composition

Changes to the grass layer species composition of the north-western corner of the TWP could be a result of the land-use history of the Park in the last two decades. Firstly, most of the north-western area has experienced just one fire since the Park opened in 1989 (Green Corps 2003), a much lower fire frequency than for other tropical savanna sites in the Top End which are typically burnt every 1-3 years (Russell-Smith *et al.* 1997, Edwards *et al.* 2001). As fire exclusion promotes the growth of woody seedlings, it contributes to increased shading and litter production, thereby leading to different microsites which may not suit the recruitment of existing species (Vazquez-Yanes & Orozco-Segovia 1993, Woinarski *et al.* 2004).

Secondly, the TWP is surrounded by a 3 m high predator-exclusion fence which has prevented the movement of wallabies, both in and out of the TWP, and has also excluded cattle. The interaction between herbivores and the grass layer can be profound, affecting grass fuel loads, the flammability of the landscape, and the growth and mortality of seedlings (Werner *et al.* 2006). Isolating the specific factor(s) which have shaped the current composition of the grass layer at the TWP will require a thorough investigation of site history, and direct experimentation with fire and herbivory.

Species list

The number of grass layer plant species listed in Table 1 represents approximately 5% of the flora recorded in the Northern Territory (Cowie & Albrecht 2005). The number of grass layer species at the TWP is approximately three times that detected at

Solar Village in 2002, 15 km to the north-east (Woinarski, unpubl.). Such differences could simply reflect a higher sampling intensity at the TWP. The proportion of forb, grass, vine and fern species is similar between the TWP and Solar Village, although sedges represent a higher proportion of the flora in the TWP (Woinarski, unpubl.). The TWP may contain a greater area of poorly drained soils (e.g. in the vicinity of Goose Lagoon), which may favour such species.

Acknowledgements

I thank Alan Andersen and Lynda Prior for providing helpful comments on a previous draft of the manuscript, and Steve Reynolds for helping to arrange the species list. Thanks to Jon Schatz and John Woinarski for providing unpublished data. Jenny Low Choy, Jon Schatz and other staff of the Biodiversity Unit (Parks and Wildlife Commission of the Northern Territory) identified many of the plant specimens in the author's collection. Funding support provided by the Bushfire Cooperative Research Centre for the author's PhD research within the TWP is gratefully acknowledged.

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Table 1. Species list of vascular plants found within the grass layer of the Territory Wildlife Park. Life-form classifications follow Brennan (1996): G - grass, SE - sedge, FO - forb, VN - vine, F - fern, SH - shrub. Plant families are arranged alphabetically under the headings of Pteridophyta (Ferns and fern allies) and Angiospermae (Flowering plants). Exotic species are indicated by an asterisk (*). Data provided by: [a]Sivertsen *et al.* (1980), [b]Green Corps (2003), [c]Scott (unpubl.), [d]Schatz (unpubl.).

	Life-form
PTERIDOPHYTA	
ADIANTACEAE	
Cheilanthes sp.	F
BLECHNACEAE	
Stenochlaena palustris[b]	F
PARKERIACEAE	
Ceratopteris australis[b]	F
Ceratopteris thalictroides[b]	F
PTERIDACEAE	
Acrostichum aureum[b]	F
SCHIZAEACEAE	
Schizaea dichotoma[b]	F
ANGIOSPERMAE	
ACANTHACEAE	
**Barleria prionitis*[b]	FO/SH
Thunbergia arnhemica[b]	VN
AMARANTHACEAE	
Gomphrena flaccida[b]	FO
APIACEAE	
Trachymene didiscoides[b]	FO
APOCYNACEAE	
Ichnocarpus frutescens[b]	VN
ARACEAE	
Amorphophallus galbra[a, b]	FO
Typhonium russell-smithii[b]	FO
ASCLEPIADACEAE	
Gymnanthera oblonga[d]	VN
Marsdenia connivens[b]	VN
Marsdenia glandulifera[b]	VN
Marsdenia velutina[b]	VN
Marsdenia viridiflora[d]	VN
ASTERACEAE	
Allopterigeron filifolius[b]	FO
**Bidens bipinnata*[b]	FO
Blumea integrifolia[c]	FO
Blumea saxatilis[b, c]	FO
Cyanthillium cinereum[b]	FO
Elephantopus scaber[b]	FO
Pluchea indica[b]	FO/SH
**Tridax procumbens*[b]	FO
BORAGINACEAE	
Heliotropium ventricosum[b, c]	FO
CAESALPINIACEAE	
Chamaecrista nomame[b]	FO
CAMPANULACEAE	
Sphenoclea zeylanica[b]	FO
CAPPARACEAE	
Capparis sepiaria[b]	VN/SH
CAROPHYLLACEAE	
Polycarpaea holtzei[b]	FO
Polycarpaea violacea[b]	FO

CLUSIACEAE	
Hypericum gramineum[b]	FO
COLCHICACEAE	
Iphigenia indica[b]	FO
COMMELINACEAE	
Cartonema parviflorum[b]	FO
Cartonema spicatum[b]	FO
CONVOLVULACEAE	
Cressa cretica[b]	FO
Evolvulus alsinoides[c]	FO
Ipomoea abrupta[d]	VN
Ipomoea coptica[b]	VN
Ipomoea eriocarpa[c]	VN
Ipomoea gracilis[c]	VN
Ipomoea graminea[c]	VN
Ipomoea lonchophylla[d]	FO
Ipomoea polymorpha[b]	FO
Jacquemontia browniana[b]	FO/SH
Merremia dissecta[b]	VN
Merremia quinata[b]	VN
Polymeria pusilla[b]	FO
Xenostegia tridentata[b, c]	VN
CYPERACEAE	
Bulbostylis barbata[c]	SE
Crosslandia setifolia[b]	SE
Cyperus castaneus[b, c]	SE
Cyperus digitatus[b]	SE
Cyperus haspan[b]	SE
Cyperus javanicus[b]	SE
Eleocharis sp. Coonjimba Billabong (T.S. Henshall 3365)[b]	SE
Fimbristylis acicularis[b]	SE
Fimbristylis cymosa[b]	SE
Fimbristylis densa[b, c]	SE
Fimbristylis denudata[b]	SE
Fimbristylis ferruginea[b]	SE
Fimbristylis littoralis[b]	SE
Fimbristylis macassarensis[b]	SE
Fimbristylis microcarya[b]	SE
Fimbristylis oxystachya[b]	SE
Fimbristylis pilifera[c]	SE
Fimbristylis sp. Charles Darwin (J.L. Egan 5300)[c]	SE
Fimbristylis tetragona[b]	SE
Fuirena ciliaris[b]	SE
Lipocarpha microcephala[b, c]	SE
Rhyncospora longisetis[b]	SE
Schoenus falcatus[b]	SE
Scleria lithosperma[b]	SE
Scleria novae-hollandiae[b]	SE
Scleria psilorrhiza[b]	SE
Scleria pygmaea[b]	SE
Scleria rugosa[b]	SE
Scleria sp. McMinns Lagoon (M.M.J. van Balgooy 1272)[b]	SE
DILLENIACEAE	
Pachynema dilatatum[b]	FO/SH
DROSERACEAE	
Drosera indica[a, b]	FO
Drosera petiolaris[a, b, c]	FO
ERIOCAULACEAE	
Eriocaulon cinereum[b]	FO
Eriocaulon setaceum[b]	FO
Eriocaulon shultzii[b]	FO
EUPHORBIACEAE	
**Euphorbia hirta*[b, c]	FO
Euphorbia schultzii[b]	FO
Phyllanthus exilis[b]	FO
Phyllanthus minutiflorus[c]	FO
Phyllanthus sulcatus[b]	FO
Phyllanthus urinaria[c]	FO
Sauropus paucifolius[b]	FO
Sauropus stenocladus[c]	FO
Sebastiania chamaelea[b]	FO/SH
FABACEAE	
Abrus precatorius[b]	VN

FABACEAE continued	
Alysicarpus brownii[b]	FO
Alysicarpus schomburgkii[b, c]	FO
Canavalia papuana[b]	VN
Chaemachrista mimosoides[c]	FO
Crotalaria brevis[c]	FO
Crotalaria goreensis[b]	FO
Crotalaria medicaginea[c]	FO
Crotalaria montana[d]	FO
Crotalaria trifoliastrum[a]	FO
Cyclocarpa stellaris[b]	FO
Desmodium brownii[c]	FO
Dunbaria singuliflora[c]	VN
Eriosema chinense[b, c]	FO
Flemingia parviflora[d]	FO
Galactia muelleri[d]	FO
**Macroptilium lathyroides*[b]	FO
**Stylosanthes scabra*[b]	FO/SH
Tephrosia remotiflora[c, d]	FO
Vigna vexillata[c]	VN
Zornia prostrata[b]	VN
FLAGELLARIACEAE	
Flagellaria indica[b]	VN
GOODENIACEAE	
Goodenia armstrongiana[a, b, c]	FO
Goodenia byrnesii[d]	FO
Goodenia purpurascens[b]	FO
HAEMODORACEAE	
Haemodorum sp.	FO
HALORAGACEAE	
Gonocarpus leptothecus[c]	FO/SH
HYPOXIDACEAE	
Hypoxis nervosa[b]	FO
LAMIACEAE	
**Hyptis suaveolens*[a, b]	FO
LAURACEAE	
Cassytha filiformis[d]	VN

LENTIBULARIACEAE	
Utricularia chrysantha[b]	FO
Utricularia lasiocaulis[b]	FO
Utricularia odorata[b]	FO
LILIACEAE	
Protasparagus racemosus[b]	VN
Sowerbaea alliacea[b]	FO
Thysanotus chinensis[b]	FO
LOGANIACEAE	
Mitrasacme aggregata[b, c]	FO
Mitrasacme connata[b]	FO
Mitrasacme exserta[b]	FO
Mitrasacme multicaulis[b]	FO
Mitrasacme subvolubilis[b]	FO
MALVACEAE	
Abelmoschus moschatus[b]	FO/SH
MENISPERMACEAE	
Stephania japonica[b]	VN
Tinospora smilacina[b]	VN
NAJADACEAE	
Najas tenuifolia[b]	FO
ONAGRACEAE	
Ludwigia hyssopifolia[b]	FO
OPILIACEAE	
Opilia amentacea[b]	VN/SH
PASSIFLORACEAE	
Adenia heterophylla[d]	VN
**Passiflora foetida*[d]	VN
POACEAE	
Alloteropsis semialata[a, c]	G
**Andropogon gayanus*[c]	G
Aristida holathera[b]	G
Aristida hygrometrica[a, c]	G
Aristida pruinosa[a]	G
Bothriochloa bladhii[a]	G
Chrysopogon fallax[a, c]	G
Chrysopogon latifolius[a]	G
Digitaria gibbosa[c]	G

POACEAE continued

Digitaria violaescens[c]	G
Dimeria acinaciformis[b]	G
Dimeria ornithopoda[b]	G
Ectrosia agrostoides[c]	G
Ectrosia leporina[a]	G
Ectrosia scabrida[a]	G
Eragrostis cumingii[b, c]	G
Eragrostis pubescens[b]	G
Eragrostis rigidiuscula[b]	G
Eriachne agrostidea[b, c]	G
Eriachne avenacea[a, c]	G
Eriachne burkittii[a, c]	G
Eriachne ciliata[b, c]	G
Eriachne schultziana[a]	G
Eriachne squarrosa[a]	G
Eriachne stipacea[c]	G
Eriachne triseta[a, b, c]	G
Germania grandiflora[a]	G
Heterachne abortiva[b]	G
Heteropogon contortus[a]	G
Heteropogon triticeus[a, c]	G
Imperata cylindrica[a, c]	G
**Melinus repens*[c]	G
Mnesithea formosa[c]	G
Mnesithea rottboellioides[a, b, c]	G
Panicum decompositum[a]	G
Panicum mindanaense[b, c]	G
Panicum trachyrhachis[a]	G
Paspalum scrobiculatum[a, b]	G
**Pennisetum pedicellatum*[a, b, c]	G
**Pennisetum polystachion*[c]	G
Perotis rara[b]	G
Pseudopogonatherum contortum[a, b, c]	G
Sacciolepis indica[b, c]	G
Sarga intrans[a, c]	G
Sarga plumosum[a, c]	G
Sarga stipoidium[a]	G
Schizachyrium fragile[a, c]	G
Schizachyrium pachyarthron[c]	G
Sehima nervosum[a]	G
Setaria apiculata[a, b, c]	G
Sporobolus pulchellus[c]	G
Thaumastochloa major[a, b, c]	G
Themeda arguens[b]	G
Themeda triandra[a, c]	G
Triodia bitextura[a, b, c]	G
Urochloa holosericea[c]	G
Whiteochloa sp.[c]	G
Xerochloa imberbis[a, b]	G

POLYGALACEAE

Polygala eriocephala[b]	FO
Polygala linearifolia[c]	FO
Polygala longifolia[b]	FO
Polygala orbicularis[c]	FO
Polygala pycnophylla[c]	FO
Polygala sp. Kakadu (L.A. Craven 5464)[c]	FO

