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Distribution and habitat use by *Hemidactylus frenatus* Duméril and Bibron (Gekkonidae) in the Northern Territory, Australia

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ABSTRACT

Hemidactylus frenatus is an invasive gecko with an expanding distribution in Australia. We collated all available locality records and investigated the habitats associated with the species in the Northern Territory. *H. frenatus* is more widespread in the Top End, Gulf of Carpentaria and Victoria River regions than previously documented. The species remains primarily associated with artificial anthropogenic structures and surrounding vegetation (particularly denser tropical forests), but there are also a small number of records of it living in natural vegetation further than 1 km from such structures. We speculate that *H. frenatus* will continue to spread through suitable habitats in northern Australia.

KEYWORDS: *Hemidactylus*, Gekkonidae, invasive species, Northern Territory.

INTRODUCTION

The Asian House Gecko, *Hemidactylus frenatus* (Fig. 1), is presently widespread in tropical and sub-tropical regions throughout the world, occurring in Asia (Manthey and Grossman 1997; Goris and Maeda 2004), Australasia (Cogger 2000), the Pacific (Case *et al.* 1994), the Americas (Savage 2002; Schmidt Ballardo *et al.*1996; Townsend and Krysko 2003; Rivas Fuenmayor *et al.* 2005), Africa and Madagascar (Spawls *et al.* 2001) and the Mascarene Islands (Cole *et al.* 2005). The species is introduced within most of its range and its origins are obscure, but they probably lie within south-east Asia. Where introduced, *H. frenatus* is normally associated with human dwellings or other structures (e.g. Galina-Tessaro *et al.* 1999; Lee 2000; McCoy 2000; Goris and Maeda 2004).

In Australia, *Hemidactylus frenatus* occurs in coastal Queensland, northern coastal New South Wales, the Northern Territory from the coast south along the Stuart Highway to 22°S, and also in scattered locations in the Pilbara and Kimberley, north-western Western Australia (Cook 1990; Wilson and Swan 2008). Typically, the species is described as almost completely confined to artificial habitats associated with humans, including derelict buildings, rubbish heaps and vehicles (Wilson and Knowles 1998; Wilson 2005). Cogger (2000) suggests "a dependance on man for its distribution in this country", and in Brisbane, south-east Queensland, this remains the case according to literature (Keim 2002; Newbery and Jones 2007). However, elsewhere in the country there are published records of *H. frenatus* in habitats away from human habitation. In the Northern Territory, as early as 1980 its presence was noted in coastal monsoon forest and mangrove at Buffalo Creek, north-east of Darwin (Kikkawa and Monteith 1980), and Keim (2002) records established populations in bushland adjacent to Darwin. Gambold and Woinarski (1993) documented further records in monsoon forest patches at Gunn Point, north-east of Darwin, and in the Daly River area. In Queensland, *H. frenatus* has recently been recorded in coastal *Casuarina* forest and adjacent littoral vine scrub on the western coast of Cape York Peninsula, approximately 100 km south of Weipa (Clarke 2006). In contrast, surveys in the immediate vicinity of Weipa (Winter and Atherton 1985), and of monsoon forests in the Kimberley, Western Australia (Kendrick and Rolfe 1991), did not find the species.

The colonisation of new areas around the world by *Hemidactylus frenatus* and its effect on indigenous gecko taxa have been the subject of much interest. A number of gecko species are known to have suffered a negative impact from it. On the Mascarene Islands for example, *H. frenatus* most likely caused the extinction of some indigenous *Nactus* spp. by outcompeting them for use of refugia and through predation and other agonistic behaviour (Cole *et al.* 2005). On some Pacific islands *H. frenatus* has replaced *Lepidodactylus lugubris* as the dominant gecko on artificial structures (Case *et al.* 1994); in Hawaii the primary mechanism for this domination is the superior foraging ability in *H. frenatus*, rather than agonistic interactions (Petren and Case 1996). Rivas Fuenmayor *et al.* (2005) suggest *H. frenatus* has caused declines of *Gonatodes albogularis* and *Phyllodactylus ventralis* in Venezuela.

A number of Australian gekkonid taxa may be impacted by the invasion of *Hemidactylus frenatus*. *Gehyra australis* and *G. dubia* are common inhabitants of anthropogenic structures (Wilson and Swan 2008). Species of both

Fig. 1. Live *Hemidactylus frenatus*, *in situ* at night, Nightcliff, Darwin, Northern Territory, 10 October 2009. **A**, In its usual hunting pose on a fly screen inside a house; **B**, on base of trunk of a *Carpentaria acuminata* palm outside a house. Photos. J. Lindley McKay.

