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# THE HERPETOLOGICAL BULLETIN

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**Editorial note.** We are trying to introduce a "new look" to the BHS Bulletin, and one of our plans is to commission articles by well-known zoologists summarising recent advances in their area of expertise, as they relate to herpetology. We are particularly pleased that Professor McNeill Alexander of Leeds University agreed to write the first of these. We hope that this masterly summary of "Locomotion of Reptiles" will be of interest to a wide range of readers. *Roger Meek and Roger Avery, Co-Editors.*

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### Locomotion of Reptiles

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**ABSTRACT** – Reptiles run, crawl, climb, jump, glide and swim. Exceptional species run on the surface of water or “swim” through dry sand. This paper is a short summary of current knowledge of all these modes of reptilian locomotion. Most of the examples refer to lizards or snakes, but chelonians and crocodilians are discussed briefly. Extinct reptiles are omitted. References are given to scientific papers that provide more detailed information.

#### INTRODUCTION

This review is an attempt to explain briefly the many different modes of locomotion that reptiles use. Some of the information it gives has been known for many years, but many of the details have been established only in the present century, as the dates of many of the papers in the References indicate. Readers who want more technical detail may find it in Alexander (2003) or (especially for more recent advances) in the papers referred to in the text.

#### Running

Lizards running quadrupedally generally move diagonally opposite feet simultaneously; the left fore foot with the right hind, and the right fore with the left hind. Figure 1 represents a single step in which the right fore and left hind feet remain stationary on the ground while the left fore and right hind move forward. At the same time the bend in the body is reversed. The feet are moved forward partly by movements of the shoulder, hip and other leg joints; and partly by the bending of the back. Figure 1 emphasises the role of the back. Running is powered partly by the leg muscles and partly by the back muscles.

Lizards stand and run with their feet well out to either side of the body. Consequently, bigger forces are needed in their leg muscles than if the legs functioned like pillars, with the feet under

the body and the leg joints much straighter, as in elephants. The bigger an animal is, the harder it is for them to support the weight of the body in a lizard-like stance. Imagine two reptiles of exactly the same shape, one twice as long as the other. It would be twice as long, twice as wide and twice as high, so eight times as heavy. Its muscles, however, would have only four times the cross-sectional area, so could exert only four times as much force. If the larger animal were made progressively bigger, it would eventually reach a point at which its leg muscles could no longer support it. Large dinosaurs could not have stood like lizards, and accordingly stood like elephants. Fossil footprints show that they placed their feet under the body, not out to the side.

Muscles can deliver more power when they are warm than when they are cold. Reptiles are perceived as “cold blooded”, so you might expect them to be rather sluggish. Their body temperatures fall at night, but (in favourable climates) can be raised rapidly in the morning by basking in the sun. In one study, the body temperatures of the lizard *Amphibolurus* (= *Pogona*) in its natural habitat in Australia were found to be about 25°C when they emerged in the mornings, but rose rapidly in the sun to about 37°C, the body temperature of a typical mammal (Bradshaw & Main, 1968). We should not be surprised that warm lizards can sprint at about the same maximum speeds as mammals



**Figure 1.** A diagram of a lizard taking a step, showing how bending the body contributes to the length of the step.

of equal mass; for example, Bonine & Garland (1999) recorded a 16 gram *Cnemidophorus* (= *Aspidiscelis*) sprinting at 6 metres per second, which is faster than most measurements of maximum sprint speeds for mammals of similar mass. Lizards also compare well with mammals for economy of energy in running; the extra energy needed to run unit distance, over and above resting energy consumption, is about the same for lizards as for mammals of equal mass (Figure 7 in Full & Tu, 1991).

Many lizards rise up on their hind legs when they run fast. This seems to be an inevitable consequence of high acceleration. If a motorcyclist accelerates violently, he or she does a wheelie; the front wheel rises off the ground. The principle is the same for lizards, and is particularly effective for them because their long tails bring the centre of mass of the body well back, close to the hind legs. The effect ends when the animal stops accelerating (Clemente et al., 2008).

Muscles that can contract fast use more energy than those that can contract only slowly. Tortoises can withdraw into their carapaces, so do not have to run away from predators. Nor do they have to pursue prey. They have no need to run, and have evolved remarkably slow, remarkably economical muscles. They walk very slowly and wobble a lot, pitching and rolling as they go; their muscles are too slow either to keep the body constantly in equilibrium, or to correct a wobble quickly. They minimise the problem by using a different gait from other reptiles, moving diagonally opposite feet a little out of phase with each other (Jayes & Alexander, 1980).

Crocodiles use several gaits. They slither down slopes such as river banks on their bellies. In addition to more-or-less lizard-like walking, with their feet on either side of the body, they use a “high walk” with their legs straighter and their feet closer under the body. Their fastest gait is the “gallop”,

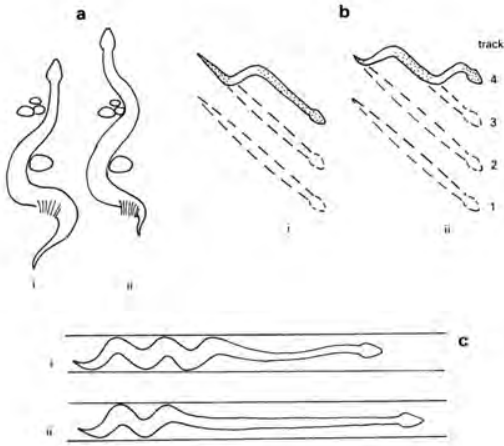
which is more like the bounding gait of rabbits than the gallops of horses and dogs. Speeds up to about 5 metres per second have been measured (Webb & Gans, 1982).

### *Crawling without legs*

Figure 2 shows three crawling techniques used by snakes. In serpentine crawling (a) the snake passes waves of bending backwards along its body. If the snake is weaving its way between stones, tussocks of grass and other obstacles, these will tend to prevent the snake’s body from sliding sideways, and each point on the body will move forward along the path that more anterior parts have already travelled. The waves will stay where they are while the body moves forward. Fixed obstacles such as stones are not, however, essential for crawling. The ventral surfaces of snakes have different coefficients of friction for sliding in different directions; low for sliding forward along the body axis, higher for backward axial sliding, and higher still for sliding at right angles to the body axis. Thus a segment of the body can slide more easily forward along the body axis, than laterally. Also, crawling snakes raise the curved parts of the body slightly off the ground. These circumstances enable snakes to crawl on flat surfaces with a moderate degree of roughness, but not on highly polished surfaces (Hu et al., 2009).

Thus lateral bending of the back is important both in the serpentine locomotion of snakes and in the running of lizards. In both cases the body is thrown into more-or-less sinusoidal waves, but there is a very significant difference: snakes use waves that travel backwards along the body, but in lizards the bends are always at the same points on the body. Serpentine locomotion depends on travelling waves and lizard running on standing waves. Legless lizards, however, use travelling waves to crawl like snakes.

Figure 2(b) shows sidewinding, a crawling technique used (for example) by rattlesnakes that works well even on loose sand. As in serpentine crawling, waves of bending form at the front end of the body and travel backwards along the body. Only the stippled parts of the body are on the ground. Each part of the body is stationary while on the ground, but is periodically lifted to a new



**Figure 2.** Diagrams of snakes crawling. (a) Serpentine locomotion; (b) sidewinding and (c) concertina locomotion. From R. McN. Alexander (1982) *Locomotion of Animals*, Blackie, Glasgow.

position. This action leaves a series of straight, parallel tracks in the sand. Sidewinding seems to be the most economical of energy of the three crawling techniques illustrated in Figure 2 (Secor et al., 1992).

Figure 2(c) shows concertina locomotion, which is effective in crevices. At any moment, short sections of the body are folded, tightly jammed against the sides of the crevice. The anterior fold of each group opens, pushing the parts of the body in front of it forwards. At the same time, new folds are added to the back of the group, drawing more posterior parts of the body forward.

Boas sometimes travel by rectilinear locomotion which, unlike the other techniques, does not involve bending of the body. Waves of rib movement move backwards along the body, shuffling the snake along.

