SHORT COMMUNICATION

Natural history of *Hoplodactylus stephensi* (Reptilia: Gekkonidae) on Stephens Island, Cook Strait, New Zealand

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Abstract: The striped gecko (*Hoplodactylus stephensi*) is one of the rarest and most elusive of New Zealand's lizards. It is currently known from just three locations; Stephens Island (Takapourewa) in Cook Strait, Maud Island in Pelorus Sound, and the Coromandel Peninsula. The striped gecko is a relatively poorly studied species with little data available on many aspects of its biology. We report on the first estimate of longevity in *H. stephensi* (a minimum of 16 years) and provide baseline data on population structure, habitat use, morphometrics and pregnancy rate. Our data show the value of permanently marked populations of reptiles available for long-term study by different researchers.

Keywords: Life history; longevity; striped gecko.

Introduction

Poor knowledge of species biology can hinder species conservation management. For example, in New Zealand, conservation management of the critically endangered kakapo (*Strigops habroptilus*) for many years included intensive supplementary feeding to encourage successful nesting. However, recent research has shown that female kakapo fed a supplemented diet produce more male offspring than female, further biasing an already male-biased sex ratio and threatening the species' recovery (Clout, Elliott and Robertson, 2002).

Ecologically, the reptile fauna of New Zealand is characterised by extended life histories and low reproductive rates, which make many species vulnerable to human disturbance and mammalian predation (Daugherty, Gibbs and Hitchmough, 1993; Cree, 1994). The striped gecko (*Hoplodactylus stephensi*) is one of New Zealand's rarest geckos. It is listed in the New Zealand threat classification system as range-restricted (Cook Strait island populations) and data deficient (Coromandel Peninsula population; Hitchmough, 2002), and as vulnerable in the IUCN Red List (International Union for the Conservation of Nature, 2002). Conservation management for *H. stephensi* is hampered by the elusive behaviour of this species and the limited information available on its general biology. This species is of moderate size (up to 85 mm snout-vent length), and is nocturnal and arboreal. It is known only from forest remnants and shrublands on Stephens Island, Maud Island and the Coromandel Peninsula, although it possibly once inhabited lowland forest throughout the North Island (Whitaker, 1991; Whitaker, Hitchmough and Chappell, 1999; Gill and Whitaker, 2001; Whitaker, 2001). The population of *H. stephensi* in 1 ha of *Muehlenbeckia australis* vine land beside Ruston Bush on Stephens Island has been estimated to number approximately 600 individuals (Cree, 1990). Data for captive specimens are also limited, with a maximum life span in captivity recorded at 10 years after capture as an adult (I. Borich, Ti Point Reptile Zoo, Warkworth, N.Z., pers. comm.).

Knowledge of a species' longevity is important for conservation management, particularly when planning post-translocation surveys and estimating population recovery times after predator removal (Bannock, Whitaker and Hickling, 1999; Towns and Ferreira, 2001). However, few studies in New Zealand have followed individually marked lizards in the wild for the decades required to trace individuals throughout their natural life span. Among those that have, considerable longevity is evident. For example, longevity of one individual *H. duvaucelii* on North Brother Island is estimated at 36 years (Thompson *et al.*, 1992). Some *H. maculatus* are estimated to reach a minimum age of 27 years at Turakirae Head, Wellington (Anastasiadis and Whitaker, 1987; Green,

2001), and 36 years on Motunau Island, Canterbury (Bannock *et al.*, 1999). Compared with other small, free-living lizard species worldwide, New Zealand geckos show extreme longevity. For example, the lifespan of the Australian geckos *Diplodactylus stenodactylus* and *D. conspicillatus* in the wild is 3 years, and of the gecko *Rhynchoedura ornata* is 2 years (Read, 1999).

The longevity of some New Zealand reptile species has been linked with their late maturity and low reproductive capacity (Whitaker, 1982; Cree, 1994). All gecko species in New Zealand have a maximum clutch size of two. Females typically give birth during late summer to early autumn, but some do not produce young each year (Cree, 1994; Cree and Guillette, 1995; Gill and Whitaker, 2001). Our study aims to provide an estimate of longevity, and baseline data on population structure, habitat use, morphometrics and reproduction of *H. stephensi.*

Materials and methods

Stephens Island (40°35'S 173°55'E) is a 150 ha Nature Reserve located at the northern tip of the Marlborough Sounds, Cook Strait. Two surveys were carried out for *H. stephensi* on Stephens Island. The first survey was conducted by AC from 01 February to 11 March 1990. The second, by KMH, was from 29 October to 8 December 2002. The 1990 study was undertaken to determine whether *H. stephensi* preferentially used the invasive weed *Tradescantia fluminensis* as habitat, prior to control of the weed (Cree, 1990,1992).

