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# Satellite telemetry and seasonal movements of Magpie Geese (*Anseranas semipalmata*) in tropical northern Australia

*Lochran W. Traill*[A,C], *Corey J. A. Bradshaw*[A,B] *and Barry W. Brook*[A]

[A]The Environment Institute and School of Earth & Environmental Sciences, University of Adelaide, SA 5005, Australia.
[B]South Australian Research and Development Institute, PO Box 120, Henley Beach, SA 5022, Australia.
[C]Corresponding author. Email: lochran.traill@gmail.com

**Abstract.** Knowledge of the patterns of movement of tropical waterfowl should assist in long-term conservation of these birds and their wetlands. Data that indicate or suggest the extent of connectivity between populations help us to make decisions, particularly when those populations are threatened by loss and fragmentation of habitat. To date, there has been little research on tropical waterfowl, with most work on this group of birds done in temperate regions. We tracked the seasonal movements of 10 Magpie Geese (*Anseranas semipalmata*) in tropical northern Australia, predominantly within Kakadu National Park, using satellite telemetry. Movements were multi-directional and the maximum linear distance travelled by an individual was 114 km from the site of release, over 38 weeks of tracking. Movements did appear to be related to seasonal environmental fluctuations, with some birds moving to favoured breeding and foraging sites, but most monitored birds were resident within the national park. No accurate data were obtained beyond 12 months, with most birds apparently losing their telemeters within 6 months. Just 62% of point-location data were accurate to within 1000 m. Our work provides further ecological data on a species threatened by sea-level rise and important to Aboriginal and recreational hunters.

**Additional keywords:** Argos system, avian movements, capture, Kakadu, tropical waterbirds.

## Introduction

Migration describes both temporary and permanent emigration and immigration (Dingle 1996) and is principally an adaptive population-level response to seasonal peaks and troughs in the abundance of resources (Alerstam *et al*. 2003; van der Graaf *et al*. 2006). Migratory behaviour is driven, in part, by density-dependent habitat use, where gains in survival and reproduction are balanced by the costs (lost foraging opportunity, energy demands and mortality) of migration (Roshier *et al*. 2008). Whereas migration describes the seasonal movement of populations, from one place to another, dispersal is seen as a one-off movement of individuals, typically away from their place of birth (Dingle 1996).

The study of avian migration has, to date, largely focused on temperate species of bird, particularly those of Europe and North America (e.g. Hestbeck *et al*. 1991; Drent *et al*. 2003). Far less is known about the migratory patterns of tropical birds, especially waterfowl (although see Roshier *et al*. 2008). This gap in our knowledge is concerning because of the threats to biodiversity in the tropics (see Colwell *et al*. 2008; Bradshaw *et al*. 2009). Here we help address this deficiency by providing data on seasonal movements of Magpie Geese (*Anseranas semipalmata*) in tropical northern Australia.

Endemic to Australia and southern New Guinea, Magpie Geese are an important source of food for Aboriginal Australians and are ecologically important as keystone herbivores (Frith and Davies 1961). Moreover, Magpie Geese have been reduced to small and isolated populations in southern Australia following European settlement (Nye *et al*. 2007). Remaining northern populations are thus of some conservation concern, and are considered to be further threatened by the loss of critical wetland habitat as a result of rising sea levels (Traill *et al*., in press). Magpie Geese are considered to be both migratory and nomadic under the classification of Roshier and Reid (2003).

Given imminent flooding of tropical floodplains by rises in sea-level, and the importance of Magpie Geese to local Aboriginal people, we developed the VHF telemetry work done by Whitehead (1998) by using satellite telemetry to track the movements of individual birds over 12 months, during 2007–08. Further, we test variation in seasonal movement patterns by bird body mass (as a surrogate for age) and describe the difficulties of satellite telemetry.

## Methods

### *Study site and species*

All Magpie Geese were caught and released within Kakadu National Park, in Australia's Northern Territory. The World Heritage-listed national park covers 19 804 km$^2$ and supports a high diversity of native vegetation and fauna species, including a diverse waterfowl guild (Finlayson *et al*. 2006). The climate is marked by two distinct seasons (Whitehead 1998): the wet season


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(December–April) associated with the north-western monsoon, and the dry (May–November). Magpie Geese rely on the extensive subcoastal floodplains of Kakadu National Park for foraging and nesting (Bayliss and Yeomans 1990), and birds are harvested regularly by Aboriginal residents of the park (Whitehead *et al*. 2000). The large dry-season congregations of Geese in Kakadu National Park (Bayliss and Yeomans 1990) provided the opportunity to catch and tag individual birds.