PORTULACACEAE

Calandrinia gracilis[b]	FO
Calandrinia uniflora[b]	FO

RESTIONACEAE

Dapsilanthus spathaceus[a]	SE

RUBIACEAE

Kailarsenia suffruticosa[d]	FO
Knoxia stricta[b]	FO
**Mitracarpus hirtus*[b, c]	FO
Oldenlandia galioides[b, c]	FO
Spermacoce articularis[b]	FO
Spermacoce auriculata[b]	FO
Spermacoce calliantha[b]	FO
Spermacoce heterosperma[c]	FO
Spermacoce stenophylla[b]	FO

SCROPHULARIACEAE

Buchnera gracilis[b]	FO

SCROPHULARIACEAE cont.	
Buchnera linearis[c]	FO
Buchnera tetragona[b]	FO
Buchnera urticifolia[c]	FO
Centranthera cochinchinensis[b]	FO
Limnophila fragrans[b, c]	FO
Lindernia sp. Mount Bundey (C.R. Dunlop 8840)[b]	FO
**Scoparia dulcis*[c]	FO
Stemodia lythrifolia[a, c]	FO/SH
SMILACACEAE	
Smilax australis	VN
STACKHOUSIACEAE	
Stackhousia intermedia[c]	FO
STERCULIACEAE	
Helicteres sp. Darwin (S.T. Blake 16793)[c]	FO
Melochia corchorifolia[b]	FO/SH
Waltheria indica[b, c]	FO/SH
STYLIDIACEAE	
Stylidium capillare[b]	FO
Stylidium fissilobum[b]	FO
Stylidium schizanthum[b]	FO
Stylidium semipartitum[c]	FO
VERBENACEAE	
Clerodendrum inerme[b]	VN/SH
Clerodendrum tatei[c]	FO
Huxleya linifolia[b]	FO
VITACEAE	
Ampelocissus acetosa[b]	VN
XYRIDACEAE	
Xyris complanata[c]	FO
Xyris pauciflora[b]	FO

One of many grasses at the Territory Wildlife Park, Northern Canegrass *Mnesithea rottboellioides*. (Ken Scott)

Northern Territory Naturalist (2007) 19: 35-45

Collecting biological specimens in the Northern Territory with particular reference to terrestrial invertebrates: guidelines to current legislation and permits

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Abstract

Guidelines to current legislation and permits regarding the collection of biological material, particularly terrestrial invertebrates, in the Northern Territory (NT) under the *Territory Parks and Wildlife Conservation Act* (*TPWC Act*) and the Commonwealth *Environment Protection and Biodiversity Conservation Act* (*EPBC Act*) are provided. Definition of several terms under the NT Government *Act*, types of permits issued by the NT Parks and Wildlife Service, and various land management systems in the NT are outlined. Contrary to popular belief that all insects and invertebrates in the NT (estimated to range from 24 900 to 63 500 species for insects) are protected, only 48 species, from the Phyla Mollusca (31), Chelicerata (13) and Insecta (4), are currently listed as protected wildlife. Of the protected species, 35 are designated as threatened wildlife, of which five are also listed nationally under the *EPBC Act*. However, all native invertebrates that occur within the boundaries of national parks and other conservation areas managed by the NT Parks and Wildlife Service or Parks Australia are protected under the *TPWC Act* or *EPBC Act*, respectively. Relative merits of the current legislation and permit system are briefly discussed.

Introduction

The following notes are provided to clarify the current situation regarding the collection of, and/or conduct of research on, biological specimens (especially terrestrial invertebrates) in the Northern Territory (NT). In particular, guidelines to the permit process administered by the NT Parks and Wildlife Service (PWS) and legislation under the *Territory Parks and Wildlife Conservation Act* (*TPWC Act*) are provided, together with the definition of several terms under the *Act*, types of permits issued by both the NT PWS and Commonwealth Department of the Environment and Water Resources (DEWR), and various land management systems operating in the NT. While these notes are compiled primarily from the perspective of insects and allied forms, the principles currently apply equally well to vascular plants and vertebrates in the NT. However, unlike invertebrates and plants, all vertebrates are protected in all areas of land in the NT, and research that involves their capture or collection requires ethics approval for the NT PWS permit process through the Charles Darwin University Animal Ethics Committee.

While some collectors are familiar with and have followed the permit process, it appears that there has been much misunderstanding in recent years of how the system works. Moreover, there appears to be a general misconception among entomologists operating outside the NT that all NT invertebrates are protected. As a result, some collectors have avoided working in the NT altogether, while others have almost certainly been breaking the law. This article has therefore been prepared partly in response to these matters; it is not necessarily intended to address or improve any inadequacies of the present system, but rather to provide an overview of the prevailing situation.

Territory Parks and Wildlife Conservation Act

Under the *TPWC Act*, invertebrates (which of course include insects) are recognised as animals. As such they are subject to the broader definition of **wildlife** which, under the *Act*, includes both animals and plants that are indigenous to Australia, migratory animals that periodically or occasionally visit Australia or the Australian coastal sea, or animals and plants of a kind introduced into Australia directly or indirectly by Aboriginals before 1788. In the NT, wildlife may be either 'protected' or 'unprotected'. Under section 43 of the *Act*, **protected wildlife** is defined as all wildlife that occurs in a park, reserve, sanctuary, wilderness zone or area of essential habitat, or wildlife that is a vertebrate that is indigenous to Australia, or the Regulations may prescribe species of wildlife that are protected wildlife, or the Minister for Parks and Wildlife may declare that a species of wildlife is protected wildlife. In the NT, the former category primarily concerns parks and reserves managed by the PWS for the conservation of biodiversity. Protected wildlife also includes 'threatened wildlife'. Under section 30 of the *Act*, **threatened wildlife** include those species for which their conservation status has been determined as either being Critically Endangered, Endangered or Vulnerable, and these taxa must be identified by the Minister by notice in the *Gazette*, the NT Government's official periodical publication. Currently, 48 species of invertebrates (from the Phyla Mollusca, Chelicerata and Insecta) are currently listed as protected wildlife, of which 35 are designated as threatened wildlife (Table 1). The remaining 13 species include the arachnids listed in Table 1, which were declared as protected wildlife under section 43(3) of the *Act* by the Minister in October 2003 (*Gazette No. G39*). The theraphosid spiders include three species in the NT: *Selenocosmia crassipes*, *S. stirlingi* and *Selenotholus foelschi*. The two genera of scorpions *Urodacus* and *Liocheles* are represented by 10 species, but others will almost certainly be found to occur in the NT. The species of scorpions currently recorded from within the boundaries of the NT are *Urodacus armatus*, *U. carinatus*, *U. centralis*, *U. excellens*, *U. giulianii*, *U. hoplurus*, *U. yaschenkoi*, *Liocheles austalasiae*, *L. extensa* and *L. waigiensis* (Brown 2007).

Table 1. Terrestrial invertebrates currently listed as protected wildlife under the NT *Territory Parks and Wildlife Conservation Act*. Conservation status of threatened wildlife is as follows: CR = Critically Endangered; EN = Endangered; VU = Vulnerable. Asterisk (*) designates those taxa also listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act*.

Mollusca: Gastropoda
Amphidromus cognatus (VU)
Basedowena squamulose (VU)
Bothriembryon spenceri (VU)
Dirutrachia sublevata (VU)
Divellomelon hillieri (VU)
Granulomelon arcigerens (VU)
Granulomelon gilleni (VU)
Granulomelon grandituberculata (VU)
Mesodontrachia desmonda (EN)
Mesodontrachia fitzroyana (CR)*
Ordtrachia australis (EN)
Ordtrachia septentrionalis (EN)
Pillomena aemula (VU)
Prototrachia sedula (VU)
Semotrachia caupona (VU)
Semotrachia elleryi (VU)
Semotrachia emilia (VU)
Semotrachia esau (VU)
Semotrachia euzyga (EN)*
Semotrachia filixiana (VU)
Semotrachia huckittana (VU)
Semotrachia illarana (VU)
Semotrachia jessieana (VU)
Semotrachia jinkana (VU)
Semotrachia rossana (VU)
Semotrachia runutjirbana (VU)
Semotrachia winneckeana (VU)
Setobaudinia victoriana (VU)
Sinumelon bednalli (CR)*
Trochomorpha melvillensis (VU)
Vidumelon watti (VU)

Chelicerata: Arachnida
Theraphosidae (all indigenous species)
Urodacus (all indigenous species)
Liocheles (all indigenous species)

Insecta: Lepidoptera
Attacus wardi (EN)
Croitana aestiva (EN)*
Euploea alcathoe enastri (EN)*
Ogyris iphis doddi (EN)

It is important to clarify the distinction between protected and unprotected wildlife as this has significant ramifications in terms of current legislation, permit requirements and penalties. All native invertebrates which occur in national parks and other conservation areas (nature parks, conservation reserves, coastal reserves, historical reserves) are by default protected wildlife within the boundary of the park or reserve. Invertebrates designated as protected wildlife (Table 1), including all threatened taxa, are deemed to be protected wildlife both on and off all parks and reserves. Invertebrates which are not listed as threatened or protected wildlife under the *Act* or that occur outside parks and conservation areas (e.g. Aboriginal lands, Territory forest/timber reserves, defence lands, pastoral lands) constitute unprotected wildlife.

However, the situation is slightly more complicated. The collection of or interference with any invertebrate for scientific purposes is classed as a 'commercial purpose'. Under section 9 of the *TPWC Act*, **commercial purpose** means the keeping, breeding, displaying, moving or other dealing with or use of the animal or plant for the purposes of selling, trading or bartering with the animal or plant or of otherwise earning a livelihood or making a profit. The *Act* goes on further to say that this "includes the use of animal or plant for scientific purposes." The *Act* does not define what constitutes a scientific purpose, but the general interpretation in the past has been that this implies a research activity leading to a scientific outcome, such as publication. In other words, even if the activity constitutes a scientific purpose without a commercial outcome, a permit is still required to take or interfere with invertebrates regardless of whether the species represent protected wildlife or unprotected wildlife. A permit is not required for general collecting of unprotected wildlife in which the activity does not constitute a scientific or commercial purpose. Additionally, a permit is not required if the scientific purpose does not involve the collecting of or interference with the wildlife, such as observational studies.

Permits issued by the Northern Territory Parks and Wildlife Service

In brief, there are several types of permits issued by the NT PWS under the *TPWC Act*, but rarely does one need to apply for more than two permits. The most important permits are as follows: (1) a permit is required to take or interfere with protected wildlife which, in the case of invertebrates, is all taxa indigenous to the NT if the activity is to occur within a park or reserve, or involves those taxa listed in Table 1 if the activity is to occur outside of a park or reserve; (2) a permit is required to take or interfere with wildlife (protected or unprotected) for commercial purposes, which includes scientific purposes, irrespective of location of the activity; (3) a permit is required to keep protected wildlife in the NT, including dead animals or parts thereof, which for invertebrates is those taxa listed in Table 1; and (4) a permit is required to import into, or export from the NT, protected wildlife. That is, an export permit is needed to take a protected invertebrate from the NT and move it interstate. Additionally, there are prohibited entrants permits, which are required to bring into, keep, and remove from the NT a 'prohibited entrant'. Under section 53 of the *Act*, a **prohibited entrant** is a species of invertebrate or plant that is not indigenous to the NT, and must be declared by the Minister (by notice in the *Gazette*) to be a prohibited entrant. The only invertebrates that are listed as prohibited entrants are all species of arachnids (i.e. spiders, scorpions, pseudoscorpions, harvestmen, mites, ticks etc) that are not indigenous to the Territory. These were declared by the Minister under section 53 of the *Act* in June 2002 (*Gazette No. G22*).

The permits most relevant to entomologists and invertebrate biologists residing in the NT are numbers (1), (2) and (3) listed above. Conversely, the permits most relevant to entomologists residing outside the NT are numbers (1), (2) and (4). Applications for these permits are relatively straightforward and are available from the Parks and Wildlife Service of the Northern Territory, PO Box 496, Palmerston, NT 0831 (or Ground Floor, Goyder Centre, 25 Chung Wah Terrace, Palmerston). Further information can be obtained from the following sources: telephone: (08) 8999 4795 / 8999 4814; facsimile: (08) 8999 4524; e-mail: pwpermits.nreta@nt.gov.au; website: http://www.nt.gov.au/nreta/wildlife/permits/index.html There is no fee to obtain these permits, but the applicant needs to allow for up to two months for the permit to be processed. The permits are generally valid for a period of up to 12 months, after which a report must be submitted to the NT PWS summarising the results of the work undertaken.

Environment Protection and Biodiversity Conservation Act and permits issued by the Commonwealth Department of the Environment and Water Resources

Invertebrates which have been listed as threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act* (*EPBC Act*) are protected nationally. There are currently five species of invertebrates in the NT that are affected by this legislation (Table 1). These are the butterflies Gove Crow *Euploea alcathoe enastri* and Desert Sand-skipper *Croitana aestiva*, both of which are listed as Endangered under the *EPBC Act*, and the three land snails *Mesodontrachia fitzroyana*, *Sinumelon bednalli* and *Semotrachia euzyga*, the first two of which are listed as Critically Endangered. *Euploea alcathoe enastri* was listed on 6 August 2003, while the four other species were listed on 18 August 2006. All five taxa are endemic to the NT and are listed as threatened species in the NT (Table 1). There are, however, proposals to align all threatened taxa endemic to the NT with the national list under the *EPBC Act*.