No snake travels fast. The black racer (*Coluber constrictor*) has a reputation for speed, but its maximum sprinting speed has been recorded as only 1.5 metres per second (Bonine & Garland, 1999).

### **Climbing**

Concertina locomotion enables snakes to climb vertical rock crevices and grooves in the trunks of trees. The folds of the body press strongly against the walls of a crevice, to secure a frictional grip to

prevent falling. In addition, the ventral scales may be raised so as to increase the frictional resistance against downward sliding (Marvi & Hu, 2012). A form of concertina locomotion is also used to crawl along slender branches. The folds of the body zigzag across the upper surface of the branch, and occasionally wrap right round it (Astley & Jayne, 2007). To bridge gaps between branches, a large proportion of the length of the body may have to be extended as a cantilever, and large forces may be needed in muscles to prevent it from sagging. Small snakes can bridge the widest gaps relative to body length (Jayne & Riley, 2012).

Lizards on slender branches cannot adopt the sprawling posture used on broad substrates, but must keep their feet under the body to grip the branch. Chameleons, which spend much of their time on slender branches, keep their feet constantly under the body, not out to the side. On broad supports that they cannot grasp, Malagasy dwarf chameleons (*Brookesia*) steady themselves by resting the tail on the substrate (Boistel et al., 2010).

Geckos have strongly adhesive feet that enable them to climb smooth vertical walls. They adhere by means of van der Waals forces (forces of intermolecular attraction) that depend on very close contact with the substrate. The close contact required is obtained by having the soles of the feet covered by a carpet-like pile of setae so fine that they can be seen only by electron microscopy. Though the feet adhere so strongly, the lizard can easily detach them from the wall that is being climbed, by peeling them off like medical adhesive plasters (Autumn et al., 2000).

### **Jumping**

Some lizards make quite impressive jumps. For a satisfactory landing, the body must be at an appropriate angle to the horizontal at the end of the jump. Lizards use tail movements to achieve this (Libby et al., 2012). This depends on the Principle of Conservation of Angular Momentum, the principle that enables divers to initiate manoeuvres such as somersaults in mid-air. Rotation of the lizard's tail or the diver's limbs in one direction, makes the body rotate in the opposite direction. Lizards whose tails had been removed did not

make satisfactory landings when they jumped. If a climbing gecko falls, it uses mid-air tail movements to ensure that it lands right way up (Jusufi et al., 2008).

Arboreal lizards may jump between flexible branches. It might be imagined that the elasticity of the take-off branch might make longer jumps possible, by functioning like a springboard. This is not the case because branches do not generally recoil quickly enough to assist the lizard's takeoff. Lizards can jump further from rigid supports, than from compliant branches (Gilman et al., 2012).

### **Gliding**

Lizards of the genus *Draco* live in forests in India and SE Asia. They travel from tree to tree by gliding, using flaps of skin supported by extensions of their ribs as wings. These are spread while the lizard is gliding; but folded like fans, against the sides of the body, while it is climbing a tree. *Draco* also have smaller wing-like structures on either side of the throat. A glide starts with a steep dive, in which the lizard gathers speed, then flattens out a bit as increasing speed enables the wings to generate more aerodynamic lift. Finally, the lizard may veer upward again to reduce its speed before landing. McGuire & Dudley (2005) induced *Draco* of various species to glide between two poles 9.3 metres apart. In the best of many trials, the angle of descent from the take-off point on one pole to the landing point on the other was 15°. This performance is poor, compared with birds; for example, the minimum equilibrium glide angle of common swifts is 5° (calculated from the maximum lift-drag ratio given by Henningsson & Hedenström, 2011). This comparison is admittedly not a fair one, and may be misleading, as the angle given for swifts referred to equilibrium gliding, not a glide between perches. The ability of *Draco* to land on a target perch shows that it has good control of its glide.

Amazingly, snakes of the genus *Chrysopelea* also glide from tree to tree or tree to ground, in S and SE Asia. As the snake takes off, it flattens its body and performs high-amplitude lateral undulations. After an initial steep dive the angle of descent decreases. The minimum recorded glide angle in the later part of a glide is 13° (Socha,

2011).

### **Swimming**

Snakes swim like eels (but with their snouts above the water), and crocodiles also swim by undulating their bodies. Marine turtles have legs modified as flippers, and swim by flapping them much as a flying bird flaps its wings. This seems to be more efficient, than if the flippers were used like oars. Some turtles can swim quite fast, for example a young *Chelonia mydas* with a carapace only 11cm long swam at a maximum speed of 1.4 metres per second (Davenport et al., 1984).

### **Running on water**

Tropical American lizards of the genus *Basiliscus* can run short distances on their hind legs, on the surface of water. They slap their large feet down on the water at high velocity. This supports them by a combination of three effects. First, the initial slap accelerates a substantial mass of water downwards and so gives rise to an upward reaction on the body. Secondly, upward hydrodynamic drag acts on the foot as it moves down into the water. And thirdly, the foot makes a temporary air-filled hole in the water, which is not re-filled until the foot is withdrawn. While the foot is in the hole, its upper surface is exposed only to atmospheric pressure, while its lower surface is exposed in addition to hydrostatic pressure (Glasheen & McMahon, 1996).

### **“Swimming” through sand**

*Scincus scincus*, a desert lizard, buries itself and “swims” in dry sand. While it is submerged in the sand, it is of course hidden from view. Baumgartner et al. (2008) used nuclear magnetic resonance imaging to study *Scincus* moving through desert sand. They observed waves of bending travelling backwards along the body, accompanied by leg movements like those of running lizards. They suggested that the lizard's movements caused decompaction of the sand around it, making the sand behave like a viscous liquid. This would help to explain the lizard's ability to travel quite fast through the sand, at up to 0.3 metres per second. In another investigation, Maladen et al., (2009) used X-ray imaging to film *Scincus* “swimming” through fake sand made of glass particles. They found that the lizards' legs were folded flat against



their sides while waves of bending travelled backwards along the body. I am unable to explain why one group found that leg movements were used while the other found that they were not.

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## Decline and flounder of a Sussex common toad (*Bufo bufo*) population

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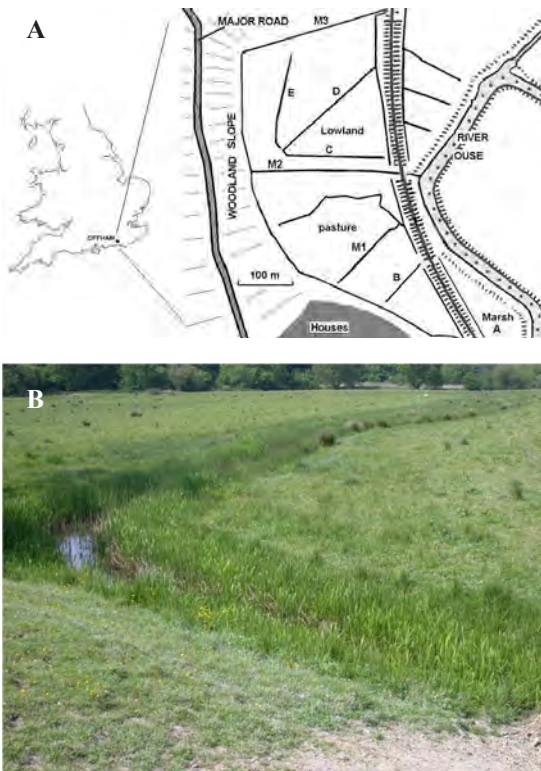
**ABSTRACT** - Common toads *Bufo bufo* have declined over much of southern and eastern England in recent decades where other widespread amphibian species have remained relatively stable. One such toad decline, at Offham marshes in Sussex, was investigated over the fifteen year period 1998-2012 immediately subsequent to a tenfold decrease in population size between 1989 and 1997. Syntopic amphibians (*Rana temporaria*, *Lissotriton vulgaris* and *L. helveticus*) probably also declined at this site. The surviving toad population continued to recruit new cohorts and had an apparently healthy age structure. Habitat quality (aquatic and terrestrial) remained good and there was no evidence of disease. An invasive species (*Pelophylax ridibundus*) was excluded as a likely cause of toad decline. However, traffic on a neighbouring road rendered more than half the previously available terrestrial habitat for toads essentially unreachable. Furthermore, reduced management of vegetation in ditches where the toads breed apparently increased mortality of developing tadpoles. Future prospects for conserving and increasing the toad population are discussed.