### *Deployment of telemeters*

During October and November 2006, we caught Magpie Geese using a baited cage-trap (see Traill *et al*. 2010). Captures were done in collaboration with the Australian Quarantine and Inspection Service. Of ~120 birds caught, we selected 10 to be fitted with KiwiSat 101 Platform Transmitter Terminals (PTTs) (Sirtrack, Havelock North, New Zealand, www.sirtrack.com). We selected a mix of adults and subadults, of both sexes, with body-weight greater than the mean of birds of respective age and sex (see Table 1). Birds were sexed through cloacal examination using cloacal pliers and aged on general size, height of the cranial knob and development of tracheal loops (Whitehead 1998). Finally, birds were banded according to the requirements of the Australian Bird and Bat banding Scheme.

Selected Geese were transported to a holding pen (15 m in diameter × 3 m high) ~100 m from the capture site. Birds were held for 8–9 weeks. The holding pen allowed us to examine (through observation) the effectiveness of the backpack design and to monitor the response of the birds to the harnesses, such as discomfort behaviour (see Garrettson *et al*. 2000). We also ensured that data obtained via the Argos system (Collecte Localisation Satellites, Ramonville France, www.cls.fr, accessed November 2008) were adequate. Each PTT measured 70 × 30 × 25 mm, weighed ~45 g (total weight including harness), and had an external antenna ~150 mm long. For all birds, the combined weight of the PTT and harness was ~2% of body-weight, which is in accordance with recommendations by Cooke *et al*. (2004). PTT units were set with a repetition rate of 75 s and a duty cycle of 8 h on and 160 h off. All PTTs were powered by one AA cell and one 2/3 AA battery (allowing longevity of 900–1000 days). Activity sensors were not included with the transmitters.

The design of the backpack (harness) was based on a previous design for use with VHF telemeters (Whitehead 1998). We used double-stitched nylon ribbon (10 × ~350 mm) as the core component of the backpack, and ran two loops from the central PTT (located on the bird's back) and around the bird. The lower part of the harness was fed under the bird's wings and in front of the bird's legs. The backpack was required to be tight enough to prevent birds sticking their legs through the lower part of the harness, which we had observed on loosely fitted backpacks. Harnesses were adjusted individually to each bird and the ribbon stitched at loops.

All ten PTTs were fitted in January 2007 and monitored for 2 weeks with the birds in the holding pen. All ten PTTs were fitted in January 2007, turned on and monitored for 2 weeks (with the birds in the holding pen). Data for the captive birds were examined manually for obvious mistakes or outliers, but none was found. All birds were released in February 2007 after we were satisfied with the harnesses. We were aware that harnessed devices could modify behaviour of the birds (Garrettson *et al*. 2000) but felt that the harness-mounted units were better than PTTs attached to neckbands given the grubbing behaviour of Geese on floodplains.

### *Acquisition of data and analyses*

We used data obtained from 1 March 2007 to March 2008 (transmitted at weekly intervals) for analysis. Data were derived from a CD-ROM mailed to the authors on project completion. We deleted all locational data with errors of >1000 m according to the scoring system provided by Argos (see www.cls.fr) and listed in Table 2. We categorised data for each individual PTT by season. Data were exported to ArcGIS version 9 (ESRI GIS software, Redlands, CA, USA, www.esri.com) and we used the *Analysis* tool to determine minimum, maximum and average distance moved by each bird.

We fitted linear models to bird mass and distance moved (after $\log_{10}$ transformation) using the *lm* function in the R software language (R Core Development Team 2009). Model strength of evidence was determined using Akaike's information criterion corrected for small samples ($AIC_c$) and their evidence ratios

**Table 1. Period of data transmission in weeks (Activity), and maximum distance travelled and mean distance moved per week, in wet and dry seasons, by Magpie Geese fitted with satellite transmitters**

| Age | Sex | Weight at release (g) | Activity (weeks) | Maximum distance travelled (km) | | Mean weekly distance moved (km) | | Platform transmitter terminal number |
|---|---|---|---|---|---|---|---|---|
| | | | | Wet season | Dry season | Wet season | Dry season | |
| Adult | Male | 3240 | 40 | 96.5 | 85 | 38.9 | 12.7 | 60606 |
| Adult | Male | 3265 | 64 | 45.5 | 50.8 | 14.1 | 12.6 | 66687 |
| Adult | Male | 3240 | 64 | 72.5 | 62.7 | 31.8 | 13.5 | 66688 |
| Subadult | Male | 2750 | 14 | 12.6 | 11.3 | 5.9 | 2.5 | 60604 |
| Subadult | Male | 2700 | 36 | 23.2 | 22 | 5.4 | 2.9 | 60605 |
| Adult | Female | 2790 | 36 | 56.5 | 41.1 | 18.9 | 11.3 | 60601 |
| Adult | Female | 2550 | 38 | 86.8 | 113.5 | 26.1 | 31.9 | 60607 |
| Adult | Female | 2750 | 32 | 43 | 49.1 | 18.7 | 19.3 | 66686 |
| Subadult | Female | 2540 | 10 | 10 | 9.5 | 2.6 | 1.5 | 60600 |
| Subadult | Female | 2500 | 26 | 17.2 | 14.6 | 4.7 | 1.6 | 60603 |