Nactus and *Lepidodactylus*, genera in which declines are documented elsewhere, occur in Queensland on man-made structures and in closed forests. Like other affected taxa, *Lepidodactylus pumilus* is restricted to an island distribution. The impact of *H. frenatus* on these geckos and other components of Australian ecosystems are yet to be documented.

Given the potential for impact on indigenous gecko species, it is desirable to investigate the ecology of *H. frenatus* in Australia. In this study the geographic focus was limited to the Northern Territory of northern Australia. We addressed the following questions: What is the current geographical range of *H. frenatus* in the Northern Territory, and with which habitat(s) is *H. frenatus* currently associated in the Northern Territory?

METHODS

Assessing current range. The current range of *Hemidactylus frenatus* in the Northern Territory was assessed using two sources of data – the Northern Territory Vertebrate Fauna Atlas (NTVFA) and field surveys. The NTVFA is a database maintained by the Biodiversity Conservation unit of the Northern Territory Department of Natural Resources, Environment, the Arts and Sport (NRETAS) which holds geolocated fauna records from an array of sources including CSIRO, the Northern Territory Biological Records Scheme, Australian museums, Australian universities, peer-reviewed literature, environmental literature (e.g. environmental impact assessments), and non-government organisations such as Birds Australia. The NTVFA contains 185 records of *Hemidactylus frenatus* between 20 February 1937 and 21 August 2001 and lists the location, date, and organisation that collected the information.

Field surveys were conducted from 23 July 2002 to 4 September 2005, in parts of the Top End of the Northern Territory north of 15° S and the Gulf of Carpentaria region. Information collected included date, location and habitat. Where possible, surveys were conducted from dusk until the third hour after sunset, as *H. frenatus* has been noted to be most active in the earlier hours of the night (Frankenberg and Werner 1981). Surveys were usually limited to 10 minutes. Identification could be made reliably and with ease as *H. frenatus* is the only gecko species with a multiple chirp call throughout most of the Northern Territory, and

in the localities where *Lepidodactylus lugubris* also occurs (Woinarski *et al.* 1999, McKay and Horner 2007), identification of *H. frenatus* can be made visually by observing the rows of spines on the dorsal surface of the tail (Fig. 1).

The combined data spanned 68 years from 1937 to 2005. All localities were combined using GIS to identify the current known Northern Territory distribution.

Assessing current habitat associations. To assess habitats associated with *Hemidactylus frenatus* we used field survey data, and any habitat information attached to the NTVFA records. During field surveys we collected the following information: date, location, distance to nearest vehicle access or artificial structure, and habitat type (i.e. artificial structure, coastal monsoon forest, riparian monsoon forest, riparian forest, eucalypt woodland, *Melaleuca* swamp forest, coastal *Casuarina* forest, mangrove, campground or open area). Habitats were classified into four categories: (1) structures (including disused vehicles and building ruins); (2) naturally occurring vegetation 0–500 m from the nearest vehicle access or artificial structure; (3) naturally occurring vegetation 500–1000 m from the nearest vehicle access or artificial structure; and (4) naturally occurring vegetation >1000 m from the nearest vehicle access or artificial structure.

The greatest portion of NTVFA records had no attached habitat data. Those that did provided various information including canopy height, canopy cover percentage and a general site description.