### INTRODUCTION

Common toads *Bufo bufo* and other widespread amphibians declined substantially in Britain during the mid 20th century primarily as a result of agricultural intensification (Cooke, 1972). Comparable trends were later identified across much of Europe (Houlahan et al., 2000). The status of *B. bufo* has continued to deteriorate, especially in eastern England (Carrier & Beebee, 2003) and similar declines have been noticed elsewhere (e.g. in northern Italy, Bonardi et al., 2011). Because of this ongoing decrease, common toads were added as a priority species to the UK Biodiversity Action Plan in 2007.

At Offham marshes in Sussex (Figure 1; also known as 'The Pells') common toad numbers have fallen dramatically. The area was scheduled as a Site of Special Scientific Interest (SSSI) in the late 1980s on account of its amphibian community which included a large population of *B. bufo* as well as substantial numbers of common frogs *R. temporaria*, smooth and palmate newts *Lissotriton*

*vulgaris* and *L. helveticus* (Banks 1987; 1988). Marsh frogs *Pelophylax ridibundus* subsequently invaded the area from an established population south of Lewes (Beebee, 1977). Toads at Offham breed in drainage ditches and many migrate to the site from woodland to the west, across a major road (A275) that has generated heavy mortality. A 'toad patrol' volunteer group formerly moved animals across this highway and accounts from this team during the early 1990s identified rapidly decreasing toad numbers. By the late 1990s there were too few to warrant retention of the patrol which was therefore disbanded. Unfortunately during this period there were no estimates of toad numbers breeding on the marshes. However, when the problem was appreciated efforts began to assess the toad population size annually and investigate possible causes of, and solutions to, the problems afflicting it. This paper reports the results of these investigations over the fifteen year period 1998-2012 inclusive.



**Figure 1.** Offham marshes. Figure A: Site location. Marsh A = main *Rana temporaria* breeding area; — = ditches; B – E = main *Bufo bufo* spawning sites; M1-M3, minor/occasional *B. bufo* spawning sites. ‡ = Railway line on raised embankment. Figure B: *B. bufo* breeding ditch (E).

## METHODS

### *The study site*

Offham marshes consist of approximately 200 ha low-lying fields intersected by numerous drainage ditches (Figure 1) which have a sporadic history of dredging to keep them open (see Results section). The north (ditches C, D, E), central (M1 area) and south (Marsh A, ditch B) parts of the marshes have separate owners but all three graze the pasture intermittently from April through to October, mostly with cattle. Management history of the area was provided by these landowners. The ditches are floristically and faunistically rich with abundant growths of water violet *Hottonia palustris* and invertebrates including great silver beetles *Hydrophilus piceus*. All the ditches support fish, including three- and ten-spined sticklebacks

(*Gasterosteus aculeatus* and *Pungitius pungitius*).

An assessment of terrestrial habitat structure and its suitability for use by *B. bufo* (Bardsley, 1998) was carried out by Dr L. Bardsley in 1998. Areas up to about 1.5 km west of the marshes (altogether >1.5 km<sup>2</sup>) were investigated on the basis of four key habitat criteria each ranked from 1 (poor) to 5 (very good): (1) Herb and ground-layer flora using the DAFOR scale, quantified in 5 x 1 m<sup>2</sup> quadrats per 100 x 100 m habitat section. Large trees and shrubs were counted in 25 x 25 m quadrats with 100 m between each. Poor habitat (grade 1) included heavily grazed pasture while very good habitat (grade 5) included long rank grassland with a litter component. (2) Number of refugia, specifically of dry stone walls, fallen logs, animal burrows and hummocks of grass litter per 25 x 25 m area. Grade 1 was <5, grade 2 was >25. (3) Soil moisture content, measured in the top 2 cm of soil every 10-20 m using a 'Rapidtest' monitor; grades were from 1 (dry) to 5 (some standing water). (4) Slope, from grade 1 (very steep, 1 metre rise in <2 metres distance) to flat (<1 metre rise over 8 metres distance). Steep slopes on soil overlying chalk (as here) are prone to rapid desiccation in summer. Final scores summed those for the four criteria. Total scores of >16 were considered excellent, 12-16 of intermediate quality and <12 unlikely to support toads except briefly or during migrations.

### *Amphibian population monitoring*

Anecdotal information about toads at Offham prior to 1987 was obtained by correspondence with local people, in one case from as early as the 1920s. Numbers of all amphibian species on the marshes were assessed by Banks (1987; 1988) prior to SSSI designation by counting *R. temporaria* spawn clumps, *B. bufo* adults by torch at night and newts *L. vulgaris* and *L. helveticus* by netting ditches for a standard time (30 minutes). From 1998 onwards I estimated population sizes of *R. temporaria* by counting spawn clumps and *B. bufo* by counting adults assembling to breed. For *B. bufo* at least three counts were made over the course of each breeding season (usually early – mid March), spaced several days apart and always on warm, still nights following observations of

Year	<i>Rana temporaria</i>	<i>Pelophylax ridibundus</i>	<i>Lissotriton vulgaris</i>	<i>Lissotriton helveticus</i>
1987	105	1	49	45
1988	123			
1999	44	10s	17	6
2012	25	10s	13	4

**Table 1.** Amphibians other than *B. bufo* breeding at Offham. Empty space = no records

the first arrivals during preliminary visits. Ditches A – E as well as M2 and M3 were walked on each occasion. Use of ditch M1 and those east of the railway line was very rare so these were excluded from the study. The highest number of toads recorded over each season was taken as a relative estimate of population size. This method cannot estimate true population size because only a fraction of the numbers present is seen even on the peak night. A capture-mark-recapture (CMR) exercise in 2002 showed that the number of *B. bufo* estimated by this more rigorous approach (c. 1200) was approximately three times higher than the number (382) counted on the peak night (Brede & Beebe, 2006). However it was not practicable to carry out CMR studies every year and I have assumed that peak counts are sufficient to indicate relative changes in the toad population over time. This method is widely used in assessment of common toad populations (Gent & Gibson, 1998; Scribner et al., 2001).

Newt numbers were not estimated regularly but in 1999 and 2012 a netting survey was repeated exactly as described by Banks (1987). Marsh frogs were recorded when observed basking along ditch banks in summer. A study of ditch preferences by marsh frogs at Offham was undertaken over one summer (Macro, 2004).

Assessing tadpole survival was problematic in the complex array of drainage ditches. A combination of visual estimates in open water with, in some cases, CMR by tail-clipping was carried out by Dr J. Denton between 1998 and 2000, from April to June each year.

#### *Demography of Offham toads*

Forty one toads were caught and measured (snout-vent length) in 1998 by Dr L. Bardsley.

In 1999 single toe tips were taken (under Home Office licence) from the hind feet of 20 adult toads during the breeding season. The animals were released immediately afterwards. The age of each toad was established by Dr L. Bardsley using skeletochronology as described elsewhere (Hemelaar, 1983).