**Table 2. Accuracy of locational data sourced through the Argos satellite system**

Classes are described by Argos as: A and B, no estimate of location accuracy; and Z, invalid location

| Accuracy of data | *n* | % |
|---|---|---|
| <50 m | 231 | 13 |
| 150–300 m | 378 | 20 |
| 350–1000 m | 527 | 29 |
| >1000 m | 207 | 11 |
| A, B and Z | 504 | 27 |

($ER = AIC_c$ weight of slope model ÷ $AIC_c$ weight of intercept-only model; see Burnham and Anderson 2002). The *ER* is useful even for a comparison of a null model to a single alternative, in a concept akin to Bayesian odds ratios (see McCarthy 2007). The *ER* is preferable to a classic null-hypothesis significance test because the likelihood of the alternative model is explicitly evaluated (not just the null). Finally, we used *Draw* tools in ArcGIS to outline movements (Fig. 1*a*, *b*).

## Results

### Movements

During both wet and dry seasons, the maximum (linear) distance moved was 114 km, indicating that Magpie Geese are not likely to move far when adequate resources are available. There was no apparent difference in movement between sexes (Table 1), although samples sizes were small. Subadults stayed closer to the release site (maximum distance moved = 23 km). There was considerable variation in individual patterns of movement and distance travelled (Fig. 1*a*, *b*). Some birds moved north along the floodplain system of the South Alligator River wheras others moved to the Mary River region and another to the East Alligator system (Fig. 1).

Considering movement by season (wet, dry), the movements of individuals followed consistent trends (Fig. 2), for example, if an individual moved much during the wet season, they also did so throughout the dry season (information–theoretic $ER = 973.4$, $r^2 = 0.81$; Fig. 2). However, rates of movement (km $week^{-1}$) in the dry season were slightly lower than in the wet season. Comparing maximum and mean weekly movements to the weight