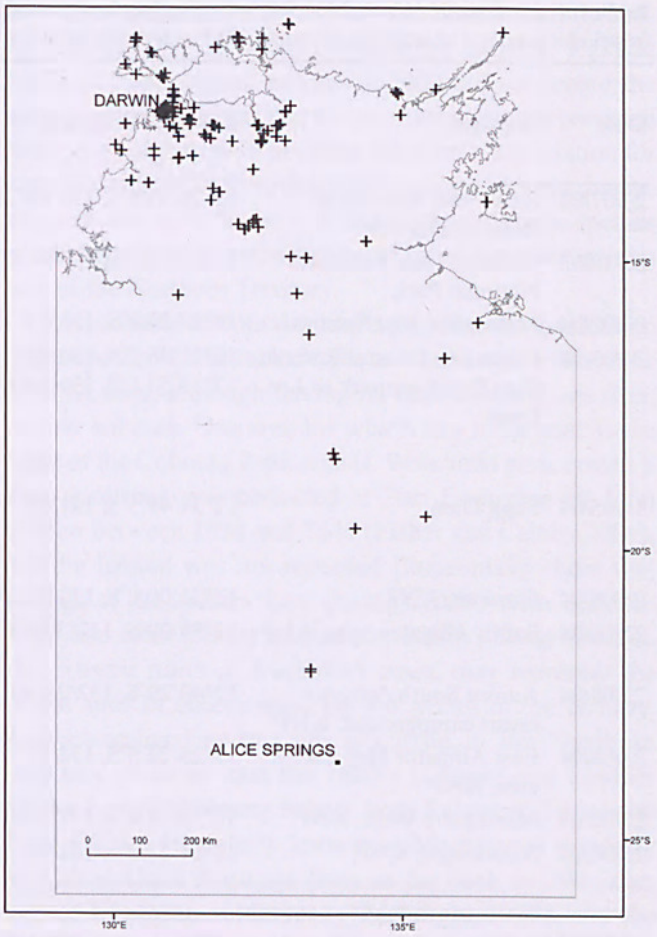

Fig. 2. Current distribution of *Hemidactylus frenatus* in the Northern Territory, from the combined records of the Northern Territory Vertebrate Fauna Atlas and field surveys.

RESULTS

Current range. Based on NTVFA and field survey data, *Hemidactylus frenatus* is currently confined to areas north of the Tropic of Capricorn in the Northern Territory, and is most densely represented by localities in the north-western Top End (Fig. 2). There are scattered records throughout other parts of the Top End, including coastal Arnhem Land, and the Tiwi, Croker, Marchinbar and Groote islands. South of 15°S localities become sparser, with records along the Stuart Highway, three records from the Gulf country and one from the Victoria River District. South of 17°S *H. frenatus* is confined to localities on the Stuart and Barkly Highways, and there are no records south of Ti Tree at 22°S.

Current habitat associations. Based on the field survey data, *Hemidactylus frenatus* utilises both artificial structures and natural habitats in the Northern Territory (Table 1). Most records from artificial structures are within the region of highest regional abundance (the western Top End), which is also the region with the largest infrastructure and human population. One record provided the second locality at which artificial structures are used in the sparsely populated Gulf of Carpentaria region.

In field surveys, *Hemidactylus frenatus* was recorded from riparian vegetation (n=8), eucalypt woodland (n=4), coastal monsoon forest (n=3), riparian monsoon forest (n=3), *Melaleuca* swamp forest (n=1), and coastal *Casuarina* forest (n=1). Of the 18 total locations where *H. frenatus* occupied natural habitats, 13 represented records within 500 m of structures or vehicle access. *Hemidactylus frenatus* occurred up to 1 km from a structure or vehicle access at two localities in the Darwin area, in coastal monsoon forest and *Melaleuca* swamp forest habitats. Records from greater than 1 km from a structure or vehicle access occurred in both the Darwin area (two localities, in coastal monsoon forest and coastal *Casuarina* forest) and Kakadu National Park (one locality, in riparian monsoon forest).

Twenty site records from the NTVFA also included data on habitat association for *H. frenatus*. Habitats were monsoon forest (n=15), woodland (n=3), woodland on foreshore (n=1), and floodplain edge with scattered low trees (n=1). The monsoon forests had canopy heights of between 7 and 20 m, and canopy covers of between 20 and 90%. Woodlands had canopy heights of 9–12 m, and canopy covers of 8–40%.

Neither field surveys nor the NTVFA provided any records from natural habitats south of 15°S.

Table 1. Habitat associations of *Hemidactylus frenatus* in the Northern Territory, from field survey records. Abbreviations: **DVA** = distance from vehicle access or artificial structure; **KNP** = Kakadu National Park.