#### *Tracking adults and toadlets*

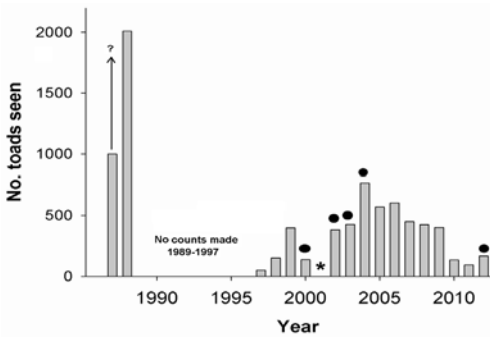
To investigate terrestrial habitat use by adults, eight male toads caught in ditch C in March 2000 were implanted abdominally with small (< 2g) radio-transmitters (Biotrack, Dorset) following anaesthesia (Denton & Beebe, 1993), all by Dr J.S. Denton under Home Office licence. The animals were allowed to recover for two days after surgery and then released at their site of capture. The toads were then relocated at approximately weekly intervals, during daytime and using a Yagi antenna, until the batteries expired around early/mid June. To investigate the fate of newly metamorphosed

Size range in mm (1998)	Number of individuals
51-60	2 (sex indeterminate)
>60-70	24 male, 3 female
>70-80	2 male, 4 female
>80	0 male, 6 female
Age (1999)	Number of individuals
3	2
4	10
5	7

**Table 2.** Size and age distributions of Offham toads, 1998-1999. The age of one individual could not be determined.

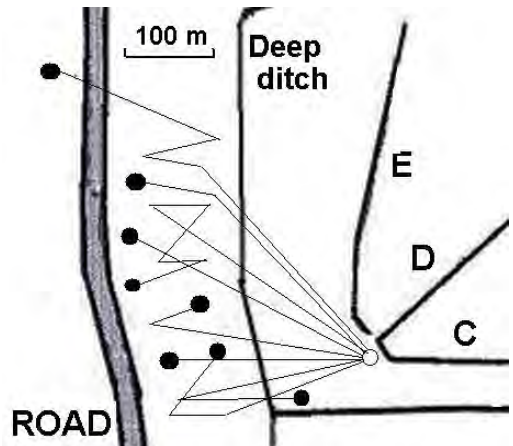
Year	Ditch			
	M2	C	E	M3
1998	-	10,700 (CMR May 7-8) 1,000s (May 27) 10s-100s toadlets (June 13)	-	-
1999	-	<30 (CMR May 15-16) No toadlets seen	-	6,000 (CMR May 15-16) 10s toadlets (June 11)
2000	100s (May 6) 1,000s (May 29) Few toadlets (June)	10,000s (May 6) Huge shoals (May 21) 1,000s toadlets (June)	10,000s (May 6) Huge shoals (May 21) Toadlets (June)	100s (May 6) 10s (May 29) Few toadlets

**Table 3.** Tadpole survival at Offham.



**Figure 2.** Toad numbers at Offham. Bars = Maximum count each year. Only a minimal estimate was available for 1987. \* = No counts possible due to foot and mouth disease outbreak. ● = Year in which ditch clearance occurred.

toadlets, eighty five roof tiles were placed along the margins of ditch C prior to toadlet emergence in June 2000 (Baynes, 2000). Ditch C supported many thousands of *B. bufo* tadpoles in that year. Nine pitfall traps (buckets) were installed, mainly around the eastern end of ditch C where most metamorphosis occurred and in the field corner near convergence of ditches C, D and E (Figure 1). When dispersal began, drift fences were used to generate nine x 20 m transects across the field north of ditch C at right angles to the main direction of toadlet movement. One square metre sampling



**Figure 3.** Movements of radiotracked toads, March – June 2000. O, point of leaving breeding site; ●, Last record.

areas at 5 m intervals along each transect were each searched for one minute to count toadlets, fifteen times between 0900 - 1200 hours every day from June 15 - June 30 and intermittently through July.

*Traffic density*

Information on traffic flow on the A275 between 1984 and 1996 was provided by Dr Alex Tait of East Sussex County Council.

Activity	North end (ditches C, D, E, M2, M3)	Central (including ditch M1)	South (including march A and ditch B)
Ditch management	5-year cycle, half ditch (longitudinal) each time	Once within previous 10 years	One operation within previous 10 years
Grazing (all April-September)	Mostly cattle, sometimes sheep	Cattle, occasional	Cattle
Chemical applications	Nitrogen fertiliser (small quantities) in April; occasional herbicide treatment of ditch dredging to control nettles	Nitrogen fertiliser applied annually, April-June. Occasional herbicides to control thistles & nettles	Very small amounts of nitrogen fertiliser (April). No herbicides used.

**Table 4.** Past management at Offham (pre-2000).

## RESULTS

### *Population dynamics and demography*

Trends in toad numbers at Offham are summarised in Figure 2. Anecdotal evidence indicated that the population was consistently high for decades prior to its first assessment in the late 1980s. Between 1988 and 1997 it apparently decreased from thousands to hundreds, in accord with reports from volunteers at the toad crossing. Since 1998 the population has remained small relative to pre-1990 but nevertheless fluctuated considerably, maximally up to more than 700 in 2004. No significant overall trend occurred between 1998 and 2012 ( $r_s = -0.134$ ,  $P = 0.649$ ). Because head-counting is an imprecise method small variations between years probably do not represent significant trends. On the other hand the very low count in 2011 was certainly real but may not reflect a change of population size. This was the driest spring ever recorded and some toads may have skipped a breeding season (Muths et al., 2006; Loman & Madsen, 2010).

In the late 1980s large numbers of toads assembled in most of the ditches shown in Figure 1. Ditches B, C/D and E were the most heavily used and in the late 1990s the pattern was broadly similar except that numbers were disproportionately reduced in ditch B relative to those further north. This pattern has persisted ever since.

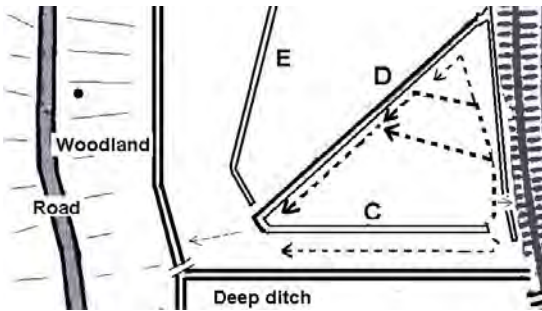
Table 1 summarises observations of other amphibians at Offham between 1987 and 2012. Since 1998 frog and newt counts have also been

lower than in the late 1980s but marsh frogs increased substantially commensurate with the toad decline.

It was important to discover whether the toads breeding in the late 1990s were constituted mostly by old animals, implying little recent reproductive success, or by a mixed-age population. Table 2 gives estimates of toad sizes and ages in the late 1990s. These indicated that by both criteria the surviving toads reflected a regularly recruiting set of overlapping cohorts (Gittins et al., 1985). Tadpoles were observed every year after 1998 and in every ditch where spawning took place though in most years no attempts were made to estimate numbers. However, reproductive success was assessed between 1998 and 2000 based on numbers of tadpoles in the ditches through the spring months (Table 3). The huge shoals seen in C and E in 2000 followed ditch clearances late in 1999 and produced many toadlets whereas highly vegetated ditches B and D supported few or no tadpoles through to metamorphosis.

### *Autecology of Offham toads*

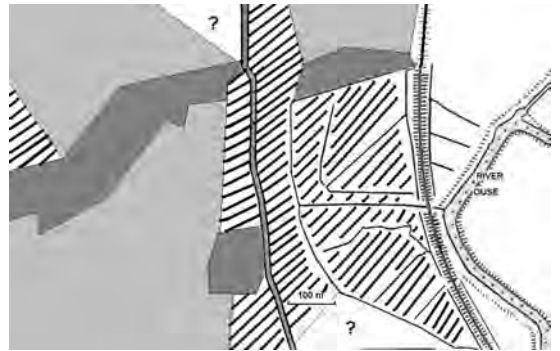
Evidently the Offham toad population was still breeding successfully in the late 1990s despite its recent size reduction. Further work was therefore carried out to investigate life history outside the breeding season. In the first instance I attempted to find out which habitats the animals selected in summer. Eight adult males implanted with radio



**Figure 4.** Toadlet movements after metamorphosis, summer (June) 2000. - - - - = Toadlet movements; arrow thickness proportional to numbers seen. ● = Last toadlet seen (August 8).

transmitters were tracked for about three months after leaving breeding ditch C in early March 2000. All the toads moved west into the steeply sloping woodland and remained within about 200 m of the ditch throughout the tracking period (Figure 3). Movement from April onwards was always over short distances and except for one individual which eventually returned to the field next to the ditches, the toads stayed in the woodland habitat. One animal crossed the road and ended up in the woodland immediately west of it. The toads were never directly encountered but were in refugia beneath ground vegetation (mostly ivy), under fallen trees or, in the case of the animal in the field, under thick grass.