To collect nationally listed species when they occur on Commonwealth land, a permit is required from the DEWR, in addition to the permits issued by the NT PWS. The relevant permit under the *EPBC Act* is a "Permit to kill, injure, take, trade, keep or move a member of a listed threatened species or ecological community, a member of a listed migratory species, or a member of a listed marine species in or on a Commonwealth area". Applications for this type of permit are available from the Wildlife Conservation Branch, Department of the Environment and Water Resources, GPO Box 787, Canberra, ACT, 2601 (or John Gorton Building, King Edward Terrace, Parkes, ACT), or can be downloaded as a Microsoft Word file from http://www.environment.gov.au/epbc/permits/species/pubs/species-application-form.doc Further information can be obtained via: telephone: (02) 6274 1111 / 6274 1907; facsimile: (02) 6274 1666; e-mail: epbcwild@environment.gov.au; or on the website: http://www.environment.gov.au/biodiversity/threatened/index.html
A fee of $100 is required for this permit and will only be issued by the Environment Minister if the activity contributes significantly to the conservation of the listed threatened species; or the specified activity is of particular significance to indigenous tradition, and will not adversely affect the survival or recovery in nature of the conservation status of the listed threatened species concerned; or the specified activity is necessary in order to control pathogens, and is conducted in a way that will, so far as is practicable, keep to a minimum any impact on the listed threatened species concerned. This permit does not cover taking or sending specimens out of Australia for which a separate export permit is required.

A DEWR permit is not required to collect nationally listed species when they occur on land other than that managed by the Commonwealth. However, the applicant must submit a referral to the DEWR in order to obtain approval to collect nationally listed species on non-Commonwealth lands.

Land management

It is important to emphasise that the permits outlined above do not provide permission to enter NT land. Land in the NT is managed by various landholders and permission must be sought well in advance to enter these lands, including Territory land (e.g. parks, reserves), Commonwealth land (e.g. national parks, defence land), and private land (e.g. pastoral, Aboriginal).

Parks and reserves

Areas of land managed by the NT PWS are divided into three main regions (Northern, Katherine, Southern), each of which comprises a number of districts. A copy of the application will be sent to the appropriate Chief District Ranger (CDR) for approval prior to a permit being issued. Once the permit has been issued, the applicant will need to contact the CDR to determine the exact times and areas to be visited in each park/reserve and to ensure that the proposed collecting activity does not conflict with park management. This is an important courtesy as it is required to ensure that collecting does not conflict with the day to day management operations or with sensitive areas (e.g. Aboriginal sacred sites). Depending on the circumstances, the applicant may also be required to meet the Senior District Ranger or Ranger-in-Charge of the park/reserve before commencing field work. If field work is to be undertaken at any of the Parks and Wildlife Service's jointly managed parks and reserves, approval must be obtained from the traditional owners. Generally, this approval is provided by the Board of Management for the park/reserve. The Boards of Management usually meet only bi-monthly or quarterly so it is essential that applications are submitted well in advance (2-4 months) of any proposed field work. Often a representative of the traditional owners will accompany collectors who may be required to meet any expenses and reimburse them for their time and expertise. Parks/reserves which fall into this category under the NT *Parks and Reserves (Framework for the Future) Act 2003* are: Nitmiluk (Katherine Gorge), Cobourg (Garig Gunak Barlu), Djukbinj, Barranyi and Tnorala National Parks/Conservation Reserves. In addition, Umbrawarra Gorge National Park and Tjuwaliyn (Douglas Hot Springs) Nature Park are to be jointly managed soon, and there are proposals to jointly manage the remaining parks within the next two years (see http://www.dcm.nt.gov.au/dcm/parks/parks/index.shtml).

Australian parks

The NT PWS permits do not provide permission to undertake research in national parks managed by the Commonwealth: Kakadu National Park and Uluru-Kata Tjuta

National Park. These two NT parks are jointly managed by traditional owners and Parks Australia from whom permits must be obtained under the *EPBC Act* to carry out research. If the research affects listed threatened species or ecological communities, then a second permit is required. As noted above, a fee of $100 is required for this second permit and will be issued only if the activity contributes significantly to the conservation of the threatened species or ecological community. Parks Australia is insistent on traditional owner involvement in the research activity wherever possible. Contact details are as follows: Parks Australia, Department of the Environment and Water Resources, GPO Box 787, Canberra, ACT 2601 (telephone: (02) 6274 1673; facsimile: (02) 6274 2309; website: http://www.environment.gov.au/parks/permits/index.html#apply to download permit application forms for Uluru-Kata Tjuta and Kakadu National Parks). Alternatively, contact the Permits Officer, Kakadu National Park, PO Box 71, Jabiru, NT 0886 (phone: (08) 8938 1120; e-mail: Kakadunationalpark@environment.gov.au), or the Permits Officer, Uluru-Kata Tjuta National Park, PO Box 119, Yulara, NT 0872 (telephone: (08) 8956 1100, facsimile: (08) 8956 2064; e-mail: uluru.admin@environment.gov.au). Allow at least 2-3 months for the application to be processed.

Pastoral land

In the case of pastoral lands (leasehold land managed by graziers), the applicant will need to write to the landholder several weeks in advance and then follow up with a phone call just prior to field work to explain what is intended. The NT PWS permit application must be accompanied by proof that landholder permission has been granted (the signed landholder declaration in the application form) for the permit to be issued.

Aboriginal land

The NT PWS permits do not provide permission to enter Aboriginal land (private land managed by traditional owners). Those intending to visit or travel through Aboriginal land in the NT are legally required to have a permit. These permits are administered by the NT Land Councils on behalf of the traditional owners. Normally two permits are required, one to enter and remain on Aboriginal land and another to conduct research (special purpose permit). Application forms for these permits are obtained from the Northern Land Council for the northern and Katherine regions, Central Land Council for all areas south of Tennant Creek, Tiwi Land Council for Tiwi Islands (Bathurst, Melville), or Anindilyakwa Land Council for Groote Eylandt. Contact details for these land councils are given in Table 2. For research permits, it is generally advised to allow at least two months in advance for processing; if approval has been granted, the traditional owners will probably accompany the applicant and may expect payment for their time and expertise.

Table 2. Contact details for Aboriginal land councils in the Northern Territory.

Address	Phone/fax	E-mail	Website
Northern Land Council PO Box 42921, Casuarina, NT 0810	Ph: (08) 8920 5100 Fax: (08) 8945 2633	permits@nlc.org.au	http://www.nlc.org.au/html/permits.html
Central Land Council PO Box 3321, Alice Springs, NT 0871	Ph: (08) 8951 6211 Fax: (08) 8953 4343	permits@clc.org.au	http://www.clc.org.au/permits/
Tiwi Land Council PO Box 38545, Winnellie NT 0821	Ph: (08) 8981 4898 Fax: (08) 8981 4282		http://www.tiwilandcouncil.net.au/Visiting/TIWI-Visiting.htm
Anindilyakwa Land Council PO Box 172, Alyangula, Groote Eylandt, NT 0885	Ph: (08) 8987 6710 Ph: (08) 8987 6638 Fax: (08) 8987 6745 Fax: (08) 8987 6293		http://www.angurugu.nt.gov.au/home/our_community/visitor_information

Discussion

It is recommended that entomologists conducting research in the Northern Territory work through the permit process. Otherwise the penalties are fairly severe, particularly for offences relating to protected wildlife. Under section 66 of the *Act*, the penalty for restraining for any length of time by any means protected wildlife without authorisation, or to take protected wildlife out of the NT without authorisation, is 500 penalty units ($55 000) or imprisonment for 5 years and, in the case of threatened wildlife, 1 000 penalty units ($110 000) or imprisonment for 10 years.

The NT PWS permits are relatively easy to obtain, and the reporting requirements are fairly minimal. Permit holders are required to submit a report within 21 days of expiration of the permit. Any publications arising from the work must also be submitted. NT PWS now prefer reports to be submitted in digital form, although it is envisaged that in future a CD, providing specific fields to be completed, will be mailed to permit holders. The basic requirements include a summary of the species (and number) recorded or collected, the locations sampled (including site, description, habitat, coordinates), date(s), and methods used. Failure to submit a return will prevent the applicant from obtaining subsequent permits. The NT differs from permit systems operating in other states; for example, the model currently adopted in Queensland by the Entomological Society of Queensland in which access to collect invertebrate material from state lands (e.g. State Forests, Timber Reserves) and conservation areas (National Parks), and/or to collect protected species, are administrated by a delegate of the society as the permit holder. There is limited provision to obtain a blanket permit to cover all parks and reserves in the NT, or parks and reserves within any of the three major regions of the NT; however, this may be improved in future. To obtain a blanket permit the applicant must either specify each park to be sampled or request 'all parks and reserves in the NT' in the application form. The application will then be sent out to each CDR and joint management committee of all parks for approval so this will take some time to process.

In summary, the NT permit system might seem on first impression a complex bureaucratic process to many entomologists. A major weakness of the *TPWC Act* appears to be the interpretation of 'commercial purpose', which I believe is ambiguous, as the *Act* does not define what constitutes 'scientific research' or 'scientific purpose'. There are, however, proposals to separate permits for scientific research, whether collection- or observation-based studies, from those for 'commercial purposes', so it remains to be seen if research on invertebrates will continued to be classed as a commercial activity. Be that as it may, the current system is designed to ensure the conservation of our biodiversity in the long term and ensure that landholders have a real input into the research activities carried out on their lands. Moreover, permits are a way of managing or monitoring research activity on lands managed by different landholders, and a mechanism whereby raw data concerning the identity and distribution of wildlife can be reported and centralised. Compared with vertebrates and vascular plants, the terrestrial invertebrate fauna of NT is poorly known – around 8 200 species of insects are currently recognised from the NT (Brown 2007), but the actual size of the insect fauna is estimated to range from 24 900 to 63 500 species (Appendix 1). Hence, there are great opportunities for discoveries of new species and new localities/range extensions of known species. It is therefore important to follow the system that is currently in place to take advantage of the opportunities that the NT has to offer.

Acknowledgements

I am particularly grateful to Keith Saalfeld for his detailed knowledge of NT legislation and permits and helpful comments on the text. John Woinarski, Chris Pavey, Chris Palmer, Tony Bowland and Ray Chatto also made constructive comments, and Graham Brown provided considerable help with the insect and arachnid fauna of the NT. Richard Weir, Don Franklin and Graham Brown provided useful comments and advice regarding the utility of the current permit system.

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The Black-headed Skimmer *Crocothemis nigrifrons*, a dragonfly (Odonata: Libellulidae). Fogg Dam, Northern Territory. (Don Franklin)

Appendix 1. Estimation of the number of terrestrial insect species in the Northern Territory.

Three estimates are provided below in an attempt to quantify the number of terrestrial insects in the NT. All estimates are based on various assumptions and extrapolations from other groups. Although the estimates vary greatly, they are of similar order of magnitude, and suggest the total insect fauna lies somewhere between 25 000 and 63 000 species. The third estimate, based on a crude determination of β-diversity (the turnover of species composition with distance), is probably too high because it is doubtful that most insect groups are represented in the NT by as much as one third of the Australian fauna (the two higher taxa used in the estimates frequently have widespread distributions within Australia due to their high dispersal ability, and consequently have a relatively high representation in the NT).

(1) The number of non-marine vertebrates in the NT is approximately 960 species (Northern Territory Government 2006). Samways (1994) estimated that vertebrates comprise around 3%, and insects around 78%, globally of all animal species. Therefore, the estimated total number of terrestrial insects in the NT, based on the number of non-marine vertebrates in the NT, is 24 900 species:

$$\frac{960 \text{ NT vertebrates}}{0.03 \text{ world vertebrates}} \times 0.78 \text{ world insects} = 24\,900 \text{ species}$$

(2) The number of described species of insects recorded from the NT is approximately 8 200 (Brown 2007). Austin *et al.* (2004) estimated that around 25% of Australian insects have been formally recorded and described. Therefore, the estimated total number of terrestrial insects in the NT, based on present knowledge of known species in the NT, is 32 800 species:

$$\frac{8\,200 \text{ NT described insects}}{0.25 \text{ Australian described insects}} = 32\,800 \text{ species}$$

(3) The terrestrial Australian insect fauna is estimated to be around 205 000 species (Yeates *et al.* 2003). Two popular groups of insects that are relatively well-known taxonomically are the Odonata (dragonflies and damselflies) and the Hesperioidea and Papilionoidea of the Lepidoptera (butterflies). Both groups are represented in the NT by around 31% of the Australian fauna [dragonflies: 100 NT species out of 324 Australian species (Theischinger and Hawking 2006); butterflies: 135 NT species out of 434 Australian species (Braby 2004 and unpublished data)]. Assuming that other groups have a similar proportional representation to dragonflies and butterflies in the NT, the estimated total number of terrestrial insects in the NT is therefore 63 500 species:

$$205\,000 \text{ Australian insects} \times 0.31 \text{ NT} = 63\,500 \text{ species}$$

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Sulphur-crested Cockatoo *Cacatua galerita* feeds on nectar

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During the dry season months of May to August, a number of the Top End's most widespread tree species flower, including the Darwin Woollybutt *Eucalyptus miniata*, the Darwin Stringybark *E. tetrodonta* and the Fern-leaved Grevillea *Grevillea pteridifolia*. As these species are prolific sources of nectar much favoured by nectar-feeding birds (Franklin & Noske 1999, 2000), nectar is an abundant resource at this time of the year over a vast area (Woinarski *et al.* 2000). This seasonal resource is exploited not only by birds that normally consume nectar – honeyeaters and lorikeets – but also by a range of opportunists including frugivores, insectivores and even granivores and a terrestrial omnivore which rarely feed on nectar at other times of the year (Franklin 1999). Here I report observations of a Sulphur-crested Cockatoo *Cacatua galerita* feeding opportunistically at flowers and apparently obtaining nectar. Nectar has not previously been reported as a food source for this species in the Top End or elsewhere (Higgins 1999).