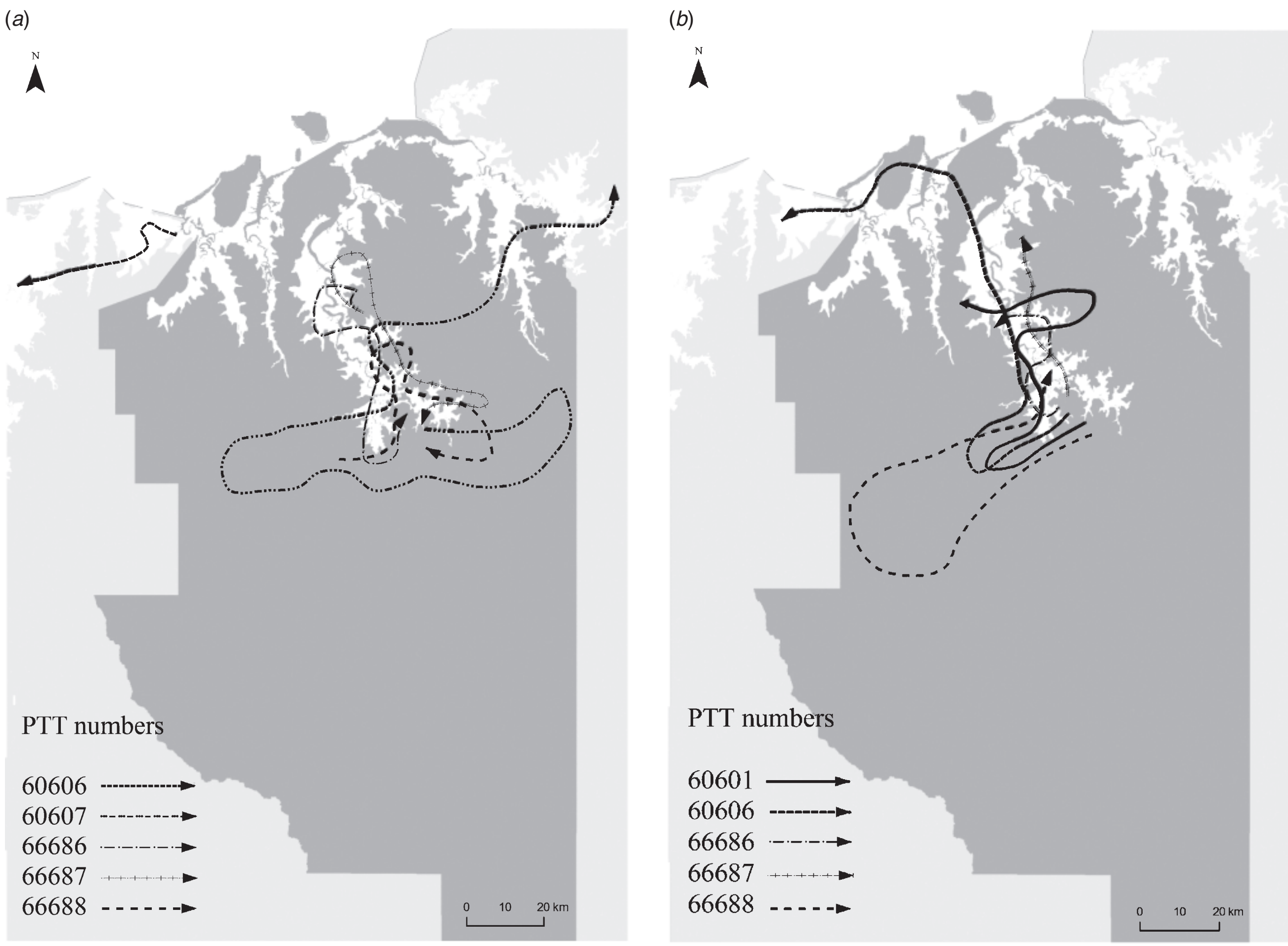


**Fig. 1.** (*a*) Movements of Magpie Geese during the wet season immediately after release (March–end April 2007). (*b*) Movement of birds during the dry season (May–November 2007). For both (*a*) and (*b*), Platform Transmitter Terminal (PTT) numbers are represented by dotted or straight lines (see legend). Subcoastal floodplains are shown in white and the boundary of Kakadu National Park is shown in dark grey.

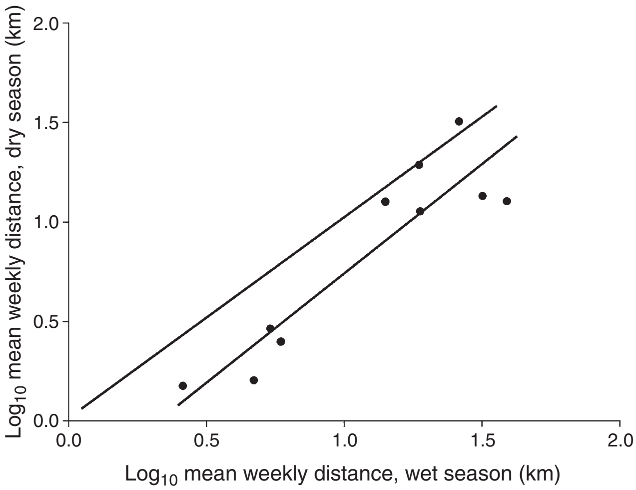


**Fig. 2.** Mean weekly distance travelled (km) during the wet and dry seasons for all birds (sexes pooled). Upper line indicates the 1 : 1 relationship; dry-season (DS) movements were shorter than those during the wet season (WS). Axes are scaled to $\log_{10}$.

of birds at time of release suggested that heavier birds could be travelling farther than lighter birds. However, the *ER* for all relationships by season and weight indicated no effect (i.e. $ER < 1$) or only a weak effect (Fig. 3).

Most birds showed an association with Kakadu National Park (Fig. 1). One individual (adult male), however, moved onto a neighbouring pastoral lease on the Wildman River. Using presence data, we inferred elevation in ArcGIS by using the *Extract* function to assign elevation to each respective location. From these data we found that birds did not use habitat >10 m above sea level (median for all data = 8 m above sea level).

### *Reliability of PTTs*

By December 2007 we had stopped transmission (by cancelling the CLS data-account) for all but three PTTs because they were either no longer relaying data or the animals had not moved for >3 months (Table 1). After 12 months, only two PTTs were still transmitting locational data. The two PTTs transmitting for longer than 12 months were stationary after 13 months and the harnesses had likely come loose and become detached from the bird. Locational data were of fairly good quality. Of all transmissions ($n = 1847$), 62% of locational datapoints were accurate to within 1000 m (Table 2), although these were not ground-truthed (see Roshier and Asmus 2009).