Date	Location	Latitude, Longitude	Habitat	DVA 0–500 m	DVA 500–1000 m	DVA >1000 m
23/07/02	East Point Recreation Reserve, Darwin	12°24′43.8″S, 130°49′24.2″E	Monsoon forest	X	X	
29/12/02	Walker Creek, Litchfield National Park	13°05′10.6″S, 130°41′57.8″E	Riparian vegetation	X		
07/02/04	Mataranka Hot Springs	14°57′29.8″S, 133°19′56.2″E	Riparian forest	X		
24/03/04	Casuarina Coastal Reserve, Free Beach carpark to Lee Point	12°21′46.7″S, 130°52′02.2″E to 12°19′55.1″S, 130°53′42.9″E	Coastal monsoon forest dominated by large *Acacia auriculiformis* and coastal *Casuarina* forest dominated by *Casuarina equisetifolia*	X	X	X
14/05/04	Fogg Dam	12°34′48.5″S, 131°20′23.6″E	Riparian vegetation dominated by *Acacia auriculiformis*	X		
05/08/04	Gunlom, KNP	13°26′00.8″S, 132°24′54.6″E	Riparian vegetation	X		
22/08/04	South Alligator river, KNP	12°39′29″S, 132°30′19″E	riparian strip along river bank	X		
22/08/04	Aurora South Alligator resort campground, KNP	12°40′29″S, 132°28′47″E	Artificial structure			
23/08/04	East Alligator Day Use area, KNP	12°25′23.8″S, 132°57′′57.9″E	Riparian forest	X		
23/08/04	Manngarre Walk, KNP	12°25′15.0″S, 132°58′01.4″E	Riparian monsoon forest	X	X	X
25/08/04	Nourlangie, KNP	12°51′51.7″S, 132°48′53.5″E	Eucalypt woodland dominated by *Eucalyptus miniata*	X		
25/08/04	Jabiru	12°40′31″S, 132°50′09″E	Artificial structure			
26/08/04	Jim Jim billabong campground, KNP	12°56′30.9″S, 132°33′13.9″E	Woodland adjacent to riparian zone	X		
29/08/04	Nitmiluk National Park	14°19′08″S 132°25′17″E	Large dense trees in the campground	X		
05/09/04	Mandorah	12°25′59″S 130°45′46″E	Artificial structure			
18/11/04	Hyptis Heights, KNP	12°48′48.5″S, 132°35′40.1″E	Artificial structure			
01/12/04	Jim Jim ranger station, KNP	12°55′48.1″S, 132°34′08.5″E	Artificial structure			
06/12/04	Mardugal campground, KNP	12°55′55.8″S, 132°32′19.1″E	Woodland and riparian vegetation, dominant trees include *Acacia auriculiformis* and *Pandanus spiralis*	X		
11/12/04	Holmes Jungle Nature Reserve, Darwin	12°24′06.5″S 130°55′53.6″E	Monsoon and *Melaleuca* swamp forest	X	X	
14/12/04	Nourlangie Camp, KNP	12°45′42.7″S, 132°39′37.9″E	Monsoon forest	X		
16/12/04	Bowali Visitor Centre, KNP	12°40′32″S 132°49′02″E	Artificial structure			
16/12/04	Bark Hut (Annaburroo)	12°54′00.7″S, 131°40′32.4″E	Artificial structure			
22/12/04	Manton Dam	12°51′44.0″S, 131°07′01.4″E	Riparian forest dominated by *Acacia auriculiformis* and *Melaleuca*	X		
23/12/04	Bardedjilidji walk, KNP	12°25′58.5″S, 132°58′11.2″E	Woodland dominated by *Eucalyptus* spp. and *Pandanus spiralis*	X		
08/05/05	Cape Crawford	16°41′01.7″S, 135°43′30.5″E	Artificial structure			
20/08/05	Gunbalanya (Oenpelli)	12°19′35.9″S 133°03′21.5″E	Artificial structure			
04/09/05	Gunn Point	12°09′33.4″S 131°01′16.2″E	Coastal monsoon forest, largest trees *Bombax ceiba* and *Acacia auriculiformis*	X	X	X