On 27 July 2006 at Butterfly Springs in Limmen National Park (proposed) (15°38'S, 135°28'E) in the Northern Territory's "Gulf country", I observed a Sulphur-crested Cockatoo feeding at flowers of the Fern-leaved Grevillea on three occasions. On one occasion the behaviour persisted for 15 minutes, and on the other two for at least five minutes. The bird (possibly the same individual) moved slowly from conflorescence to conflorescence, working over each for up to about a minute. When the angle of observation was suitable, I could clearly see its tongue moving rapidly in and out of the flowers, probing near the base of the style. I saw no behaviour suggesting that the bird was chewing the flowers, nor any evidence of flower parts being dropped. On one occasion the bird was noted biting off an entire conflorescence, feeding from it whilst holding it in its foot, then dropping it.

Fern-leaved Grevillea is a small tree. There were numerous specimens of it in heavy bloom in the vicinity. Examination of the conflorescences revealed an abundance of exposed nectar near the base of the style in flowers in which the style was about to open or had recently unfurled. As the pollen-presenter in *Grevillea* is at the tip of the style (Olde & Marriott 1995), which in open flowers of *G. pteridifolia* is held about 4 cm from the nectary (pers. obs.), the cockatoo was not seeking pollen.

Franklin (1999) observed 21 species of opportunists, and gleaned records of a further eight speeies from the literature and other sources. Amongst these were one other cockatoo, the Little Corella *Cacatua sanguinea* feeding at the flowers of a eucalypt, as well as four speeies of parrots other than lorikeets. As the foraging in this observation was non-destruetive and brought the faeial feathers into the vieinity of the pollen-presenter, it is possible that the species at least occasionally serves to pollinate Fern-leaved Grevillea. Whether eockatoos, parrots and other opportunists provide pollination serviees to trees in the cool dry season appears worthy of further investigation.

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Sulphur-erested Cockatoo *Cacatua galerita* feeding at the flowers of Fern-leaved Grevillea *Grevillea pteridifolia* at Butterfly Springs. (Don Franklin)

Northern Territory Naturalist (2007) 19: 48-50

Love is in the air: Arboreal copulations in the Pheasant Coucal *Centropus phasianinus*

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The mating behaviour of birds often involves loud calls for mate attraction and conspicuous courtship displays, typically by the male, which are sometimes followed by copulation (Andersson 1994). However, unlike calls and courtship displays, which are designed to draw attention to the bird, copulations are rarely observed. This scarcity of observations is not unexpected as copulations are usually short and infrequent, and often take place when or where observations are difficult, such as before sunrise or in dense vegetation (Kempenaers *et al.* 1995, Double & Cockburn 2000). Since copulations are central to the mating behaviour of birds, even a few observations can improve our understanding of mating systems and sex-roles.

A better knowledge of the copulation behaviour of Pheasant Coucals *Centropus phasianinus* is of particular interest because of their unusual sex-roles and an extreme and reversed testis asymmetry. In Pheasant Coucals, parental care is predominantly performed by the male, which weighs about 50% less than the female (Taplin & Beurteaux 1992, Higgins 1999). Based on these features, a reversal of the classic sex-roles of male mating competition and female mate choice (Darwin 1871) has been suggested for Pheasant Coucals (Higgins 1999), but a recent observational study contradicts this idea (Maurer 2006).

Coucals are exceptional amongst birds for their reduction or loss of the left testis (Bernstein 1860, Ligon 1997). Normally the left testis of birds exceeds the right testis in size (Lake 1984) and this asymmetry may have evolved as a consequence of the lack of a right ovary in most female birds (Delehanty *et al.* 2005). A bigger left than right testis, with concomitant increases in sperm production by the left testis, could promote sperm-transfer and fertilization. The mechanics of avian copulations may mean that sperm transfer is further enhanced if the male mounts the female from the left rather than the right side (Delehanty *et al.* 2005). This hypothesis is supported by the finding of a left side bias in mountings by the Chukar-partridge *Alectoris chukar* (Delehanty *et al.* 2005). The reversed testis asymmetry in coucals raises the question of whether coucals also preferentially mount from the right side.

Two copulations of Pheasant Coucals have been described in detail and these took place on or near the ground (Mackness 1979, Coates 1985). This is not surprising, since coucals are largely terrestrial and hunt and nest mainly on the ground (Higgins 1999). Both copulations were preceded by a chase, during which both birds were crouched and the male followed the female, sometimes carrying a food item such as a grasshopper (Orthoptera). Eventually the female stopped and straightened her body, which seemed to prompt the male to mount her and then feed her while copulating. Neither description of copulations mentions the direction of the mounting.

Ten copulations by five different pairs were observed during a larger behavioural study of coucals, conducted near Howard Springs, Northern Territory between December and March during 2003-2006. In contrast to previous observations, none of these copulations took place on the ground. Instead, the pairs copulated sitting on a horizontal branch approximately 5–20 m above the ground. The copulations took place between 07:20 and 10:30 hours. Pheasant Coucals were seen copulating at all stages of the breeding cycle, except when they had fledglings, as follows: once during the laying period, twice during the incubation period, once during the nestling period, and five times at an unknown stage. One copulation took place straight after a nest loss, but it is not clear whether it preceded a new nesting attempt. This was the only copulation for which the identity of the resident male and female could be confirmed due to individual moult-patterns. An additional four copulations involved the resident male but the female's identity was unclear, while in the remaining five copulations either or both sexes may have been strangers to the territory where the copulation took place. Most observations involved a single copulation, but two and four consecutive copulation attempts were observed once each.

Typically, the arboreal copulations of Pheasant Coucals followed the pattern described below. In the 30 minutes before the copulations, each sex gave a few territorial Scale and Monotonous calls (Higgins 1999) from trees up to 100 m apart. Sometimes, either sex also joined their partner's Scale calls to form a Duetting Scale call (Higgins 1999). Then the male approached the female, usually carrying a food item (five times) or a leaf (twice) in his beak. During this approach, the male drooped his wings and fanned his tail and sometimes bobbed his head and tail up and down. Quiet chuffing and grunting noises were given by both birds as the male drew closer. In about half the cases the male then mounted the female within 30 seconds and fed her. In the other cases the male faced the female and she assessed the nuptial gift before allowing the male to mount, or pecked his head, presumably because she was dissatisfied with the item presented. The pecking usually prompted the male to return to the ground for approximately 5 minutes to find a different food item and repeat the courting. Cloacal contact lasted for approximately 10 seconds although some copulation attempts only took 2–3 seconds and were possibly unsuccessful. The direction of mounting was noted three times and the male mounted from either the right (twice) or the left side. After copulation, the male usually left within a minute, while the female remained in the tree for several minutes.

Pheasant Coucals may perform copulations in trees, despite their otherwise largely terrestrial habits, to reduce the risk of predation. As one coucal's attention is drawn towards the other during copulation, its vigilance may be reduced, while its pre-copulatory calls could make it more obvious to predators. In the dense undergrowth of the study site, this could give predators such as Dingoes *Canis lupus dingo* an opportunity to creep up on the birds unnoticed. Alternatively, arboreal copulations could function to advertise a mating and territorial ownership to neighbours, although no neighbours were seen to observe such matings.

The observed pattern of copulation indicates that female Pheasant Coucals decide whether to mate or not based on the nuptial gifts the male offers, and suggests female choice. It therefore supports classical, rather than reversed, sex roles in Pheasant Coucals. Duetting behaviour may play a role in coordinating some copulations, but is not essential. Males mount females from either side, but more observations are needed to assess whether the reversed testicular asymmetry of Pheasant Coucals also leads to a preference to mount from the right rather than the left side of the female.

Acknowledgements

I am grateful to Sam Quinlan and Olya Milenkaya for their detailed descriptions of additional observations of arboreal copulations and to Stuart Cooney for comments which greatly improved the manuscript.

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Northern Territory Naturalist (2007) 19: 51-53

A "lost years" Flatback Turtle *Natator depressus* (Garman, 1858) found

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Post-hatchling marine turtles are generally considered to be those that have completed their frenzied swim away from the nesting beach, absorbed their internal yolk sac in the process and entered the pelagic stage of their lifecycle; a phase which ends when they switch to benthic food items on the continental shelf (Limpus *et al.* 1991). The period between hatching and later appearing in coastal waters is known as the "lost years", as juvenile marine turtles are infrequently observed during this period (Carr 1982). The following is a record of a post-hatchling Flatback Turtle *Natator depressus* that was recorded near the edge of the continental shelf in northern Australia.

In November 2005, a healthy juvenile turtle attracted to the lights of the *FV Deep Tempest* was dip-netted at the surface in 95 metres of water, 111 kilometres north-east of Cape Van Diemen (10° 12' S, 130° 40' E; Figure 1). The verifying photograph accompanying the report revealed the turtle to be a post-hatchling Flatback Turtle with a straight carapace length (SCL) of 70 mm (Figure 2).

This record represents the smallest post-hatchling Flatback Turtle yet recorded. There are 140 published records of post-hatchling Flatback Turtles currently available (Table 1), the smallest of which is a record of a post-hatchling found beneath a White-bellied Sea-eagle *Haliaeetus leucogaster* feeding station on the east coast of Queensland with an estimated SCL of 113 mm (Walker 1991a). The smallest previous record of a post-hatchling Flatback Turtle in Northern Territory waters was an individual of 122 mm SCL, also collected from beneath a Sea-eagle feeding station (Walker 1991b).

Flatback Turtles appear to lack an oceanic stage in their development and instead complete their early development over the Australian continental shelf, where they are common in turbid waters between 5 and 20 m and rare at depths of greater than 45 m (Walker & Parmenter 1990). Walker and Parmenter (1990) came to their conclusion after examining available post-hatchling records of animals living within a few kilometres of the coast and in waters of less than 60 m. However, specimens of less than 113 mm SCL are missing from these records. This record indicates that the post-hatchling phase of Flatback Turtles in northern Australia may include a wider range of habitats than previous records suggest.

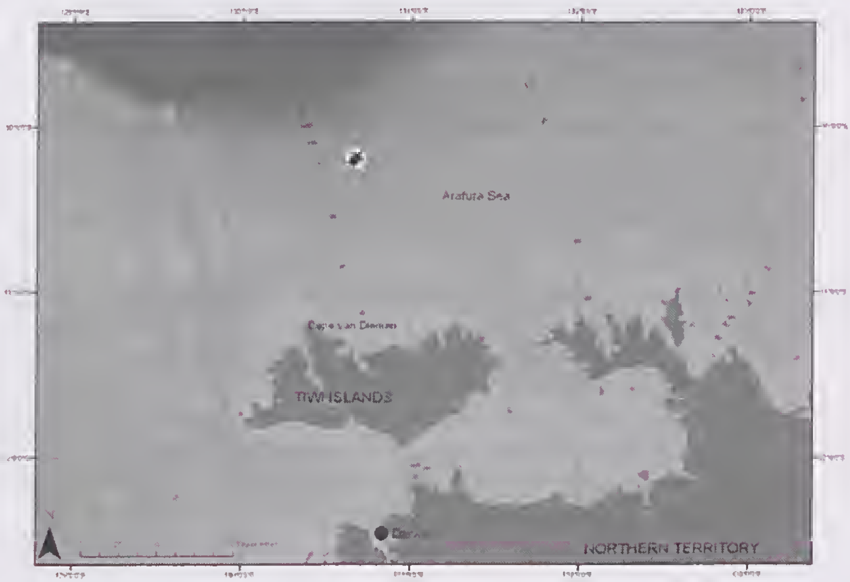

Figure 1. Location of post-hatchling Flatback Turtle when dip-netted.