During the 1990 study, the distribution and range of habitats of *H. stephensi* was estimated by 1) repeated spotlight searching over several nights in study plots of 10×10 m in three habitat types (mature forest, *T. fluminensis* and vinelands), 2) timed spotlight searches at night in areas outside the study plots (Table 1), and 3) daytime searches under debris and *T. fluminensis* within mature forest (Keepers Bush).

Some habitat types searched in 1990 were unavailable for searching in 2002. For example, access was not permitted to the southern end of the island including inner Ruston Bush and the Frog Bank. Also, *T. fluminensis* was greatly reduced after the 1990 study (very few *H. stephensi* were present in this vegetation). During the 2002 study, animals were located by spotlighting along forest margins or forest tracks at night, or searching under debris within mature forest during the day (Keepers Bush). Only forest margins and tracks were searched at night as the 2002 search season was during spring when sea birds (e.g. *Pachyptila turtur*) nest in the forest, and it is very difficult to move under the canopy at night without breaking burrows and possibly burying chicks alive.

To minimise habitat disturbance during spotlighting, only geckos readily seen on exposed surfaces were recorded. Captured animals were given permanent, individual marks by clipping three toes (1990), or temporarily marked with a number on the ventral surface (2002). Sex, and size measurements (snout-vent length (SVL), vent-tail length (VTL), regeneration (R)±1 mm, and mass±0.1 g) were recorded. Reproductive status of females was also recorded, including pregnancy status (yes/no) and number of embryos felt by abdominal palpation (Cree, 1990; see Cree and Guillette, 1995 and Wilson and Cree, 2003 for information on accuracy of this procedure in other New Zealand geckos).

Morphometric data from 1990 and 2002 were pooled and analysed using the statistics programme SAS (Version 6.21). All data were tested for normality, and statistical significance was assumed at $P < 0.05$. Data are expressed as mean±1 SE.

Longevity was estimated using recapture data of permanently marked individuals over the two trips. We analysed whether size is sexually dimorphic in *H. stephensi* by assessing the differences in SVL between all adult males and females using a general linear model (GLM) with sex as the independent factor and SVL as the dependent variable. Mass was also compared between sexes, with SVL as a covariate. Similarly we tested whether reproduction is size-related in females by determining whether pregnant females were larger (SVL) than non-pregnant females using a GLM, with reproductive status as the independent factor and SVL as the dependent variable. We analysed whether tail loss as an adult is significantly different between the sexes using Chi-squared (χ^2) analysis.

Results

The overall capture rate of *H. stephensi* at night was 0.52 geckos/person hour in 1990 and 0.46 geckos/person hour in 2002. A total of 40 *H. stephensi* were seen during the 1990 search, and 33 captured. In 2002, 19 individuals were seen and captured. Recruitment into the population was evident in both studies by capture of juveniles (Table 2), with juveniles accounting for 18% of the total captured population in 1990 and 5% in 2002.

In 1990 and 2002 all animals were found between 0.1 and 3.5 m above the ground. The maximum height of vegetation varied in different habitats: vine land about 2.5 m, *T. fluminensis* 1 m and mature bush 6 m. The slopes of Stephens Island between the cliffs and summit were once covered by dense native forest, but lighthouse operations since 1892 led to the loss of around 90% of the original forest (Diffenbach, 1843; Walls, 1983). In 1990 vegetation cover was estimated

using a planimeter from an aerial photograph of Stephens Island taken in 1989; mature forest covered 5.5 ha with Ruston Bush 3 ha, Keepers Bush 2 ha and the Frog Bank Bush 0.2 ha (Cree, 1990). In 2002 vegetation cover was estimated using the computer programme AutoCad. Intensive regeneration efforts since 1990 meant that mature and 10+ year regenerating forest covered approximately 21.6 ha with Ruston Bush extending to 4.8 ha and Keepers Bush 2.5 ha. Search effort (person hours) was not equal over all the available habitat types due to access restrictions. More time was spent searching the edges of forests than the interior. Therefore, capture rate (geckos/person hour) was estimated for each vegetation type (Table 1).