It was also desirable to determine the fate of toadlets after metamorphosis as mortality can be very high at this life stage and influence overall population dynamics (Vonesh & De la Cruz, 2002). Mark Baynes followed a large cohort of toadlets (thousands) that metamorphosed from the eastern end of ditch C in June 2000. Very few moved east towards the railway bank, despite its proximity. The great majority moved west, either directly along the southern side of ditch C or along shallow, damp hollows towards ditch D after first migrating north parallel to the railway (Figure 4). Baynes (2000) also showed that the animals selected corridors of relatively high humidity (damp hollows with long grass) in preference to open, short-turf pasture. The overall directionality of movement was striking, with toadlets converging towards the woodland habitat also used by adults. A single well-grown



**Figure 5.** Terrestrial habitat at Offham. Dark grey = optimal, score >16; oblique black bars = intermediate quality, score 12-16; light grey = poor quality, score <12. ? = mostly urban areas, quality not known (but probably good). Areas east of the railway line were not assessed

toadlet was seen in the woods in August. Such directionality towards woodland has been noted in studies with other amphibians (Malmgren, 2002) but not, as far as I am aware, with *B. bufo*.

Terrestrial habitat within 1-2 km westwards from Offham was investigated in 1998. Results are shown in Figure 5. By the criteria applied, neighbouring woodland as well as the pasture surrounding the breeding ditches provided adequate habitat for common toads. There were, however, areas of higher quality habitat immediately to the north and also west of the woodland slope high on the downs. Overall there were about 500 ha of potentially suitable terrestrial habitat for *B. bufo* within 2 km west of the breeding ditches. The railway embankment might also be adequate but access for assessment was prohibited and no toads have been seen migrating in from that direction.

#### *Anthropogenic influences on toad population dynamics*

Road traffic is well-known as a cause of amphibian mortality and the daily pattern of use on the main A275 in 1996 is shown in Figure 6A. Vehicle numbers declined through the evening and early night when most toad migration occurred but nevertheless still averaged about 200 per hour. Somewhat surprisingly, traffic flow decreased by 20% over four years during the early 1990s simultaneous with the toad decline (Figure 6B).

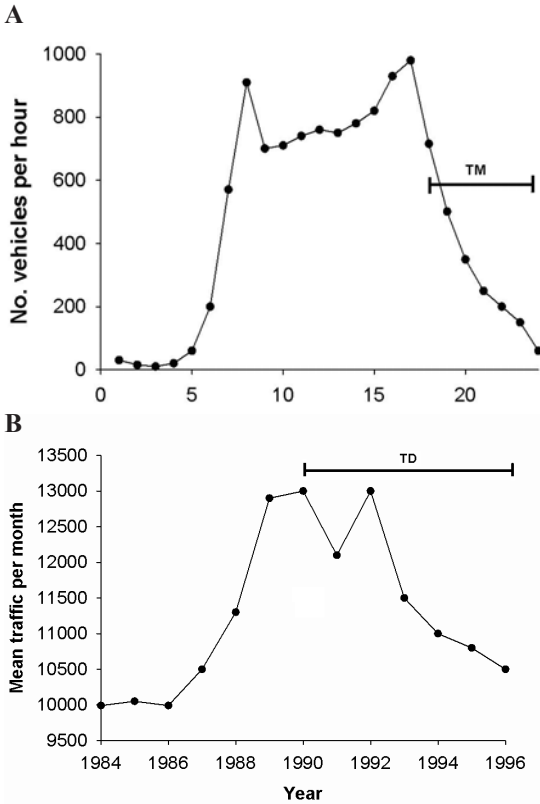


Figure 6. Traffic intensity on the main road (A275). A: Average traffic flow in relation to time of day, February – December inclusive, 1996. TM = Main period of toad migrations. B: Mean traffic (no. vehicles) per month, February and March combined, 1984-1996 inclusive. TD = Main period of toad population decline.

This was ascribed by the Local Authority to the newly opened Brighton by-pass diverting traffic that previously used the A275. However, immediately prior to this the traffic use rose steeply, by 30% within three years. It remains a very busy highway.

Another potentially important factor was land use and management by the site owners. Information on this subject was obtained from each of the three families involved in 1999 and is summarised in Table 4. All had grazed livestock on the pasture for decades past and there were no recent alterations in their minor applications of fertilisers or pesticides. Only with respect to ditch management was there evidence of change. Two of the three owners had carried out almost no dredging over the previous decade whereas the one at the north end, on the

advice of English Nature, had adopted a policy of half-clearing each ditch longitudinally every five years. Previous to that there was no specific information but in the past it was common practice for farmers to maintain clearance cycles whereby any one ditch would be dredged about every five years. Based on observations that toad tadpoles seemed to survive well in open water (i.e. in recently dredged ditches) but much less well in densely vegetated water, I recommended that the five-year cycle of ditch management was restored. This was agreed in principle but after implementation starting in 2000 the process was abandoned after a few years and only reinstated in 2012 (Figure 2). However, toad numbers increased for several years following restoration of ditch management in 2000 and decreased in subsequent years when management ceased. Assuming most toads matured at three or four years of age (Table 2), adults resulting from improved larval survival in dredged ditches should have peaked between 2003 and 2007. Average numbers counted in that period = 563 (SD = 136), more than twofold higher than mean counts between 2008 and 2012 (= 245, SD = 156), a highly significant difference (Wilcoxon signed rank test,  $U = 0, 25$ , exact  $P = 0.008$ ).

**DISCUSSION**

Common toads declined at Offham by an order of magnitude during the early 1990s when detailed monitoring was not in place. Since then the population has persisted but at a smaller size than in previous decades. The decline was not confined to toads. Other native amphibians (common frogs, smooth and palmate newts) probably also decreased although there are fewer data upon which to make this inference. No species disappeared and amphibian diversity actually increased with the appearance of marsh frogs at Offham. Various possible reasons for the toad decline are considered below.

*Climate change*

Reading (2007) showed that body condition, survival rates and fecundity of common toads at a pond in Dorset declined as a correlate of increasingly mild winters. He proposed that toad physiology requires a cold spell during hibernation



and that climate change was therefore a possible cause of population declines. Numbers of toads and therefore the actual rate of decline were not shown but the most dramatic effects on physiology occurred during the mid-late 1980s, after which there was little change. This time scale did not coincide with the main decline at Offham and although effects of climate cannot be discounted, other explanations seem more likely (see below).

#### *Habitat change*

Loss of and damage to habitats are well-known causes of amphibian declines (e.g. Beebee & Griffiths, 2005). However, habitat quality and extent did not change appreciably in the Offham area during or after the period of toad decline. Water quality in the ditches, as judged by other flora and fauna, has remained high and no amphibian mortality (such as might be induced by fertilisers or pesticides) has ever been seen. In 1998 there were at least 500 ha of good terrestrial habitat within the species' likely range. Much was beyond the top of a steep slope but toads have been found there and *B. bufo* can move to summer habitat 400 m higher than the breeding site (Sztatecsny & Schabetsberger, 2005). In mid Wales adult toad densities in terrestrial habitat were estimated at 23 per ha (Gittins et al., 1980). On that basis Offham could theoretically have supported more than 11,000 individuals although whether habitat qualities in the two areas are strictly comparable is not known.

#### *Disease*

No sick or dead amphibians have been reported at Offham, though this might have gone un-noticed during the poorly monitored period of main decline. Nevertheless, disease seems unlikely to have been an important factor. *Ranavirus* is common in south-east England but is more pathogenic to frogs (*R. temporaria*) than to toads (Teacher et al., 2010). Yet frogs survived at least as well as toads at Offham, as they have generally in south-east England (Carrier & Beebee, 2003). The fungus *Batrachochytrium dendrobatidis* (Bd) occurs in British *B. bufo* but not at Offham, where amphibians were tested for its presence in 2007 (Cunningham & Minting, 2008). Although this pathogen can kill common toads,

*B. bufo* expanded its range in part of Spain where Bd devastated *A. obstericans*, presumably due to relaxed competition (Bosch & Rincon, 2008).