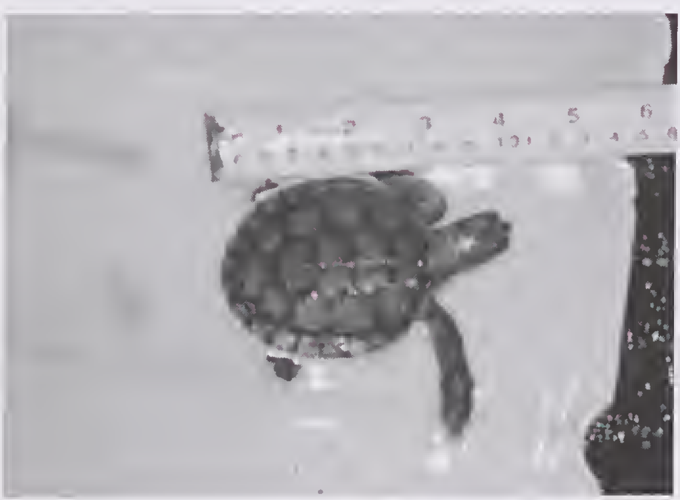

Figure 2. Post-hatchling Flatback Turtle shortly before being released.

Table 1. Post-hatchling Flatback Turtle records from Australian waters, collection type, number of individuals and source of records.

State	Collection type	N	Range (mm)	Reference
WA	Terrestrial	2	160 CCL*	Chevron Australia 2005
WA	Beach-washed	5	121–145 SCL†	Prince 1996
NT	Beach-washed in derelict fishing nets	6	198–290 SCL†	Roeger *et al.* 2004
WA, NT, QLD	Sea eagle feeding stations, gillnets, trawl bycatch, tiger shark stomach contents, beach-washed or observed in estuary or coastal waters	127	113–320 SCL†	Limpus *et al.* 1991

*Curved carapace length †Straight carapace length

Acknowledgements

The authors would like to thank Dr Scott Whiting for comments during draft preparation and the loan of reference materials, and Karen Cook for providing the map featured in this note.

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Northern Territory Naturalist (2007) 19: 54-57

Some notes on polyads and seed set of some northern Australian species of *Acacia*

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Introduction

The majority of plant species produce single pollen grains but there are many taxa in which pollen grains are commonly held together in multiples of four, the multi-grained structures being referred to as polyads. Polyads are found in the genus *Acacia*, with any one species usually producing a constant number of pollen grains per polyad. Kenrick and Knox (1989) reported that 90% of Australian species they surveyed have 16-grain polyads, with 4-, 8- and 12-grain polyads in the remainder. Macphail and Hill (2001) noted that 10-grain polyads also occur in Australia. Some species are polymorphic for grain number, variation occurring in individuals and between populations.

Once a polyad is fixed in the cup-shaped stigma the chances of other polyads attaching themselves to a stigma are low (*e.g.* Kenrick & Knox 1982, Kenrick & Knox 1989, Moncur *et al.* 1991). For example, in *A. mearnsii* (native to SE Australia) less than ten percent of stigmas have more than one polyad per stigma (Moncur *et al.* 1991). Furthermore, the number of ovules per ovary in species of *Acacia* seems to range from 2 to 15 (Kenrick & Knox 1982, Kenrick & Knox 1989) and the number of grains/polyad is correlated with ovule number. Published information suggests that the number of grains generally exceeds the number of ovules (*e.g.* 4:1 to 4:3 in *A. baueri*, 16:7 in *A. suaveolens*). Even when ovule number is slightly higher (8 grains:10 ovules in *A. mitchellii* and *A. paradoxa*) there is apparently no record (at least in natural populations) of seed set per pod ever exceeding the number of grains in a single polyad.

With these facts in mind, and aware that many northern Australian species have not been examined in regard to grains/polyad and seed set, in 2001 I examined herbarium specimens of some species found in the Northern Territory. Furthermore, in May of that year, during a training camp for National Park (NT) rangers held in the Victoria River, some rangers kindly helped to count seed set in shrubs of *A. conjunctifolia*. The results are presented here.

Methods and Results

For all species the number of seeds per fruit were determined from herbarium specimens housed in the Northern Territory Herbarium (DNA). Depending on the number of fruit present, one or more counts were determined from each specimen. The total number (n) of fruit counted for seed set is shown in Table 1, as is the total number of herbarium specimens examined.

The number of pollen grains per polyad was determined for one or two specimens of each species; the voucher specimens from which numbers were ascertained are indicated in Table 1.

For *A. conjunctifolia*, seed set was recorded for five shrubs growing within 20 metres of each other at Joe Creek, c. 5 km W of the Victoria River Crossing, Victoria Highway. More than 70 fruit were examined from each shrub and the results are summarised in Table 2.

Table 1. Pollen grains per polyad and fruit set of some Top End species of *Acacia* as determined from herbarium specimens.

Taxon	Grains per polyad; voucher(s)	Seeds per fruit mean ± SD (range)
Subgenus *Acacia*		
A. pachyphloia W.Fitzg. & Maiden	16; *Egan 2531*	4.86 ± 1.75 (2-8) n = 14 (specimens 8)
A. pallidifolia Tindale	16; *Barritt 2029*	3.66 ± 1.95 (1-8) n = 24 (specimens 8)
Subgenus *Heterophyllum*		
Section *Juliflorae*		
A. conjunctifolia F.Muell.	16; *Tindale 10153*	8.2 ± 1.91 (3-11) n = 30 (specimens 15)
A. megalantha F.Muell.	12; *Menkhorst 334* 12, 16; *Sivertsen 742*	7.24 ± 1.77 (4-12) n = 54 (specimens 16)
A. pellita O.Schwarz	16; *Brock 102, King 118*	7.92 ± 2.61 (3-12) n = 25 (specimens 8)
Section *Lycopodiifoliae*		
A. lycopodiifolia A.Cunn. ex Hook.	16; *Cowie 6266, Cowie 6317*	5.12 ± 2.52 (1-12) n = 199 (specimens 58)
Section *Phyllodineae*		
A. alleniana Maiden	16; *Russell-Smith 639*	7.39 ± 2.72 (1-13) n = 252 (specimens 39)
Section *Plurinerves*		
A. hemignosta F.Muell.	12, 16; *Brock 11*	4.9 ± 2.2 (1-12) n = 89 (specimens 12)

Table 2. The number of seeds per pod obtained from five bushes of *Acacia conjunctifolia*, a species with 16 pollen grains per polyad. n = number of fruit examined.

Plant	1	2	3	4	5
mean	7.21	7.78	8.56	8.97	9.15
SD	2.82	2.16	1.85	2.45	1.88
range	2–13	1–12	3–11	2–12	4–12
n	79	73	75	76	75

Discussion

Given the results of the survey by Kenrick and Knox (1982), the fact that all eight species examined here produce 16-grain polyads is not surprising. That *A. megalantha* and *A. hemignosta*, also produce 12-grain polyads is of interest in that their formation is sometimes associated with taxa of hybrid origin. For example, the Victorian species *Acacia grayana* produces 8-, 12- and 16-grain polyads and is a known hybrid between *A. brachybotrya*, which has 8-grain polyads, and *A. calamifolia* with 16-grain polyads (Leach & Whiffin 1978).

Whether the 12-grain polyads are associated with hybridity in *A. hemignosta* and *A. megalanthera* is beyond the scope of this note. However, *A. hemignosta* is widespread in northern Australia and exhibits considerable morphological variation (Pedley 1978, Cowan & Maslin 2001), suggesting the possibility of hybridization. In contrast, Pedley (1978) made no mention of any unusual variation in *A. megalanthera* and he considered the species to have no close relative. Tindale and Kodela (2001) also referred to the large individual flowers on interrupted spikes as readily defining *A. megalanthera*, but did note that a specimen from Keep River had particularly large leaves and spikes.

Macphail and Hill (2001) indicated that species with 12-grain polyads are to date only known from south-west Western Australia. Clearly, some species in northern Australia also produce them.

For all species examined the number of seeds set per pod never exceeded the maximum number of grains per polyad found in any species, results consistent with those obtained by others. The variation in seed set, rarely only one per pod and averaging less than ten per pod for every species examined, is also consistent with data presented for other species by Kenrick and Knox (1982, 1989).

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In the flowers of many *Acacia* species, the pollen grains are held together in clusters known as polyads. (Russell Willis)

Northern Territory Naturalist (2007) 19: 58-59

Road kill predation by a Children's Python *Antaresia childreni* (Serpentes: Boidae) at Adelaide River, Northern Territory

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Traditionally, most species of snakes are thought to prey upon live items and the idea that they could consume carrion has typically been ignored (DeVault & Krochmal 2002). However, a review by Devault and Krochmal (2002) found that members of the Colubridae, Viperidae, Acrochordidae, Boidae, and Elapidae consume carrion on a more frequent basis than originally thought. Although most snakes in captivity will accept dead prey items, the extent to which they consume carrion, particularly road kill, in the field is largely unknown. Among the Australian snakes, road kill predation has been observed in *Tropidonophis mairii* (Bedford 1991a), *Pseudechis australis* (Bedford 1991b), *Aspidites melanocephalus* (Bedford & Griffiths 1995), *Antaresia stimsoni* (Switak 1989), *Boiga irregularis* (Torr & Richards 1996) and *Morelia amethistina* (Anderson 2000). Here we report on the observation of road kill predation by a Children's Python *Antaresia childreni.*

On the 12th March 2006 we observed a female *Antaresia childreni* (snout vent length 582 mm, total length 641 mm, weight 55 g) (Figure 1) on Dorat Road, Adelaide River (13°32'11"S 131°12'51"E) at 20:30 hours during light rain. Upon closer inspection of the *A. childreni* we observed it swallowing a road killed agamid lizard *Lophognathus gilberti.* The *L. gilberti* was not fresh and appeared to have been killed hours before as most of its body had been repeatedly run over by motor vehicles. The *A.childreni* was observed to swallow the prey and once it had completed its meal we then moved it safely off the road.

Most species of snakes are thought to locate their prey visually by either active foraging or sit-and-wait predation. Pythons of the genus *Antaresia* are known to consume a wide array of vertebrate prey (Bedford 2003, Shine & Slip 1990) although published records of predation by this genus are rare. With the large number of roads throughout Australia, road kill predation probably occurs more than is noticed. As most species of snakes will readily accept dead prey items in captivity there is probably no reason why they would not in the wild, and this observation provides further evidence that some species may supplement their regular diet with these items.

Figure 1. Children's Python *Antaresia childreni* and road killed *Lophognathus gilberti.*

Acknowledgements

Thanks to Paul Horner of the Northern Territory Museum and Art Gallery for identification of the *Lophognathus gilberti.*

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Northern Territory Naturalist (2007) 19: 60-68

Some common names for Top End frogs

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Introduction

Animals that are noticed because they are abundant or readily observed tend to acquire common names, and for many people these names are easier to remember than Latin (scientific) names. Fauna with specific, easily recognisable or distinguishing features also frequently have common names. A short history of association in Australia between non-indigenous people and native animals, and for much of the populace, minimal interest in native fauna, have meant that many species do not have designated labels. The human population in the far north of Australia is small and development of a detailed knowledge of the fauna is still in its infancy. As a consequence, many species in the Top End lack common names. For example, many tropical plants lack widely accepted common names, there are few regularly used names for lizards, and practically none for invertebrates (although see Horner 1991, Braby 2000, Andersen 2002). For various reasons, however, fish, birds, snakes and mammals almost invariably have common names in general use. Many frogs are cryptic, so there has been little opportunity for these species to acquire popularly accepted names. In the Top End, few frog names have infiltrated the vernacular; perhaps Green Tree Frog, Rocket Frog and Marbled Frog are the best known.

Ideally, common names should be adopted by general consensus or through widely accepted usage, but this has not been the case with native frogs. Tyler and Davies (1986), for example, did not include common names in their book 'Frogs of the Northern Territory', whereas the FrogWatch North website lists species alphabetically by common name. As a first step toward designating appropriate and acceptable common names for Top End frogs, I collated names for all species listed by NRETA (2006), FrogWatch North (2006), Tyler (1992), Barker *et al.* (1995), Clayton *et al.* (2006), Ingram *et al.* (1993), and Frank and Ramus (1995). I have also provided additional suggestions from myself and others. It is hoped that this list will provide a point of discussion from which a series of apposite names can be selected and adopted; as such it is not meant to be prescriptive, merely descriptive.

Included in the list are species that occur in the Top End of the Northern Territory (NT), defined here as north of the vicinity of the 15th parallel, extending from the Victoria River drainage in the west to the Roper River in the east, and largely excluding the Cretaceous Sturt Plateau. This area is similar to the outdated Arnhem 'natural region' of Barlow (1985) (see Beard 1985), but has the advantage of irregular boundaries that are drainage systems, natural features of the landscape that are likely to influence amphibian distributions. The area encompasses the Tiwi Cobourg, Top End (Darwin & Arnhem) Coastal, Pine-Creek Arnhem Plateau, Central Arnhem and Daly Basin bioregions of Environment Australia (2000), extends partway into the Victoria Bonaparte bioregion, and largely excludes the Gulf Coastal, Gulf Fall and Uplands, and Sturt Plateau bioregions. The region supports a distinct suite of species (including several endemics) that are confined to higher rainfall areas of the monsoonal north, as well as species that penetrate inland. As such it is a convenient line of demarcation with some biogeographical utility (e.g. Beard 1985, Bowman *et al.* 1988, Cracraft 1991) but in reality there is gradual species turnover in response to the latitudinal climate gradient (Fisher 2001). The frog fauna of the region has similarities with that of north Queensland (Tyler 1999, Woinarski *et al.* 1999) and the Kimberley region, which Tyler *et al.* (2000) judged 'a separate herpetofaunal unit in Australia'.