In 1990, *H. stephensi* were predominantly located on *Muehlenbeckia australis* ($n = 22$), or on mature trees or low vegetation that were partly overgrown by, or within 2 m of, *M. australis* ($n = 15$). A few animals ($n = 3$) were found on *T. fluminensis* (Table 1). No animals were found under debris during day searches, on *M. complexa,* or in mixed vine vegetation along the eastern cliff edges. In 2002, most individuals were found on *M. australis* or on mature trees or low vegetation associated with *M. australis* ($n = 12$). However, four were also found in regenerating forest on flaxes (*Phormium cookianum*) over 10 m from *M. australis* (Table 1). Three animals were found under large piles of nikau palm (*Rhopalostylis sapida*) leaves during day searches (capture rate = 0.5 geckos/person hour). No animals were found under any other type of debris, or on *M. complexa.*

Mature geckos ranged in size from 60 mm SVL to 81 mm SVL (Table 3). There was no difference in SVL between pregnant and non-pregnant females ($F_{1, 19} = 3.72$, $P = 0.07$) or between the sexes ($F_{1, 42} = 1.00$, $P = 0.32$). Pregnant females were significantly heavier for their length than non-pregnant females or males ($F_{2, 50} = 12.94$, $P < 0.01$). Males were significantly heavier for their length than non-pregnant females ($F_{2, 34} = 68.59$, $P < 0.01$). The frequency of tail loss for this species was 43% of the captured population. Tail loss was not significantly different for adult males and females ($\chi^2_1 = 0.77$, $P < 0.01$). The sex ratio of the adult population is approximately 1:1 male:female, with males making up 52% of the adult population (Table 2). Of the 11 adult females caught in summer 1990 only four were pregnant (36%), and by palpation it was determined that three carried two embryos and one probably carried one embryo. Of the 10 adult females caught in spring 2002 only three were pregnant (30%) with two embryos each. Thus, the annual reproductive output for *H. stephensi* is 0.62 offspring/female/yr.

One male marked as an adult in 1990 was recaptured in 2002 within 5 m of the original capture site. Age in relation to SVL could not be estimated directly for *H. stephensi* due to the low number of recaptures. However, assuming that *H. stephensi* has a life history comparable to the similar sized *H. maculatus* (Anastasiadis and Whitaker, 1987), conservatively the male was at least 4 years old at first capture, and thus a minimum of 16 years old when recaptured. The recaptured animal had lost its tail between captures,

Table 1. Search intensity (number of person-hours) and capture rate (geckos observed/person-hour) of *H. stephensi* during night searches of some habitat types on Stephens Island during summer 1990 and spring 2002. Value ±1 S.E.

Habitat type		1990		2002	
		person-hours	geckos per hour	person-hours	geckos per hour
Forest	Frog Bank	1.5	0	-	-
	Keepers (tracks)	-	-	10.0	0.2
Forest margins (fence lines)	Southern Ruston	8.0	0.9	8.0	0.9
	Eastern Keepers	-	-	1.0	0
	Northern Keepers	-	-	9.0	0.3
	Regenerated (Ruston)	-	-	4.5	0.9
Plots	Forest[1] ($n = 3$)	9.9	0	-	-
	M. australis[2] ($n = 3$)	15.6	0.6±0.4	-	-
	T. fluminensis[3] ($n = 2$)	5.6	0.1±0.1	-	-
Vineland	*M. australis*[4]	4.0	0.5	-	-
	M. complexa[5]	4.0	0	1.0	0
	Mixture of two[6]	5.0	0	-	-
Wooden shed and overgrown gardens in Keepers[7]		3.0	0	1.5	0

[1]Two plots in Ruston and one in Keepers; [2]Southern Ruston; [3]Keepers Bush; [4]North-east of radar station; [5]Track to radar station; [6]Above Queens and Landing Beaches; [7]Includes only overgrown gardens for 2002 searches

Table 2. Number of *H. stephensi* individuals captured on Stephens Island during summer 1990 and spring 2002. np = not pregnant, p = pregnant, * = including one recaptured individual, toe-clipped in 1990

		1990	2002	Total
Female	p	4	3	7
	np	7	7	14
Male		16	8*	23
Immature		6	1	7

Table 3. Mean (± 1 s.e.) snout-vent length (SVL) and body mass of *H. stephensi* captured on Stephens Island during summer 1990 and spring 2002; np = not pregnant, p = pregnant,

			SVL (mm)		Mass (g)	
		n	Mean ± SE	Range	Mean ± SE	Range
Female	p	7	75.4 ± 1.1	72–81	11.4 ± 0.6	9.6–13.5
	np	14	71.3 ± 1.4	60–78	7.9 ± 0.5	4.4–11
Male		23	74.0 ± 2.0	60–80	9.6 ± 1.2	5.8–12.3
Immature		7	54.0 ± 2.3	44–60	4.2 ± 0.5	2.0–5.0

but the SVL (76 mm) was only 1 mm different from the original measurement (75 mm). Three other individuals captured in 2002 had some missing toes (maximum of two missing), but these were from natural toe loss.