#### *Displacement by invading marsh frogs*

*Pelophylax ridibundus* increased rapidly at Offham in the period commensurate with toad declines. This invader might oust native species, especially common frogs (Smith, 1951) but in Sussex this concern has not been borne out (Beebee, 1980). Toads breed before most marsh frogs emerge from hibernation. Adult marsh frogs remain in or close to water all summer and were not seen preying on toadlets by Baynes (2000). Stomach contents from three adult marsh frogs lavaged by J. Denton at Offham in July 1998 included fragments of alderfly and dragonfly larvae but no toadlets although these were in the immediate vicinity. *Pelophylax ridibundus* actively avoids toad tadpoles (Innocenzi, 1995). There is therefore no evidence to suggest that marsh frogs were responsible for the toad decline.

#### *Traffic mortality*

Toads often migrate long distances between summer and breeding habitats. They probably cross roads more often than other British amphibians and are potentially more vulnerable to traffic mortality. Large numbers have been killed on the A275 over many years, but could this account for the population decline? Although traffic intensity decreased on this highway during the early 1990s, in 1996 there was still an average of more than three vehicles per minute during the evening/early night peak migration times. Based on road mortality analysis of amphibians including *B. bufo* at a site in Denmark (Hels & Buchwald, 2001) this traffic intensity would kill more than 50% of toads attempting to cross the A275. Since adults must also make a return journey after breeding and toadlets face the same problem, the overall chances of a toad establishing a home range west of the A275 must now be less than 10%. Cooke (2011) demonstrated that falling numbers of toads killed on roads around three sites in Cambridgeshire between 1990 and 2010 correlated strongly with falling numbers turning up in the ponds. Furthermore, the rate of decrease in casualties

(reflecting the population decline) correlated with traffic flow across the various sections of road involved. Traffic intensity at Offham between 1990 and 1996 was similar to or higher than that estimated by Cooke in Cambridgeshire. It seems likely that traffic deaths have become sufficiently high at Offham to effectively cut off a high proportion of good quality summer habitat (Figure 1). If the surviving toads mostly use woodland below the road, as indicated by the radiotracking studies, a much reduced area of suitable habitat has become safely accessible. Thus the effect of the road may have been to kill most toads attempting to access good habitat to the west of it, and therefore be the primary driver of population decline. Numbers of dead toads on the A275 have never been counted even during the toad patrol years but, while corpses are still occasionally seen, they are few and imply little recent cross-road migration.

#### *Habitat management*

Although Offham habitats have remained generally good, a reduction in ditch clearance frequency has occurred (Table 1) and this probably affected the toad population adversely. *B. bufo* thrives in relatively large water bodies, especially where fish are present (Beebee, 1985; Laurila 1998). Their tadpoles are distasteful to most vertebrates but more vulnerable than those of frogs *R. temporaria* to invertebrate predators such as odonate larvae (Manteifel & Reshetnikov, 2002; Alavarez & Nicieza, 2009), probably because *Bufo* larvae are more continuously active (Chovanec, 1992). Clearance generates open water with fewer invertebrate predators than the dense vegetation of unmanaged ditches. Evidence that this has been important at Offham is both direct (larval mortality estimates, Table 3) and indirect. Toad declines in the area around ditch B were much more severe than in the northern area. In 1987-8, 22-25% of toads at Offham spawned in ditch B. After 1998 the proportion was never higher than 10% and usually much less (results not shown). However, ditch B is furthest from the main road and close to suburban gardens which are likely to be good toad habitat (Beebee, 1985). But it is in the southern area that ditch clearance decreased most markedly. Ditches C, D and E were still cleared

occasionally throughout the toad decline period, albeit longitudinally, a technique following which open water areas persist for a much shorter time than in the traditional full-dredging days.

#### *Future Conservation*

Of three possible causes of toad declines identified at Offham, two are intractable. Climate change is not amenable to any short-term or local action. Evidence that this could be a problem for *B. bufo* comes from a single site in Dorset (Reading, 2007). More research is needed to establish how serious this issue might be. The road will remain a major cause of mortality. *B. bufo* can be induced to use under-road tunnels (Lesbarreres et al., 2004) but construction and maintenance of a tunnel with the necessary associated fencing would be impossible (or at least extremely expensive) at Offham because of the very steep and densely vegetated slopes on both sides of the A275. Furthermore the well-drained chalk substrate west of the road is not amenable to constructing new ponds to sustain a population there, a solution which can work in some situations (Schlupp & Podlucky, 1994). However, restoring a regular cycle of ditch clearance in the historical tradition could increase the population to higher numbers than have been typical since the early 1990s. Evidence from recent clearances suggests that tadpole survival, and later adult population size, respond positively to this management which restarted in 2012. The Offham toads remain genetically diverse (Brede & Beebee 2006) and surely have the potential to increase above recent numbers if appropriate ditch management is reinstated and the existing good habitat is maintained.

Declines of *B. bufo* have been widely reported in southern England and it will be interesting to discover whether likely causes identified at Offham are more generally applicable. They are in accord with other evidence that road traffic mortality is playing an increasingly damaging role in reducing amphibian populations, especially of species such as *B. bufo* that regularly migrate over large distances between summer and breeding habitats. However, synergistic effects of two or more factors, as implied here, may be widespread in nature and it is clearly important to consider more

than single causes in complex situations such as alterations in population dynamics. The likelihood that other amphibians have also declined at Offham infers that other as yet unidentified factors might also have affected this apparently pristine site.

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# Behavioural repertoire and a new geographical record of the torrent frog *Hylodes cardosoi* (Anura: Hylodidae)

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There are 24 currently recognized species in the genus *Hylodes*, which are distributed into Atlantic Forest and some areas of Cerrado from the State of Espírito Santo to State of Rio Grande do Sul, Brazil (Lingnau et al., 2008; Frost, 2011). These frogs are diurnal and have a strict association with fast-water rock streams, where they call on rocks or falling trunks (Nascimento et al., 2001; Lingnau & Bastos, 2007; Silva & Benmaman, 2008). Commonly, the species of *Hylodes* exhibit two kinds of call: the advertisement call and the territorial call (“encounter call” by some authors) (Narvaes & Rodrigues, 2005; Hartmann et al., 2006; Lingnau & Bastos, 2007). In the genus, there appear to exist two main types of advertisement call and *H. cardosoi* and *H. dactylocinus* (both in the *nasus* group) present the more uncommon type, characterized by notes more spaced. The courtship and territorial defences involves a complex combination of sound and visual signals (Haddad & Giaretta, 1999; Hödl & Amézquita, 2001; Pavan et al., 2001; Wogel et al., 2004; Hartmann et al., 2005; Lingnau et al., 2008). According to Haddad & Prado (2005), species of *Hylodes* spawn in streams inside constructed subaquatic chambers.

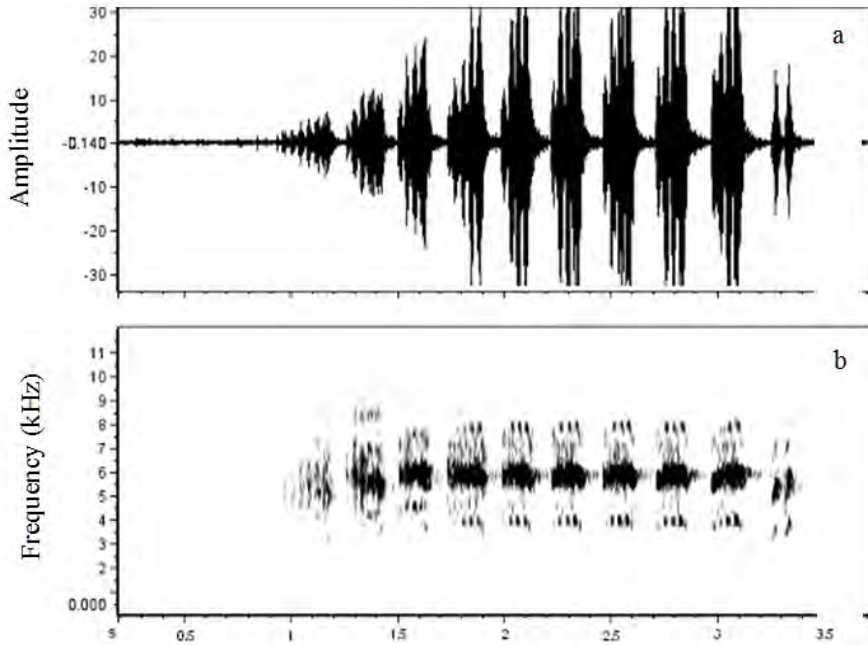
*H. cardosoi* (Lingnau et al., 2008) belongs to *H. nasus* (Lichteinstein, 1823) group and was recently described from Morretes municipality, state of Paraná, Brazil (Lingnau et al., 2008). Besides the type-locality, this species occurs in Apiaí, Capão Bonito and Iporanga municipalities, state of São Paulo, southeastern Brazil (Lingnau et

al., 2008).