The region as thus delimited therefore includes the islands, coastal and sub-coastal zones and exorheic drainages of the northern portion of the NT. It embraces frogs that occur on Melville Island (Tyler *et al.* 1991), Groote Eylandt (Tyler *et al.* 1986), other offshore islands (Woinarski *et al.* 1999), Cobourg Peninsula (Cogger & Lindner 1974), Arnhem Land (Cogger 1981, Gambold & Woinarski 1993) and Kakadu (Tyler *et al.* 1983, Braithwaite *et al.* 1991, Press *et al.* 1995). Species that occur only at or beyond the western and eastern boundaries of the region (*e.g. Litoria splendida* and *Cyclorana alboguttata* respectively) or that occur predominantly in the semi-arid transition zone (*e.g. Uperoleia trachyderma, Cyclorana maculosa*) were excluded from the list. Only those species that have been described are listed, including a recently recognised species from near Darwin (Young *et al.* 2005). There are almost certainly more species from the region that await description pending anatomic, genetic and bioacoustic analyses.

Comments

A total of 28 native species are included in Table 1, slightly less than the 31 species listed by Gow (1981) for the 'northern sector' of the NT (north of 18°S). The introduced Cane Toad *Bufo marinus* has become established in the region, but is not listed. Of the 28 frogs, 20 are known from the immediate vicinity of Darwin (Table 1). Tyler and Davies (1986) listed only 16 species for areas within 50 km of Darwin, but Dostine (2003) listed 21 species for the Darwin Harbour catchment. Species not found near Darwin are restricted to rocky streams (e.g. *Litoria meiriana*), higher rainfall areas (e.g. *Rana daemeli*), or are endemic to the Arnhem Land escarpment (e.g. *Uperoleia arenicola, Litoria personata*). Most names used by the various authors correspond to those used by Tyler (1992), as adopted by NRETA (2006) and CSIRO (Clayton *et al.* 2006) (Table 1). The major points of difference are the Ingram *et al.* (1993) list for Queensland frogs (although not all Top End frogs occur there), and Frank and Ramus (1995), who seem to have essentially ignored any previously published common names. Additional suggestions are provided in the last column.

Table 1. List of common names for native frog species that occur in the Top End. Published names: T = Tyler (1992), B = Barker *et al.* (1995), F = Frog Watch North (2006), N = NRETA (2006), C = CSIRO list of vertebrates, I = Ingram *et al.* (1993), FR = Frank and Ramus (1995). Names preferred by the author indicated in bold.
† = does not occur within the vicinity of Darwin (~50km radius)

FAMILY ***Species***	**Published common names**	**Other names**
HYLIDAE (Pelodryadinae)		
Cyclorana australis	Giant Frog [TBFNC] Northern Snapping-Frog [I] Australian Water-holding Frog [FR]	Giant Burrowing Frog Giant Ground Frog 'australis' Barra Frog
C. longipes	Long-footed Frog [TBFNC] Collared-Frog [I] Kimberley Water-holding Frog [FR]	Blotchy Frog Variegated Burrowing Frog
Litoria bicolor	Northern Dwarf Tree-frog [TFNC] Green Reed Frog [B] Northern Sedgefrog [I] Northern Dwarf Treefrog [FR]	Lined Grass Frog Pandan Frog Bicolored Grass Frog 'bicolor'
L. caerulea	Green Tree-frog [TN] **Green Tree Frog** [BFC] Green Treefrog [I] White's Treefrog [FR]	'GTF' 'caerulea' Smiling Frog Dumpy Tree Frog
L. coplandi†	Copland's Rock Frog [TBFNC] Sandstone Frog [I] Saxicoline Treefrog [FR]	Rocky River Frog
L. dahlii	Dahl's Aquatic Frog [TBFNC] **Northern Waterfrog** [I] Dahl's Olive Treefrog [FR]	Floodplain Frog Northern Lagoon Frog
L. inermis	Peters' Frog [TBC] Peter's Frog [FN] Bumpy Rocketfrog [I] Fleck-lipped Treefrog [FR]	Bumpy Frog Bumpy Ground Hylid
L. meiriana†	**Rockhole Frog** [TBFNC] Australian Cross-banded Treefrog [FR]	Skipping Frog
L. microbelos	Javelin Frog [TBFNC] Pygmy Rocketfrog [I] Cairns Treefrog [FR]	Midget Grass Frog
L. nasuta	**Rocket Frog** [TBFNC] Striped Rocketfrog [I] Australian Rocket Frog [FR]	'butwick'
L. pallida	Pale Frog [TBFNC] Peach-sided Rocketfrog [I] Coastal Floodplains Treefrog [FR]	Variable Frog Plain Ground Hylid

Table 1 continued

FAMILY *Species*	Published common names	Other names
L. personata†	Masked Rock-frog [T N]	Escarpment Frog
	Masked Frog [B C]	**Masked Scarp Frog**
	Masked Cave-Frog [F]	
	Sandstone Treefrog [FR]	
L. rothii	Roth's Tree-frog [T N]	Cackle Frog
	Roth's Tree Frog [B F C]	Laughing Tree Frog
	Red-eyed Treefrog [I]	
	Rust-eyed Treefrog [FR]	
L. rubella	Red Tree-frog [T N]	Seagull Frog
	Desert Tree-frog [T]	Little Red Tree Frog
	Red Tree Frog [B]	Brown Tree Frog
	Desert Tree Frog [F C FR]	
	Naked Treefrog [I]	
L. tornieri	Tornier's Frog [T B F N C]	'tornieri'
	Black-shinned Rocketfrog [I]	
	Tornier's Australian Treefrog [FR]	
L. wotjulumensis	Wotjulum Frog [T F N C]	Large Ground Hylid
	Watjulum Frog [B]	Large Rocketfrog
	Giant Rocketfrog [I]	'wotjulumensis'
	Watjulum Mission Treefrog [FR]	
MYOBATRACHIDAE		
Crinia bilingua	Bilingual Froglet [T B N C]	Riparian Froglet
	Bilingual Frog [F]	Rattling Froglet
	Ratchet Frog [F]	
	Bleating Froglet [FR]	
C. remota †?	Remote Froglet [T B F N C]	
	Torrid Froglet [I]	
	Paperbark Froglet [FR]	
Limnodynastes ornatus	**Ornate Burrowing Frog** [T B F N C I FR]	Ornate Frog
		Ornate Ground Frog
L. convexiusculus	**Marbled Frog** [T B F N C I]	Garden Frog
	Australian Marbled Frog [FR]	Tropical Garden Frog
Megistolotis lignarius†	**Carpenter Frog** [T F N]	Big-eared Rock Frog
	Woodworker Frog [B C]	
Notaden melanoscaphus	Northern Spadefoot Toad [T B N C FR]	Black-tipped Spadefoot
	Golfball Frog [F]	Northern Round Frog
	Brown Orbfrog [I]	Whooping Frog
Uperoleia arenicola†	Jabiru Toadlet [T B F N C]	Jabiru Upe
	Alligator River Toadlet [FR]	
U. inundata	Floodplain Toadlet [T F N C]	Floodplain Upe
	Flood Plain Toadlet [B]	Northern Seep Frog
	Floodplain Gungan [I]	
	Mottled Toadlet [FR]	
U. lithomoda	Stonemason Toadlet [T B F N C]	Tapper Upe
	Stonemason Gungan [I]	'tap'
U. daviesae	Howard River Toadlet [F]	Howard River Upe
		Sandsheet Upe

Table 1 continued

FAMILY *Species*	**Published common names**	**Other names**
MICROHYLIDAE		
Austrochaperina adelphe†	Northern Territory Frog [TBFNC] Chirper [I] Peeping Land Frog [FR]	**Top End Chirper** Top End Microhylid Top End Tiny Frog
RANIDAE		
Rana daemeli†	Water Frog [IBN] Wood Frog [FC] Australian Bullfrog [I] Australian Wood Frog [FR]	Arnhem Rana

In selecting names, it is preferable that a familiar appellation be applied to each species, however, some common names, particularly the 'official' names of Tyler (1992) are unappealing. In some cases this is because they are a direct translation of the scientific name, in others it may be due to a lack of inventiveness or familiarity with the species' habits. The rationale for allocation of common names should be decided on by a group consensus, not an individual decision, and RAOU (1978) and Yearsley *et al.* (2006) in their selection of common names for birds and fishes respectively, provide general principles that may be appropriate to the current discussion.

Ideally, any name applied to an animal should incorporate a uniquely identifying feature, or should characterise the animal in some way. Names may be based on specific morphological features (e.g. scaphus, patterning), species-specific calls (e.g. Carpenter Frog), or relate to the general habitus (shape) of the frog (e.g. Rocket Frog). In some instances names may relate to habitat preferences, particularly where these are relatively restricted. An example is the Rockhole Frog, which is virtually confined to the immediate vicinity of permanent, residual waters in rocky gullies. In certain cases geographical locations may be used, but this is best suited to highly localised or endemic species (e.g. Howard River Toadlet, Jabiru Toadlet). In contrast, the ground hylid *Litoria wotjulumensis* was originally collected from Wotjulum in the northern Kimberley, but has a broad geographic distribution that extends to Queensland. The use of a person's name, for example Peter's Frog for *Litoria inermis*, is less desirable because the person has no specific relation to the innate qualities or existence of the animal; its biology, behaviour, anatomy, morphology or evolutionary history.

The genus *Litoria* (Family Hylidae), as currently recognised, incorporates species with a diverse range of habits, and these could perhaps be reflected in the common names. Several of the hylid frogs (commonly called 'tree frogs') are terrestrial ground-dwellers, notably *Litoria pallida, L. inermis, L. wotjulumensis* and *L. tornieri*. One possibility would be to use the term 'Ground Hylid' in combination with a specific variant for these frogs. A minor issue is the use of Tree Frog versus Tree-frog; the standard in ornithology is to use upper then lower case, e.g. Fairy-wren, but there is not necessarily a standard in herpetology. Barker *et al.* (1995) and others tend to employ 'Tree Frog', whereas Frank and Ramus (1995) have adopted 'Treefrog'. The tree frog *Litoria rubella* is widespread and clearly not restricted to deserts, hence an alternative to 'Desert Tree Frog' is required in this case.

Among the myobatrachids the term 'Upe' is a possible alternative to 'toadlet' for the various species of *Uperoleia*. Alternatively, the aboriginal term 'Gungan' was suggested by Ingram *et al.* (1993) for Queensland species. Providing suitable names for new species of small, cryptic frogs could be a difficult proposition, since few morphological features are present that distinguish these species from one another. Species-specific calls can also be similar, as is the case with the newly described *U. daviesae* and its congener *U. inundata* (Young *et al.* 2005). It is unclear as to which other species of *Crinia* in addition to *C. bilingua* occur in the region (Table 1), and the situation needs to be clarified to facilitate establishment of correctly applied common and scientific names. The general term 'froglet' however seems suited to these diminutive swamp and riparian zone inhabitants. Application of the term 'toad' to native frogs is confusing, since there are no native representatives of the family Bufonidae in Australia. There is the potential to confuse 'Spadefoot' with members of the well-studied genus *Scaphiopus* of the United States. Ingram *et al.* (1993) also suggest avoiding the term toad, and perhaps 'Golfball Frog' or 'Round Frog' is appropriate for *Notaden melanoscaphus.*

Several species of frog are restricted to the NT, so that 'Northern Territory Frog' seems inappropriate for the sole representative of the Microhylidae in the Top End (*Austrochaperina adelphe*). Top End Chirper may be a suitable name in this case.

There has been and will continue to be some instability associated with the scientific nomenclature of frogs. Some researchers consider *Megistolotis lignarius* (Tyler *et al.* 1979) to be a member of the genus *Limnodynastes* (Schauble *et al.* 2000). Likewise, our *Sphenophryne* is now *Austrochaperina* (Zweifel 2000). The genus name *Ranidella* has been used in certain instances (e.g. Tyler & Davies 1986), but *Crinia* is now widely adopted as an all inclusive generic name. The most recent suggestions that affect the scientific names of Top End frogs are a change from *Limnodynastes* to *Opisthodon* for *L. ornatus* and from *Rana* to *Sylvirana* for *R. daemeli* (Frost *et al.* 2006). Further alterations to specific and generic names for Australian frogs are likely in the future (although see Kluge 2005).

Whilst I have provided a comprehensive list of English common names for Top End frogs, it is possible that other colloquial usages have become established in the Kimberley region and in the northern NT, and there are almost certainly a range of indigenous names for some species. Until such time as a consensus decision has been made it would be injudicious to commit to a series of names. Some suggested names are preferred by the author and these are indicated in Table 1. For the remaining species it may be simpler in the interim to use the designated scientific name, as does Menzies (2006) for New Guinea frogs. Language is ultimately a means of communication, and it would be desirable to have a set of common names that are standardised and appropriate to particular frog species, but that also reflect the regional flavour associated with the naming of animals.