## Discussion

Our satellite telemetry data has added to our understanding of the movements of Magpie Geese by providing more detailed information at finer spatial scales than previously available. We observed extensive individual variation in distances moved and the direction of movement. Despite observing only limited movements (≤120 km), other, anecdotal, evidence suggests that birds can move up to 500 km in one event during catastrophic periods of resource scarcity (Frith and Davies 1961), and Magpie Geese have been observed flying over the Torres Strait between Australia and New Guinea (Draffan *et al*. 1983).

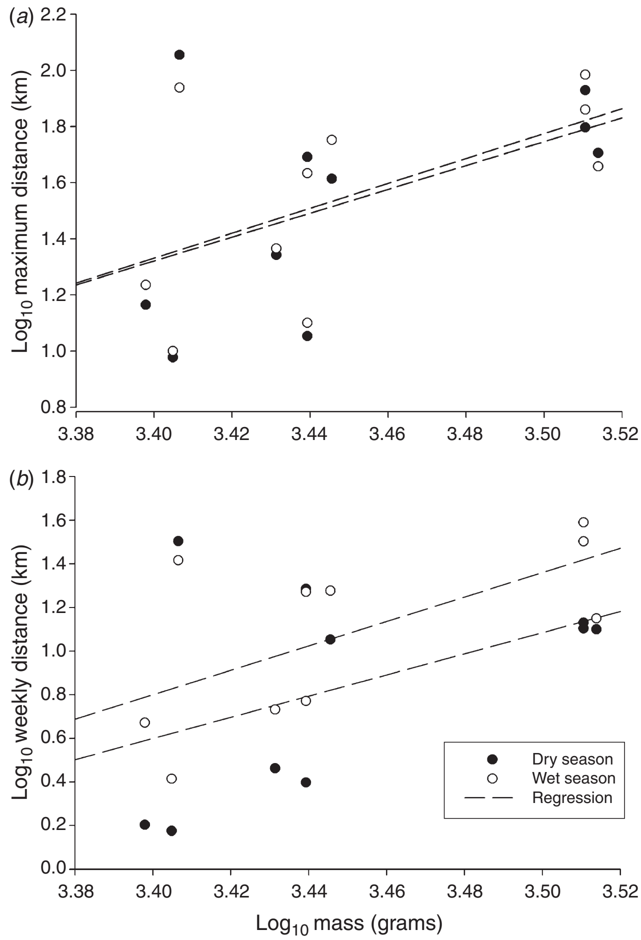


**Fig. 3.** (*a*) Maximum and (*b*) mean weekly distance moved by birds relative to weight ($\log_{10}$ transformed) at time of departure (time at release from holding pen) during the dry and wet seasons. Data for sexes are pooled. Information–theoretic $ER < 1$ (i.e. the null model had most support) for all relationships except for mean weekly distance moved in the wet season relative to body mass ($ER = 1.5$, $r^2 = 0.33$).

Although we did not examine use of habitat by Magpie Geese, previous research (Bayliss and Yeomans 1990; Whitehead 1998) suggests that birds associate with low-lying black clay floodplains during the period after the monsoonal rains and transient or permanent lagoons during the dry season. Rainfall is the principal driver of migratory behaviour in Magpie Geese (Bayliss 1989).

It appears that Magpie Geese pursue ranging-type behaviour (see Dingle 1996), moving between forage sites in response to resource availability. From our small sample, we found that adults moved farther than subadults. Whitehead (1998) suggests that birds do not typically breed until their fifth year (although they attain sexual maturity by 24–36 months old), and that birds use the first 3–5 years of life to gather knowledge of seasonal variation in availability of resources. Further, the potentially greater distances moved by larger birds could be attributed to their increased foraging efficiency and thus better body condition (Whitehead and Tschirner 1992).

Should wetlands be lost through rises in sea level, as projected by Traill *et al*. (in press), there will be potential for fragmentation of the present-day population of Magpie Geese. Protection of habitat and continued movement between populations will be important for the long-term persistence of Magpie Geese in tropical Australia. Indeed, research such as this provides important background information on the potential for population resilience through movement. Our data confirm that Magpie Geese are highly mobile. Thus, dispersion away from areas of exploitation or in response to habitat degradation is an option available to the species.

In closing, we recommend more research on tropical populations of Magpie Geese using molecular genetic analyses to define more systematically metapopulation structure, patterns of movement, including any migration, and demographic histories of subpopulations across their range (see Frankham *et al*. 2002). These data will focus conservation effort and provide the information required if future translocations are required to maintain viable populations.

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