Herein, we characterize the behavioural repertoire of a non-topotypic population of *H. cardosoi* from Tapiraí, State of São Paulo, southeastern Brazil, including a comparison of its body size and advertisement call with its original description.

## MATERIALS AND METHODS

A population of *H. cardosoi* was observed in fast water streams at the Parque do Zizo, inside Paranapiacaba Mountains, municipality of Tapiraí, São Paulo State, southeastern Brazil (24°00'46"S; 47°48'45"W, 650m elev.). This place is characterized by Atlantic Rain Forest vegetation (Morellato & Haddad, 2000). The climate of the region is warm and wet without drought (Moraes et al., 1999). The field work was carried out between March 2005 and February 2006, with one additional visit in November 2009, totalling 49 days of data collection. The naturalistic observations were made mainly during the day using “animal focal” method (Lehner, 1996). Some nocturnal observations were made to evaluate if the individuals are active at this time. Under natural conditions the calls from six males were recorded using a Marantz PMD660 digital recorder and YOGA EM 9600 directional microphone. The advertisement calls were analyzed and the Waveform and the Spectrograms were made in Cool Edit 96™ (Syntrillium), with 16 bits resolution and FFT size of 1024. The recordings were broadcasted experimentally to



**Figure 1.** (a) Waveform and (b) Spectrogram of *H. cardosoi* advertisement call from Tapiraí, SP. Recorded on 11 November 2009; Water temperature approximately 18°C.

territorial males in order to stimulate the exhibition of territorial behaviours. The visual signals and the reproductive behaviour of *H. cardosoi* individuals were documented with camcorder Sony DCR-HC21 NTSC model.

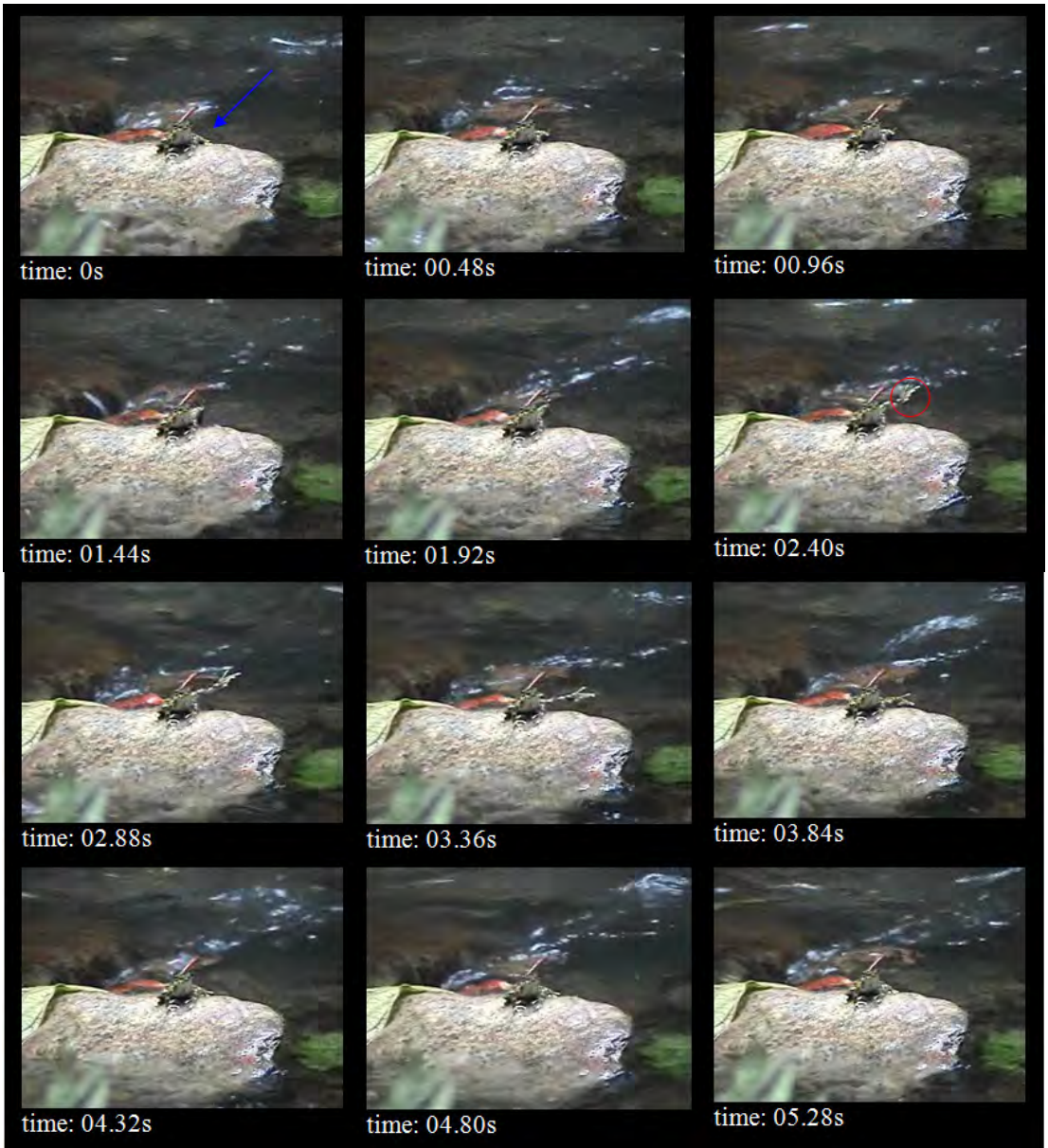
## RESULTS

Our record extends the species distribution at least 50 km northeast from its known distribution. Males call on rocks and falling trunks in streams during the daytime. The calling males were observed throughout the months of data collection. *H. cardosoi* is sympatric with *Crossodactylus caramaschii* Bastos & Pombal, 1995 in most streams of this region. At night we registered individuals resting on leaves at the stream-margins. The advertisement call of *H. cardosoi* from Tapiraí is composed of 3 to 13 notes. The note duration is 0.18 s ( $\pm 0.03$  s; range: 0.12-0.25; N=31). Each note is pulsed with 4 to 7 pulses (N=31 from 6 males). The calls occupy the frequency range between 4.3 and 6.9 kHz, with the main frequency from 4.9 – 6.0 kHz (N=31 from 6 males).

We observed two territorial interactions among

males that involve exhibition of visual signals besides advertisement and territorial call (Table 1). The visual signals were registered in four situations during courtship events and besides males, females were observed exhibiting the foot-flagging on some occasions (Table 1). The play back experiments provoked reactions in territorial males that responded by displaying visual signals and territorial calls (Table 1). The foot-flagging display may be accompanied by advertisement calls simultaneously and has about five seconds of duration (Figure 2).

