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Supplementary material

Seasonal habitats, decadal trends in abundance and cultural values of magpie geese (*Anseranus semipalmata*) on coastal floodplains in the Kakadu Region, northern Australia

Peter Bayliss[A,D] *and Emma Ligtermoet*[B,C]

[A]CSIRO Oceans and Atmosphere Business Unit, Queensland BioSciences Precinct,
St Lucia, Qld 4072, Australia.

[B]CSIRO Tropical Ecosystems Research Centre, Land and Water Business Unit,
564 Vanderlin Drive, Berrimah, NT 0828, Australia.

[C]The Australian National University (ANU), Fenner School,
Canberra, ACT 0200, Australia.

[D]Corresponding author. Email: peter.bayliss@csiro.au

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Magpie goose aerial-survey metadata and data used in spatial and temporal analyses

Table S1. Metadata for aerial surveys of magpie geese and their nests in the Kakadu Region (1981–2003) used in spatial analysis

Northern Territory (NT) Parks and Wildlife Commission (PWCNT) surveys in the wet seasons of 2006 and 2007 were not used because different observation platforms were employed (helicopter cf. fixed wing), requiring derivation of different visibility correction factors, and only 'core' or selected floodplains were surveyed (Delaney *et al.* 2009). Dry-season surveys in 1994 and 1996 were also not used because aerial photography was used instead of observer counts (Delaney *et al.* 2009) and results would not be comparable. Additionally, the 1996 survey did not include floodplains in the Kakadu Region (Delaney *et al.* 2009; K. Saalfeld, pers. comm.). ARR, Alligator Rivers Region (or Kakadu Region); OSS, Office of Supervising Scientist (now Supervising Scientist Division, Commonwealth Department of Environment); NTG, NT Government; NT Top End, northern end of NT

Scope	Who	Month and year	Season	Transect width per observer (m)	Counts from both sides of aircraft	Transect spacing (km)
ARR	OSS	June 1981 to Nov. 1981 (n = 6)	Dry	100	Yes	2.0
ARR	OSS	May 1982 to Nov. 1982 (n = 7)	Dry	100	Yes	2.0
ARR	OSS	May 1983 to Nov. 1983 (n = 7)	Dry	100	Yes	2.0
ARR	OSS	May 1984 to Aug. 1984 (n = 4)	Dry	100	Yes	2.0
ARR	OSS	Dec. 1981 to Apr.1982 (n = 5)	Wet (no nest counts)	100	Yes	2.0
ARR	OSS	Dec. 1982 to Apr.1983 (n = 5)	Wet (no nest counts)	100	Yes	2.0
ARR	OSS	Dec. 1983 to Apr.1984 (n = 5)	Wet (no nest counts)	100	Yes	2.0
NT Top End	NTG	Nov. 1983	Dry	200	Yes	5.4
NT Top End	NTG	Feb. 1984	Wet	200	Yes	5.4
NT Top End	NTG	Nov. 1984	Dry	200	Yes	5.4
NT Top End	NTG	Mar. 1985	Wet + nest counts	200	Yes	5.4
NT Top End	NTG	Mar. 1986	Wet + nest counts	200	Yes	5.4
NT Top End	NTG	Mar. 1987	Wet + nest counts	200	Yes	5.4
NT Top End	NTG	Mar. 1988	Wet + nest counts	200	Yes	5.4
NT Top End	NTG	Mar. 1989	Wet + nest counts	200	Yes	5.4

Scope	Who	Month and year	Season	Transect width per observer (m)	Counts from both sides of aircraft	Transect spacing (km)
NT Western Top End	NTG	Mar. 1990	Wet + nest counts	200	Yes	2.7
NT Western Top End	NTG	Mar. 1991	Wet + nest counts	200	Yes	2.7
NT Western Top End	NTG	Mar. 1992	Wet + nest counts	200	Yes	2.7
NT Western Top End	NTG	Mar. 1993	Wet + nest counts	200	Yes	2.7
Kakadu NP only	NTG	Nov. 1994	Dry	200	Yes	2.7
NT western Top End	NTG	Mar. 2000	Wet + nest counts	200	No, one side	2.7
Kakadu NP only	Parks	Nov. 2003	Dry	200	Yes	2.7

Table S2. Cross-calibration of magpie geese population estimates derived by Tulloch and McKean (1983) with those derived by Morton *et al.* (1990) and the Northern Territory Parks and Wildlife Commission surveys (Bayliss and Yeomans 1990*a*; Delaney *et al.* 2009) in the Kakadu Region

All surveys are late dry-season surveys (October to November)