Acknowledgements

I prepared this paper whilst in receipt of a scholarship from the Australian Postgraduate Awards Scheme. K. Scott and K. Christian provided comments on a previous draft and discussions with R. Noske resulted in some not inconsiderable alterations to the manuscript. P. Doughty directed me to the Ingram *et al.* paper and P. Horner suggested inclusion of the CSIRO list. I am indebted to various people over the years who have disclosed their names for frogs.

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The Marbled Frog *Limnodynastes convexiusculus* inhabits moist soil under leaf litter during the day and is common in some suburban Darwin gardens. (Stephen Reynolds)

Northern Territory Naturalist (2007) 19: 69-75

Nesting biology of Striated Herons *Butorides striatus* in Darwin, Northern Territory

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Introduction

Unlike elsewhere in its pantropical range, where it may be found to 4 050 m above sea-level (del Hoyo *et al.* 1992), the Striated or Green-backed Heron *Butorides striatus* in Australia is largely associated with intertidal areas and as a consequence has a strictly coastal distribution. While its affinity for mangals (mangrove communities) spawned the popular name 'Mangrove Heron', the species more than occasionally occurs in freshwater wetlands in Australia, as well as on reefs and beaches far from mangals. For a species occurring around at least two-thirds of Australia's coastline, including Sydney and Brisbane, surprisingly little has been recorded about its breeding biology, as evidenced by only 13 records in the Birds Australia Nest Record Scheme (NRS) until 1990 (Marchant & Higgins 1990). One of the earliest observations of nesting by the species originates from Port Essington, Northern Territory, where the naturalist John Gilbert reported a colony of some 30 birds nesting in mangroves and yellow hibiscus (North 1913). However, as noted by Hindwood (1933) in his detailed account of the nesting behaviour of Striated Herons in Sydney Harbour, this species normally nests solitarily. Indeed, Marchant and Higgins (1990) rejected the claims of Gilbert and others of colonial nesting by the species.

In the Northern Territory (NT), the Striated Heron (race *stagnatilis*) is fairly evenly distributed around the mainland coast and offshore islands, with no areas of obviously higher densities (Chatto 2001). Chatto (2001) concluded that Striated Herons breed as single pairs all around the NT coast, although he reported one breeding "colony" containing five nests on the mid north coast. In this paper I summarise opportunistic observations of 32 nests of the species in the Darwin region, all but four from around Nightcliff reef, and clarify the breeding season, clutch size and spatial distribution of nests of the species in this region. I also provide the first description of the nestling of this race, and a possible pre-copulatory display involving reddening of the bare parts and a low booming call.

Methods

Opportunistic observations were made of nesting Striated Herons in mangal near Nightcliff reef (12°23'12"S, 130°50'40"E) and other coastal areas in the Darwin region, between 1998 and 2006, during studies of mangrove phenology and mangal-dwelling passerines. The nests at Nightcliff were found within a near-continuous 500 m stretch of mangal, varying in width from 50 to 90 m, and fringing rock platforms or narrow sandy beaches. For accessible nests, I climbed the nest tree, but for most, I used a mirror mounted on a pole to check the contents. For nests that produced chicks, I estimated the age of chicks from descriptions in Hindwood (1933) and estimated the laying date of the clutch, based on a maximum incubation period of 25 days (Hindwood 1933). Otherwise I assumed the laying date to be in the same month as the complete clutch was found, unless this date fell within 3 days of the start of a month, in which case the clutch scored 0.5 for that month and 0.5 for the preceding month. The height of nests and nest trees < 4 m was measured using a tape measure, but otherwise estimated to the nearest metre. Nest trees were identified to species; English names follow those given by Wightman (2006). Geographical coordinates of nest trees were recorded using a GPS unit, with accuracy to about 10 m, and inter-nest distances were calculated using 'OziExplorer' GPS mapping software.

Results

Most nests were found in the northern portion of the Nightcliff reef mangal, which was overwhelmingly dominated by Small Stilt-root Mangrove *Rhizophora stylosa*, except in the small sheltered bay closest to suburban houses, where Pornupan (Star) Mangrove *Sonneratia alba* was co-dominant. Fewer nests were found in the mangal along the southern border of the southernmost rock platform, where Pornupan Mangrove was clearly dominant. Eggs were found from August to March, with almost two-thirds (64%) in the two months of September and October (Figure 1). However, no nests were found at Nightcliff reef beyond January, and the three nests in March were at Shoal Bay (2) and lower Rapid Creek. An additional record of a nest with a well-developed chick from Sandfly Creek, Casuarina Coastal Reserve (G. and M. O'Brien, pers. comm.), suggests egg-laying in November.

The nests were typically rather untidy platforms of sticks, built in the forks of branches of mangroves. Of 31 active nests, 25 (80.6%) were built in Small Stilt-root Mangroves, three in Pornupan Mangrove, two in Grey Mangrove *Avicennia marina* and one within a Mangrove Mistletoe *Amyema mackayensis* clump on a Small Stilt-root Mangrove. However, several of these nests were apparently refurbished nests from the previous season(s). The heights of 22 nests (excluding known refurbished nests) varied from 2.0 to 6.3 m, averaging 4.27 m (SD ± 1.14), while the heights of 14 nest trees varied from 3.8 m to 9.0 m, averaging 6.3 m (SD ± 1.7), excluding one nest tree (in *S. alba*) that was estimated to be c. 20 m in height, at Shoal Bay. The closest distances between two concurrent nests found in any one season were 34 m (1999), 33 m (2000) and 57 m (2006). In 2005, three nests formed a triangle with inter-nest distances of 19, 34 and 36 m.

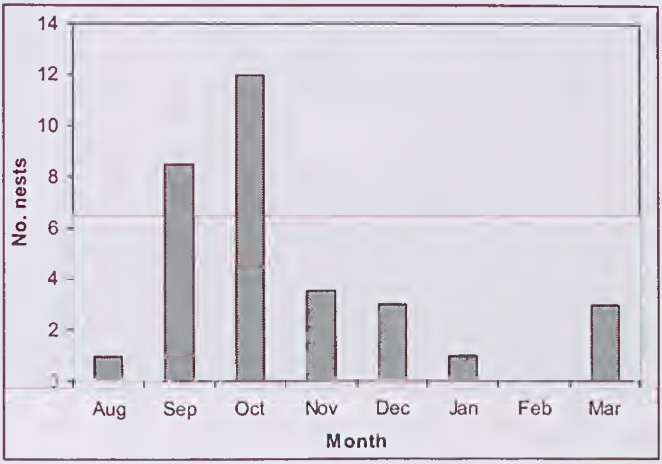

Figure 1. Estimated egg laying dates of Striated Herons in the Darwin region (n = 32). Where dates straddled two months, each month was assigned 0.5.

Of 14 clutches seen in the Darwin region, 12 were of two eggs and the remaining two were of one and three. Of an additional 13 nests, in which only young were observed, nine contained two chicks; the remaining four nests contained one chick only, although it is possible that some had lost a second chick due to premature fledging or predation. From these data it seems safe to conclude that two is the normal clutch of the species in the Darwin region (Figure 2).

Of two young nestlings at a nest on 5 January 1999, one was found on the ground below its nest 15 days later, while the other remained in the nest. The period between first and last sightings of nestlings at four other nests was 13 (n = 2) and 14 days (n = 2). At one of the latter nests, only one of the two nestlings had disappeared on the 14th day since their discovery, suggesting different fledging times, perhaps due to asynchronous laying. In a separate instance, two young (one perched 2 m from the nest, the other on the ground) were observed 18 days after eggs had been seen in the nest, indicating a maximum nestling period of 18 days for the fledged bird. Furthermore, one nest gave a minimum total nest period of 39 days, from the first sighting of eggs to the last sighting of chicks perched 1-2 m from the nest, while at another nest, a fledgling was found below its nest 42 days after eggs had been recorded.

Figure 2. Nest and eggs of the Striated Heron at Nightcliff reef.

Nestlings were not inspected closely due to either the inaccessibility of nests or the high risk of premature fledging. However, on 14 October 1997 I found a prematurely fledged bird 2 m below its nest, and 3 m from the ground (photograph on rear cover). The bird was c. 20 cm from bill tip to cloaca. Pale grey down covered much of its body, mostly concealing its skin, which was lime-green. There were short brown quills on the wings only, and an unfeathered patch of yellow skin around the cloaca. The legs and feet were green with yellow soles; the iris was yellow and bill pale grey.

Nests were not monitored sufficiently to determine fledging success. However, fledglings from five nests were discovered on the ground and were capable of running at speed amongst the roots of the Small Stilt-root Mangroves dominating the habitat. In 1998, one nest was depredated within seven days after eggs had been recorded. In this year I also watched a small group of indigenous people roasting a freshly caught Striated Heron chick on a small fire built on the beach c. 50 m from a nest I had observed. In 2000, a Black Butcherbird *Cracticus quoyi* approached to within 3 m of a nest with eggs, but this potential predation event was thwarted by the prompt action of the incubating heron returning to sit on the nest. In 2002 two nests which had eggs on 31 Oct. were empty by 16 Nov., but as this is just within the time frame given for young to clamber out of the nest (see Discussion), nest predation cannot be assumed.

On 23 September 2006 I witnessed a possible pre-copulatory display by a motionless adult perched c. 6 m from the ground in a Small Stilt-root Mangrove (c. 9 m tall) in which a nest with eggs was found three weeks later. The bird gave at least six low booming growl-like calls ("hwow") at 2-3 min intervals, and its facial skin (eye-ring and lores) and legs were strongly suffused with red, appearing a deep salmon-pink.

Discussion

The above observations clearly indicate that egg laying by Striated Herons around Darwin begins in late August, peaks in September-October, and extends until March, thus straddling the late dry and wet seasons. On the mid-north coast of the NT, Chatto (2001) found five nests containing eggs and small young in March, but suspected that breeding occurred between September and January at several other sites. Moreover, the Birds Australia NRS contains one record of an occupied nest in April in the NT (Marchant & Higgins 1990). Thus, the breeding season in the NT is considerably longer than the three months (November to January) given by Storr (1977), and appears to be longer than in Western Australia (August to January) or the Sydney region (September to January)(Hindwood 1933, Johnstone 1990, Marchant & Higgins 1990). Given that pairs normally rear two broods per season in the Sydney region (Hindwood 1933), it is likely that pairs in the Darwin region also at least occasionally raise second broods, although this was not investigated in the present study.

Not dependent on the flooding of seasonal wetlands, Striated Herons in the Darwin region commence nesting 4-5 months earlier than other herons breeding in the Top End. In colonies of egrets and Pied Herons *Ardea picata* in the NT, eggs appear mainly from mid January to late March or early April, except in the case of the Cattle Egret *A. ibis,* which commences breeding as early as late November (Chatto 2000). As breeding is generally synchronous within colonies, young tend to be present in March and April, with the last young leaving by late June (Chatto 2000). The only other heron species breeding colonially in the NT is the Nankeen Night Heron *Nycticorax caledonicus*, which breeds between March and June (Chatto 2000). The late dry breeding season peak of Striated Herons, by contrast, more closely resembles the breeding activity of large terrestrial insectivorous passerines in the region (Noske & Franklin 1999). The Eastern Reef Egret *Egretta sacra*, a species with a similar coastal distribution to the Striated Heron, may also have an early breeding season in the NT. Chatto (2001) found few active nests of this species, but suggested that it bred in pairs or small groups from August to December.

Gilbert's report of colonial breeding by some thirty Striated Herons at Port Essington was dismissed by Marchant and Higgins (1990) on the grounds of "probable confusion with Nankeen Night Herons, unsuitable habitat and small clutch size". There are no recent records of heron breeding colonies in the Port Essington area, but Chatto (2000) found most colonies (with an average of 700 birds) of Nankeen Night Herons in mangals, similar habitat to that of the Striated Heron. Moreover, all of Gilbert's nests contained either two eggs or two young, which seems consistent with my observations of the clutch size of local birds. Chatto (2001) reported one breeding "colony" containing five nests on the mid north coast of the NT but gave no further particulars. Indeed, elsewhere in the world the species is known to breed alone or in small groups, exceptionally forming colonies of up to 300-500 pairs, and rarely nesting alongside other species (del Hoyo *et al.* 1992).

At Tuggerah Lakes on the central coast of New South Wales, Morris (1990) reported a breeding "colony" of three nests of Striated Herons among nine nests of the Little Egret *E. garzetta*. As Marchant and Higgins (1990) noted, however, these three clutches were started 3-10 weeks apart, and were well spaced, with inter-nest distances of 61, 67 and 87 m (Morris 1990). These distances are indeed greater than those I measured at Nightcliff in 2005 (19-36 m). That concurrent nests closer than 60 m were found in most years at Nightcliff suggests that the local population is loosely colonial, with pairs probably benefiting from improved vigilance against predators.