Discussion

Habitat use by *H. stephensi* in 1990 and 2002 was similar, with the highest capture rates from the forest margins of Ruston Bush. Most captures were also made on vegetation associated with *M. australis* and during night searches. However, it does appear that *H. stephensi* is occupying more habitat as it becomes available in the form of regenerating forest. Perhaps the concentration of *H. stephensi* in vegetation associated with *M. australis* is simply a reflection of the fact that, for many years, the largest continuous area of vegetation on Stephens Island was Ruston Bush plus the surrounding vinelands.

The higher capture rate of *H. stephensi* in vegetation associated with *M. australis* and Ruston Bush margins could also be due to the physical structure of the habitats. Most trees in Ruston Bush have associated *M. australis* vines. Also, *H. stephensi* may be underestimated in the canopy. Forest margins are easier to search than the tree canopy, and the vinelands reached a maximum of 2.5 m in height, which enabled most vineland areas to be effectively searched. The forest canopy is substantially higher and more difficult to search effectively. However, the edges of Keepers Bush were also searched, and had relatively low capture rates of *H. stephensi* compared with Ruston Bush forest margins. Again, Keepers Bush margins have fewer vines associated with the vegetation.

The sex ratio of *H. stephensi* on Stephens Island is 1:1 male:female and the minimum size at maturity is likely to be 60 mm SVL, as the smallest sexually mature individuals of both sexes captured were this size. Several other *Hoplodactylus* species or populations are also sexually mature at around 60 mm SVL, e.g. *H. maculatus* from Motunau Island, Canterbury, is sexually mature at 61.5 mm SVL (Bannock *et al.*, 1999) and *H. chrysosireticus* at 60 mm SVL (Flannagan, 2000). There was no apparent difference between the sexes of *H. stephensi* for SVL at maturity. In other species of *Hoplodactylus* differences in SVL between the sexes at sexual maturity are minor. For example, *H. duvaucelii* females mature at 95 mm SVL, whereas the males mature at 98 mm SVL (Barwick, 1982).

There is no sexual size dimorphism in SVL in *H. stephensi*, the mean adult SVL being 74.2 mm (± 0.6). However, there is sexual dimorphism in shape, with mass relative to SVL significantly greater in adult males than in non-pregnant females. This trend is apparent in another New Zealand reptile, *Sphenodon guntheri*, where females (gravid and non-gravid combined) also have a much lower mass relative to SVL than males (Hoare, 2002). Differences in shape could be due to females expending more energy on reproduction than males. Males also have a bulkier body shape and a proportionally wider head than females (Cree, 1990).

Clutch size in *H. stephensi* is the same as in other

New Zealand viviparous geckos, i.e. one or two offspring (Cree, 1994). The low pregnancy rate of female *H. stephensi* captured in 1990 and 2002 suggests a low reproductive output for this species of around 0.62 offspring/female/yr, which is a trait found in other New Zealand geckos. For example, the annual reproductive output of *H. maculatus* at Macraes is 0.85 offspring/female/yr (Cree, 1994; Cree and Guillette, 1995), and of *Naultinus manukanus* on Stephens Island is 1.28 offspring/female/yr (Hitchmough, 1978; Cree, 1994). This is very low when compared with the annual reproductive output of (oviparous) geckos worldwide, which range from 2 to ≥ 4 offspring/female/yr (Cree, 1994).

Our research demonstrates the value of having marked populations available for long-term study by different researchers and adds another species to a growing list of New Zealand *Hoplodactylus* with extreme longevity in the wild. The recaptured male was found at virtually the same location at which it was first marked, suggesting strong site fidelity, comparable with *H. chrysosireticus*, *H. duvaucelii* and *H. maculatus* (Whitaker, 1982; Thompson *et al.*, 1992; Bannock *et al.*, 1999; Flannagan, 2000).

Toe clipping has been a valuable permanent identification tool for long-term studies of New Zealand geckos (Anastasiadis and Whitaker, 1987; Thompson *et al.*, 1992; Cree, 1994, Bannock *et al.*, 1999; Green, 2001) and does not appear to affect locomotor performance or survival in several lizard species elsewhere (Petren and Case, 1996; Paulissen and Meyer, 2000; Borges-Landáez and Shine, 2003). For example, toe clipping of the arboreal gecko *Hemidactylus turcicus* did not lessen individual climbing ability compared with non-toe clipped individuals (Paulissen and Meyer, 2000). However, natural toe loss can occur, so to minimise misidentification of individuals we recommend that at least three toes be marked.

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