Survey and source	Aerial-survey variables and design	Year (late dry season)			Correction factor
		1980	1981	1983	
Tulloch and McKean (1983)	Two observers either side plane; 150-m altitude; 167 km h^{-1}; fixed transects for total coverage floodplains, no transect width; total counts used as index of population size	360 900	None	None	2.66× to cross-calibrate with Morton *et al*. surveys
Morton *et al*. (1990); Morton *et al*. (1991)	Two observers either side plane; 30-m altitude; 140 km h^{-1}; fixed east–west transects 2 km apart; 100-m transect width per observer; density per square kilometre of floodplain used as population index	None	960 159	525 740	3.88× to cross-calibrate with Bayliss and Yeomans surveys
Bayliss and Yeomans (1990*a*)	Two observers either side plane; 61-m altitude; 185 km h^{-1}; fixed east–west transects 5.3 or 2.7 km apart; 200-m transect width per observer; seasonal visibility corrections factors used to estimate absolute population size	None	None	2 040 976	2.66 × 3.88 = 10.33 to indirectly cross-calibrate Tulloch and McKean with Bayliss and Yeomans surveys

Table S3. Estimates of magpie goose population size in the western northern end ('Top End') of the Northern Territory (NT), source of data and derivation of corrections used to standardise data between the Tulloch and McKean (1983) data set (1958-1980) and subsequent surveys conducted by the NT Parks and Wildlife Commission (1983-2007)

Population estimates from 1958 to 1980 are from Tulloch and McKean (1983) and were derived from their fig. 2 and accompanying text. Their population indices were then multiplied by a correction factor of 10.33 (see Table S2 above) to standardise to NT Parks and Wildlife Commission aerial survey methodology (after Bayliss and Yeomans 1990*a*, 1990*b*; PWCNT 2003; Delaney *et al.* 2009) by adjusting for a combination of negative-visibility biases. Population estimates from 1983 to 1986 are from appendix 2 in Bayliss and Yeomans (1990*a*). Population estimates from 1987 to 1999 were derived from fig. 4 in PWCNT (2003) and fig. 2 in Delaney *et al.* (2009), apart from that for 1990, which was taken from Saalfeld (1990). Population estimates from 2000 to 2006 were reconstructed from fig. 2 in Delaney *et al.* (2009). Note the exclusion of some survey data sets between 1994 and 2007 for a variety of standardisation reasons. n = 42 years and 34 surveys selected for the time series (note exclusions in later years)

Year	Season	Numbers $\times 10^6$	Notes
1958	Dry	3.63	CSIRO Tulloch and McKean (1983) magpie goose aerial surveys in the western Top End of the NT
1959	Dry	3.40	
1960	Dry	3.10	
1961	Dry	2.85	
1962	Dry	2.04	
1963	Dry	1.69	
1964	Dry	1.52	
1965	Dry	1.36	
1966	Dry	1.13	
1967	Dry	1.10	
1968	Dry	1.03	
1969	Dry	0.99	
1970	Dry	0.92	
1971	Dry	0.61	
1972	Dry	0.53	
1973	Dry	0.98	
1974	Dry	1.37	

Year	Season	Numbers $\times 10^6$	Notes
1975	Dry	2.05	
1980	Dry	3.83	
1983	Dry	2.97	PWCNT magpie goose aerial surveys in the western Top End of the NT
1984	Wet	2.48	
1984	Dry	3.87	
1985	Wet	2.36	
1986	Wet	1.85	
1987	Wet	2.30	
1988	Wet	1.20	
1989	Wet	1.30	
1990	Wet	1.90	
1991	Wet	1.10	
1992	Wet	1.20	
1993	Wet	1.70	
1994	Dry	–	Excluded – reduced coverage western Top End and aerial photography trialled.
1995	Dry	1.75	
1996	Dry	–	Excluded –reduced coverage in western Top End and aerial photography trialled.
1999	Wet	2.20	
2000	Wet	3.20	One observer only, data adjusted.
2006	Wet	2.40	Excluded – helicopter used and reduced coverage western Top End.
2007	Wet	Not available	Excluded – helicopter used and reduced coverage in western Top End.

Cultural harvesting values of magpie geese in the Kakadu Region

Table S4. Respondent comments illustrating the diverse attributions of causality to changes in magpie goose abundance (from E. Ligtermoet, unpubl. data.)