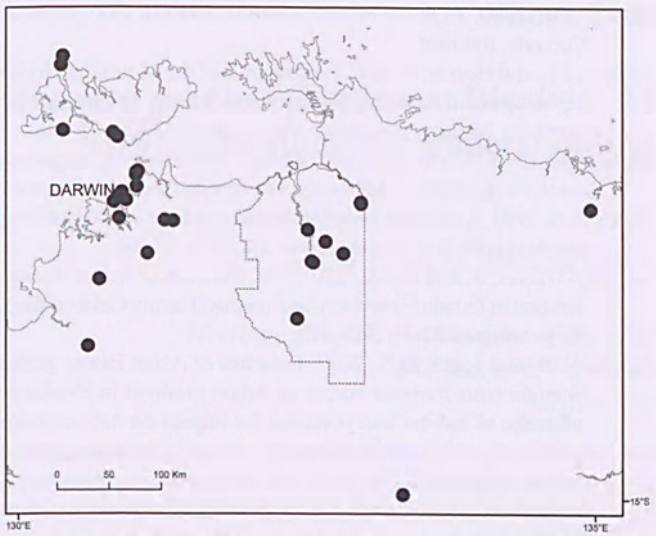

Fig. 3. Distribution of *Hemidactylus frenatus* in natural habitats in the north-east and central-north of the Northern Territory, Australia, from the combined records of the Northern Territory Vertebrate Fauna Atlas and field surveys. Dashed line indicates the border of Kakadu National Park.

DISCUSSION

The collation of site records clearly shows that *Hemidactylus frenatus* is established in many areas of the tropical Northern Territory, in particular the Top End north of 16°S, although some records may represent temporary introductions. Recent literature (e.g. Cogger 2000) portrays a distribution confined to localities along the Stuart Highway – essentially a strip down the centre of the Northern Territory. But here we show that *H. frenatus* is present to the east and to the west of the Stuart Highway, with many localities broadly distributed north of 16°S, and more sparsely separated localities further south. Both this study and previous literature indicate a southerly range limit of 22° S. Ota (1994) found that eggs of *H. frenatus* would not hatch below 19° C, and this is probably one factor limiting the southerly distribution.

Habitat association data presented here show *Hemidactylus frenatus* utilising both artificial and natural habitats (Table 1). Much recent literature has regarded the species as dependant on artificial habitats (e.g. Cogger 2000, Wilson 2005) and overlooked or ignored the few documentations of natural habitat use (Kikkawa and Monteith 1980; Gambold and Woinarski 1993; Keim 2002). From this study it can be seen that *H. frenatus* commonly occurs in natural vegetation proximate to human habitation or vehicle access in the Northern Territory north of 15°S (Fig. 3). The most frequently recorded of these natural habitats were forests with comparatively dense canopies or eucalypt woodland adjacent to closed forests. These types of forests possibly provide a preferable thermal range for a species adapted to mesic tropical conditions. Alternatively, tree species associated with denser forests may provide more suitable refugia for the colonisers than the smooth-barked eucalypts that predominate in open woodland. In the one woodland site not adjacent to denser forest where *H. frenatus* was recorded (Nourlangie carpark, Kakadu National Park), repeat surveys in 2004 did not record the species, and we suspect that the population has not persisted there. Although data do not show the habitat association for records south of 16°S, the distribution along major highways suggests that with the lack of mesic vegetation the species is more likely to be restricted to artificial structures in this part of the Northern Territory.

It is probable that our data underestimates the distribution of the species in natural habitats, as we are aware that some NTFVA sites, although having no data attached, are from natural habitats. One area for which this is the case is the coast of the Cobourg Peninsula (J. Woinarski pers. comm.). One specimen was collected at Port Essington by John Gilbert between 1838 and 1841 (Fisher and Calaby 2009), but the habitat was not recorded [Incidentally there was no sign of the species there during CSIRO visits between 1966 and 1969 (Fisher and Calaby 2009).] These sites, on the extreme north of Australia's coast, may represent the oldest sites of colonisation by this gecko in the country. *Hemidactylus frenatus* has occurred in the Northern Territory since at least the 1800's (Cogger and Lindner 1974), however trepang fishers from Sulawesi, Timor and New Guinea (popularly known as Macassans) regularly visited northern Australia from as far back as 100 years before European settlement (Macknight 1976), and the Cobourg Peninsula was a well-known destination of these traders (see Mitchell 1995).

Many features of the biology of *Hemidactylus frenatus* make this gecko well suited for colonisation, such as the ability of females to store sperm for up to 36 weeks (Murphy-Walker and Haley 1996), the ability to outcompete other geckos without costly agonistic interactions (Petren and Case 1996), and the ability to use its own species as a food source (Galina-Tessaro *et al.* 1999). Given these findings, it seems probable that *H. frenatus* will colonise suitable artificial anthropogenic and natural habitats throughout tropical Australia. We are aware of a number of undocumented populations in Arnhem Land (P. Horner pers. comm.) and inland Queensland (JLM unpub. data). Further study of *H. frenatus* provides numerous opportunities for research into both theoretical issues, such as the mechanisms of competition, and applied management issues, such as the anthropogenic means of dispersal in invasive species.

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