Most nests in the Darwin region were built in Small Stilt-root Mangroves, and the clutch size was usually two, though one clutch of three was observed. In mangals of northern Western Australia, nests are said to be placed mostly in *Avicennia* and *Rhizophora*, and contain clutches of two or three (Johnstone 1990). In Sydney, the clutch size is three or four, mostly three (Hindwood 1933), while in the Clarence district of north-eastern New South Wales, clutches of four eggs are reputedly typical (North 1913). Whilst these data suggest a general increase in clutch size with latitude, as is typical for many species in the North Temperate region, there are insufficient Australian data to test this trend. Elsewhere the species is known to lay clutches as large as eight (del Hoyo *et al.* 1992).

Although the nestling period of the Striated Heron in Australia has not been precisely timed, young birds in Sydney Harbour usually spent about four weeks in the nest or nest tree after hatching (Hindwood 1933). Combined with the 21-25 days of incubation, the total nest cycle should be 49-53 days. However, Hindwood (1933) found that 3-week old nestlings would sometimes drop into the water or onto the mud, and swim or run away with ease; and that even 16- or 17-day old nestlings would "make off into the outer branches" and remain motionless if the nest was approached. Morris (1990) observed that even 12-day old nestlings climbed up to 2 m from the nest when capture was attempted. This is consistent with behaviour I observed in Darwin, and it is possible that the apparently short nestling periods and total nest period (39-42 days) I recorded are due to nestlings straying to places where they could not be detected, aided by their cryptic behaviour.

Hindwood (1933) reported that the down covering of nestlings in Sydney (race *macrorhyncha*) predominates until the ninth or tenth day, after which the quill sheaths start to become dominant and the bright green colour of the skin becomes evident. This description is consistent with the bird I photographed (rear cover), suggesting that the local race is similar in nestling morphology to southern birds.

I can find no reference to a pre-copulatory display, but Marchant and Higgins (1990) state that during breeding, possibly during courtship only, the iris becomes bright yellow, the legs and feet become yellow or orange, and "several quiet calls" are given (original sources unknown). However the bird I watched in September 2006 gave distinctive booming calls, and had reddish bare parts. In Western Australia the legs and feet of *stagnatilis* normally range from light green to bright yellow, the facial skin greenish-yellow or yellowish-green and the irides yellow to bright yellow (Johnstone 1990). Schodde *et al.* (1980) noted that breeding birds, at least in Arnhem Land, acquire a dull-orange tone to the legs, which at other times are dull olive, with a yellowish stripe along the soles. Yet they do not mention seasonal changes in the colour of the facial skin. Clearly more information is required to determine temporal variation in the coloration of bare parts of the species.

Little is known about breeding success of the Striated Heron in Australia. Hindwood (1933) suspected crows (*Corvus* spp), White-bellied Sea-Eagles *Haliaeetus leucogaster* and Grey Shrike-thrushes *Colluricincla harmonica* were predators of nests of Striated Herons in Sydney. Nests are at least occasionally destroyed by storms and high tides (Marchant & Higgins 1990), and possibly lizards (North 1913). From observations in Darwin, humans, and possibly Black Butcherbirds, can be added to the list.

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Orange-footed Scrubfowl in Darwin – horticultural pest or partner?

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Unique among Australian capital cities, Darwin (12°27'S, 130°50'E), Northern Territory, lacks feral populations of non-indigenous bird species, apart from occasional outbreaks of Feral Pigeons *Columba livia*. With 68 species confirmed as breeding within the metropolitan area, and at least 12 others likely to do so (R. Noske, unpubl. data), the birdlife of Darwin owes its richness to the retention of corridors of diverse natural habitats, as well as the small size (112 km²) of the city, with few suburbs far from protected or undeveloped areas on its coastal or inland fringe. While many bird species of mangals (mangrove communities) have specialised habitat requirements that preclude their colonisation of urban areas, all of the local frugivores typical of rainforest (e.g. Pied Imperial-Pigeon *Ducula bicolor* and Figbird *Sphecotheres viridis*) are attracted to the abundant fruit-bearing trees in well-watered suburban gardens and parks. Perhaps the most recent colonist from rainforests is the Orange-footed Scrubfowl *Megapodius reinwardt*, which, like its better-studied larger cousin in eastern Australia, the Australian Brush-turkey *Alectura lathami*, builds large mounds to incubate its eggs.

In the early 1980s, populations of Scrubfowl were known from only three areas of Darwin (Thompson & Goodfellow 1987). During their 1998 survey, however, Franklin and Baker (2005) documented 82 records of the species from 23 of the 30 named suburbs in Darwin, and noted records of mounds. They also reported that the Wildlife Rescue Unit of the Parks and Wildlife Commission of the Northern Territory received many complaints from the public about the garden-raking activities of Scrubfowl. This paper summarises the results of a telephone survey conducted in 2002, designed to ascertain public attitudes towards the species, as well as any obvious change in their local distribution. Information was gained through the use of the media. An article was printed in local newspapers (*Northern Territory News* and *Sunday Territorian*) on the weekend of 7-8 September 2002, and MG had two consecutive radio interviews inviting people to respond by phone if they had seen the Scrubfowl in their backyards. Respondents were asked to provide information pertaining to the number of birds and mounds in their area of residence, number and type of pets, and their attitude towards, and relationship with, the species.

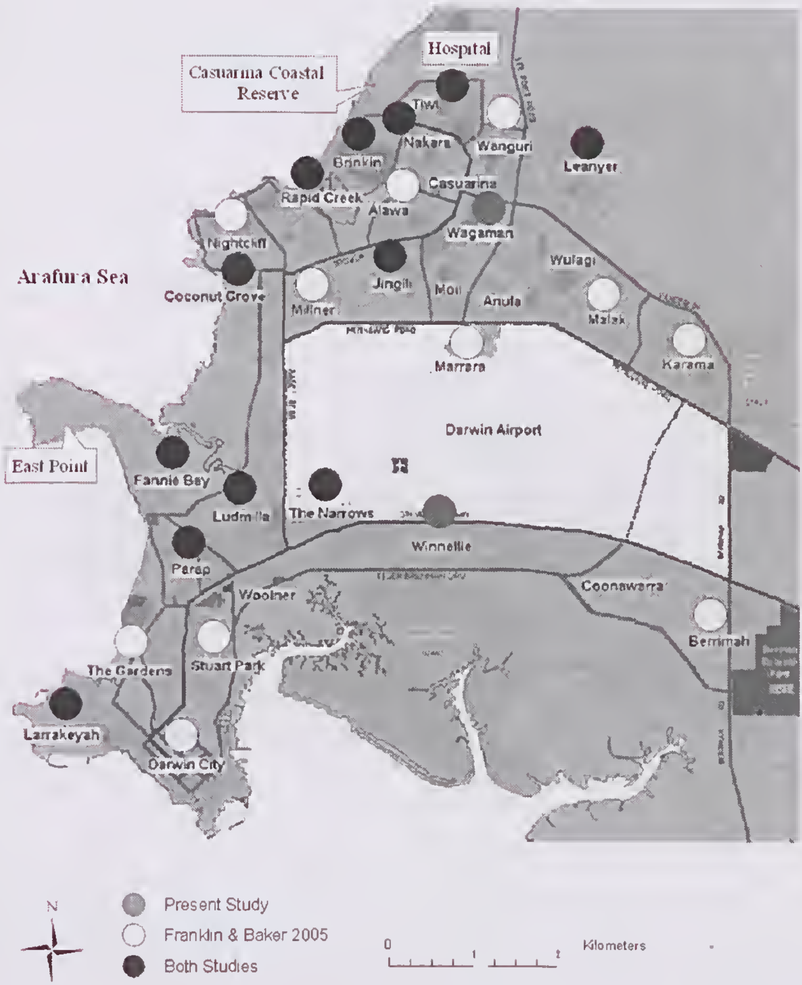

Figure 1. Map of Darwin area, showing locations of Scrubfowl from Franklin and Baker (2005) and the present study.

From 50 phone calls, 84 records of birds were obtained, including 62 records from 14 Darwin suburbs (Figure 1), two from Palmerston, and 20 from six rural areas: Knuckeys Lagoon, Howard Springs, Humpty Doo, Noonamah, McMinns Lagoon and Virginia. Of the 62 records for Darwin suburbs, 32% were from the coastal suburbs of Rapid Creek and Fannie Bay (Figure 2). This contrasts somewhat with the findings of Franklin & Baker (2005), in which the latter two suburbs constituted only 11% of records (n = 82), while the highest-scoring suburb, with 27% of records, was Millner (27%). We also received reports from two suburbs (Wagaman and Winnellie) for which Franklin and Baker (2005) had no records. However, whilst the present survey yielded only four suburbs with mounds, Franklin and Baker (2005) reported mounds in eight suburbs.

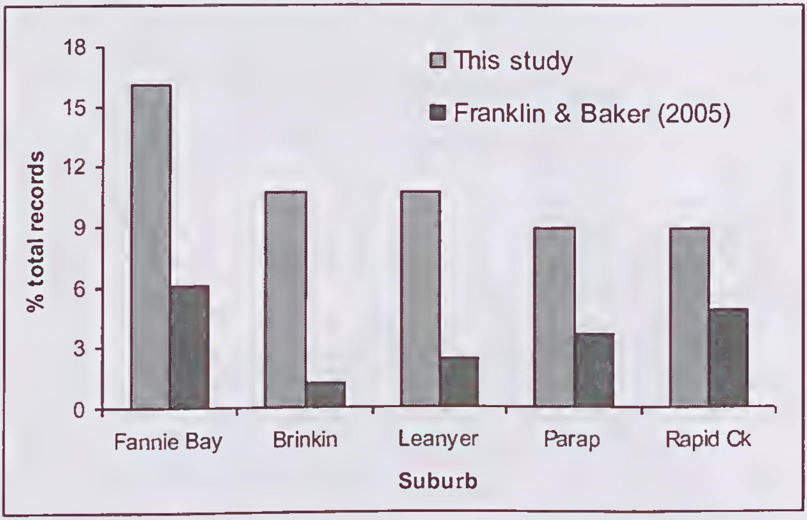

Figure 2. Darwin suburbs where records of Scrubfowl exceeded five during the present survey.

All 50 respondents indicated that they were content with the Scrubfowl visiting their yards and rural blocks. Many residents did not begrudge re-raking the mulch, and some had changed their gardening practices by allowing for disturbance to particular areas of their garden whilst protecting other areas with wire mesh. Indeed several respondents expressed positive attitudes towards Scrubfowl, suggesting that they were helpful in (1) cleaning out gutters, (2) eating termites and cockroaches in the garden, and (3) aerating the soil in gardens by turning over the litter and soil surface. Of the ten respondents who kept pets, two had allegedly trained them to ignore the birds.

Three respondents reported dogs injuring or killing juvenile Scrubfowl, suggesting that pets pose a threat to dispersing juveniles. Dogs or foxes killed up to 15% of dispersing Australian brush-turkey chicks near Brisbane (Göth & Vogel 2003).

Reporting of the Scrubfowl in this survey was undoubtedly biased towards members of the public that read the local newspaper, and listen to local radio. This survey is not directly comparable with that of Franklin and Baker (2005) as they used numerous personal observations and records from amateur and professional naturalists, as well as two interviews on local radio stations. Nevertheless the reporting rates from each suburb differ sufficiently to indicate that there may have been some changes in the distribution and abundance of urban Scrubfowl over the four years between surveys. In particular, populations in the suburbs of Fannie Bay and Rapid Creek may have increased, possibly due to their proximity to the monsoon rainforest in East Point Reserve and a major riparian corridor, respectively. On the other hand, the paucity of records of mounds – even fewer than reported by Franklin and Baker (2005) – suggests that the number of breeders within the suburbs has not increased. These trends support the contention of the above authors that the suburbs act mainly as population 'sinks' for excess young from nearby monsoon rainforests.

The total absence of complaints during the present survey may signal a gradual change in public attitudes towards Scrubfowl. Since the 1980s, residents have complained about Scrubfowl to the Parks and Wildlife Service, especially during the mound building season of September-April (Palmer *et al.* 2000). Householders' complaints concerned the destruction of landscaping and plantings, creation of debris, harassment of pets and loud, early morning calling by Scrubfowl. In contrast, during the present survey some respondents admitted to actively encouraging Scrubfowl by feeding them with food scraps and chicken pellets. A similar variation in attitude towards the Australian Brush-turkey was found in Brisbane suburbs (Jones & Everding 1991, Jones *et al.* 1993).

The participation of the public in wildlife surveys indicates some sympathy for wildlife among suburban householders. Nevertheless conflict between humans and Scrubfowl seems likely in the future and we suggest that such conflict can be ameliorated through (1) education programs designed to increase public awareness of the peculiar breeding biology of the bird; and (2) changes in gardening practices, such as the use of coarse or heavy mulch, placing of rocks or logs around new plants, and the covering of seedlings with wire mesh.

Acknowledgements

We thank the *Northern Territory News* for running the story on the Scrubfowl, and the many people that participated in the radio interviews.

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At home in suburbia: the Orange-footed Scrubfowl *Megapodius reinwardt.* (Heather Ryan)

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