Goose resource	Change	Illustrative quotation	Respondent	Causal theme
Geese egg harvesting	No eggs available	'This year – no eggs. They did try to go nesting, but didn't lay. Normally nest and lay around Gunbalanya. This year not good year for goose hunting. Not enough water. Water level dropping here'; 'Last year, Magpie goose didn't lay eggs. None at all. Never seen that before. First time for me. This year, did lay, lots now. Maybe because of water level, main reason, maybe too much current from upstream, and grass change. Or burning. Used to burn, but keep grass for egg [packing].'	CN, female, Kunbarlanja, 7-Aug-13; CN, female, Kunbarlanja, 29-Jul-14	Changes in water level, grasses, or fire regime
	No eggs available	'This year (2013) tried for eggs, but none.' [Why no geese eggs this year?] 'Not sure – maybe goose moved to another place? Not much wet, little bit dry?'	JG, male, Ardjumarllarl Ranger, Kunbarlanja 19-Sep-13	Geese movement or insufficient wet season
	No eggs available	This year didn't get any. [Why?] Someone maybe goose cook in wrong way, perhaps in ground oven. Should only cook it in the ashes. That can change numbers. Next year might be ok.'	JN, male, Kunbarlanja 20-Sep-13,	Transgression traditional rules
	Reduction in eggs available	'Not many [magpie goose eggs] this year. '[Why?] 'Because water chestnut not growing on the floodplain anymore. Got that salvinia and para grass now and less chestnut now.'	GM, male, Kunbarlanja 10-Oct-13,	Invasive weeds outcompeting native floodplain vegetation
	Goose egg availability variable, but reduced from childhood	'Sometimes in big flood- nest gets washed away, then not so many. This year ok, but last year- not so many. Up and down, bit of a change from when boys. Never had salvinia and para [grass] then, or so many ginga [salt water crocodiles].'	AN, male, Kunbarlanja, 31-Oct-14	Abundance: Flooding (normal dynamic), invasive weeds (para grass and salvinia). Access: increase in crocodile population
	Variable egg abundance	'Goose eggs – go when water starts going down, people go looking for eggs. Not so many eggs sometimes- getting washed out when it floods'	BG, female, Kunbarlanja, 4-Jul-14	Flooding variability
Geese nesting	Loss of goose nesting area	[visiting goose nesting location in Kakadu] 'Now nothing. Maybe they moved. Up to Boggy plains way. They lay but sometimes floodwater washes them away, or if not enough water, might not lay much. Used to walk to get eggs. Can't walk in water anymore, those crocs.'	AN and NM, female, Kakadu, 5-Dec-14	Abundance: Migration, flooding, Access (egg harvest): increase in crocodile population
Geese abundance	Reduction in geese abundance	'Special rule for the dreaming ones. We have to smoke it. Have to get stick and go all around the dreaming rock. Used to do it before, but no one feels	SB, male, Kunbarlanja, 7-Sep-14	Lack of continuity in customary ritual protocols

Goose resource	Change	Illustrative quotation	Respondent	Causal theme
		like it. If they do it now, will get more. First people did. Magpie goose dreaming- the same, if they could do it, would have more manimunak [magpie goose] in this billabong.'		
	Reduction in geese abundance and access	'Used to be able to wade across the floodplain [Canon Hill, East Alligator] … hunting magpie goose all along. Now completely covered in para, can't get through, can barely get air boat in. No geese at all.'	SN, male, Kakadu, 24-Jul-14	Invasive para grass inhibiting access
	Reduction in geese abundance	'Goose numbers have dropped. I've noticed decreases in numbers at Mumukala and Palms area. Reckon they've gone to Darwin mango farms.'	IC, Ranger, male, Kakadu 10-Sep-14	Regional goose migration (feeding preference for mango farms)
Geese and egg abundance	Reduction in geese and geese eggs	'Magpie goose, when I was younger there were a lot more… Goose eggs, not so much this year [Why?] 'Don't know. Around Nimbabirr, used to eat the chicks. Old fellow would say don't get too much. Just few eggs, share with families. 1980s, 90s, 2000s, 2007 ok. 2013 none. Flying over in the wet saw big mob [geese] still around, but not sure what's happened, maybe change in weather, season.'	IN, male, Kunbarlanja, 11-Oct-13	Uncertain, change in weather, season

Aboriginal perceptions of changes in goose abundance and access to hunting sites (E. Ligtermoet, unpubl. data.)

Most respondents identified past changes in the abundance of, and access to, magpie geese and their eggs and gave a range of explanations. For example, altered floodplain hydrology and traditional burning regimes as a result of buffalo (*Bubalus bubalis*) removal (Petty *et al*. 2007); a reduction or transgression of customary practices; and an increase in the abundance of invasive species such as feral pigs and weeds, with a concomitant reduction in nesting habitat and availability of goose food, particularly the bulbs of water chestnut (see Table S4). All respondents described how thicker introduced grasses restrict ongoing access to hunting sites, in particular, para grass. Loss of access to goose eggs in the late wet season was primarily attributed to increased numbers and encounters with large saltwater crocodiles (*Crocodylus porosus*), which made wading or canoeing unsafe and required access to aluminium boats. Several respondents described changing inter-generational interests and the influence of non-Aboriginal hunting practices among younger Aboriginal men. There was a range of responses to perceived threats to goose harvests from future saltwater inundation due to sea-level rise; some respondents felt that sufficient alternative hunting options will become available, whereas others felt that there will be some inevitable loss. Although several respondents attributed possible changes in weather or climate to changes in goose abundance, they all noted that existing multiple socio-ecological factors outlined above are of more immediate concern than future climate-change impacts.

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