Sometimes, when displaying, males were seen diving in the water among the rocks then returning to the display location. We define these submerged locations as nests that are visited by males. During pair formation (N=3) that were always observed close to midday (1200hrs) the females approached the territories of males and at about a distance of 60 cm the males performed a series of visual signals. The females may perform the foot-flagging for three or four times, apparently a response to male signals. The foot-flagging performed by females was seen in two courtship events. Then,



**Figure 2.** Movement sequence of foot-flagging displayed by a territorial male of *H. cardosoi* in the municipality of Tapiraí, São Paulo State, Brazil (time expressed in seconds (s)). Blue arrow shows the male on the rock and the red circle shows the foot location during the foot-flagging display.

the males while emitting the territorial call generally approach and touch the females with their hands or snout. After that, the males were always observed guiding the females to the submerged nest whilst still using advertisement

calls. We did not find the egg masses.

#### DISCUSSION

The diurnal calling activity on rocks amidst streams registered to *H. cardosoi* (this study and Lingnau

Behaviours	Description	Advertisement	Social context	
			Territorial	Courtship
Advertisement call	Figure 1	♂	♂	
Body raising	Elevating the body by totally extending the arms and partially the legs		♂	♂
Foot-flagging	Raising one hind leg, extending it slowly out and back in an arc above the substrate level, and returning it to body side	♂♀	♂	♂♀
Foot-flagging with toe wave movement	Same foot-flagging movement with toe vibrating at maximum extension feet	♂	♂	♂
Leg kicking*	It seems that the animal is “kicking the air” laterally or backwards	♂	♂	♂
Leg stretching with one leg	Stretching a hind leg rapidly to substratum level	♂		♂
Leg stretching with two legs	Stretching both the hind legs rapidly to substratum level	♂		♂
Limb lifting	Rapid up-and-down movements of an arm	♂	♂	
Territorial call	Short call with spaced notes emitted (not detailed here)		♂	♂

\*New behaviour recorded to the genus *Hylodes*.

**Table 1.** Summary of behavioural displays of *H. cardosoi* from municipality of Tapiraí, São Paulo State, Brazil. The behavioural categories follow the descriptions given by Hödl & Amézquita (2001) and Hartmann et al. (2005). The symbols ♂♀ indicate the sexes that perform the behaviour.

et al., 2008) is common to other species of *Hylodes* (Almeida-Gomes et al., 2007; Lingnau & Bastos, 2007). The advertisement call of *H. cardosoi* is similar to *H. dactylocinus* because both have more spaced notes than the advertisement call of other *Hylodes* sp. This similarity of call-properties between *H. cardosoi* and *H. dactylocinus* may help to elaborate a new phylogenetic hypothesis to the genus based in bioacoustic traits. A detailed comparison of *H. cardosoi* advertisement call properties with other *Hylodes* species is provided by Lingnau et al. (2008). The advertisement call of *H. cardosoi* from Tapiraí is about 200 Hz higher than the call of the toptotypical population (Lingnau

et al., 2008). Probably this feature is associated with the difference on body size from these two populations (Table 2).

Lingnau et al. (2008) observed males of *H. cardosoi* displaying visual signals, for example body raising and foot-flagging. Here we extend the list of display behaviours of *H. cardosoi* complemented with social context information. One visual signal recorded to *H. cardosoi* (leg kicking) is new to the genus *Hylodes*. The foot-flagging exhibited by females described in the present paper is probably unknown to any anuran species. Something unclear from our data is why males display territorial calls in an aggressive



Locality	Mean of Snout-Vent Length (mm)	
	♂	♀
Tapiraí, SP	32.2 (S.D. = 1.3, range = 30.9-34.0, N=7)	35.5 (S.D. = 0.7, range = 34.3-36.5, N=4)
Morretes, PR	40.4 (S.D. = 2, range = 35.6-44.1, N=32)	42.4 (S.D. = 2.6, range = 36.7-46.5, N=31)

**Table 2:** Body size of two populations of *H. cardosoi*, southeastern Brazil. For the last population (Morreates, PR), data are from Lingnau et al. (2008).

context during the pair formation? We believed that, initially, males may have problems in recognizing females, making visual and tactile signals important mechanisms in identifying competitors or the available females to reproduce with. Once a female is not able to reproduce she is regarded as a competitor in the male territory. Thus, the foot-flagging employed by females makes sense for communication between sexes during courtship. However, further work is needed to confirm this hypothesis. Visual signals are known in other species of *Hylodes* (Haddad & Giaretta, 1999; Hartmann et al., 2005; Narvaes & Rodrigues, 2005; Wogel et al., 2004). Hödl & Amézquita (2001) explored a hypothesis of a relationship between of visual signals with diurnality and noisy environments. For these conditions, visual signals seem to be favoured as an evolutionary trait and *H. cardosoi* with a diverse set of visual displays support this view.

Although we did not find any egg clutches of *H. cardosoi*, the reproductive behaviour described in the present paper is similar to *H. dactylocinus* (Narvaes & Rodrigues, 2005) and agrees with previous knowledge about reproductive mode indicated by Haddad & Prado (2005) for *Hylodes*. This study contributes to our knowledge of the natural history of *H. cardosoi*, which represents a step in the effort to understand the evolution of complex behaviours in the Hylodidae.

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# Annual and daily activity cycles of snakes in northern Virginia, USA

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The annual and daily activity cycles of North American reptiles are determined by physiological responses to both temperature and light; and are seasonal (Gibbons & Semlitsch, 2001). While many field studies of North American snakes have included data on seasonal activity patterns, their daily activity cycles have been mostly under reported in only general terms. This is the only long term study of a snake in the middle Atlantic region of the USA, and as such is valuable for comparison with other such North American research; and reports baseline information which may also be critical to future studies on the effects of global warming on snake communities.

Ecology of 16 snakes (Table 1) was studied at the Mason Neck National Wildlife Refuge, Fairfax County, Virginia, USA (38° 67' N, 77° 10' W, ~25-35 m elevation), from April 1982 to August 2006, but concentrated from 1990 to 2006 (Hartsell, 1993; Ernst et al., 1997; Creque, 2001; Orr, 2003, 2006). Calculations of the annual and daily activity cycles are reported below.

## METHODS AND MATERIALS

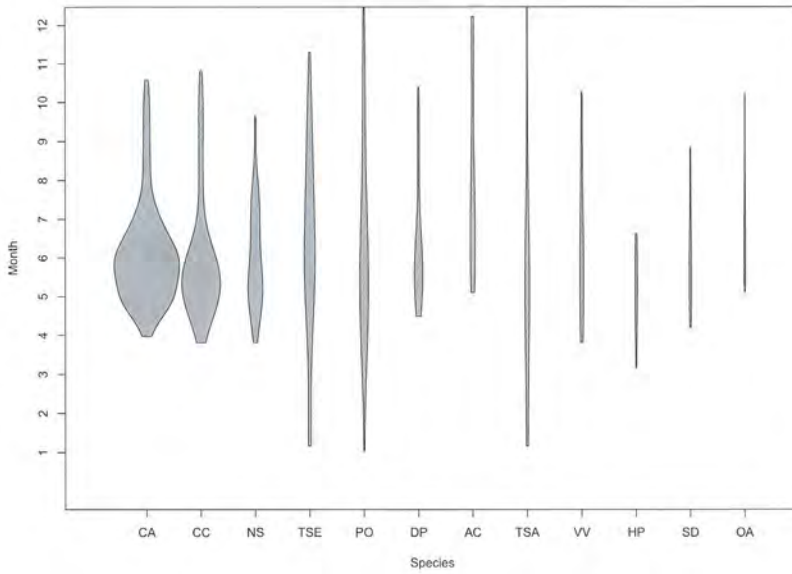
Most snakes were collected by hand. Surveyor effort was as constant as possible from March through November. Data recorded at each snake encounter included sex and life stage (male, female, hatchling/newborn, juvenile or immature; Ernst & Ernst, 2003); total body length (TBL), snout-vent length (SVL) and tail length (TL, from vent to

tip), measured with a cloth measuring tape (large snakes) or a standard metric ruler (small snakes); mass recorded to the nearest 0.1 g with Pesola scales or an ACCulab portable electronic balance (large snakes); date and 24-hour time (military); and activity. All snakes were scale-clipped. A small PIT-tag, read with an Avid tag reader, was inserted subcutaneously into the larger species.

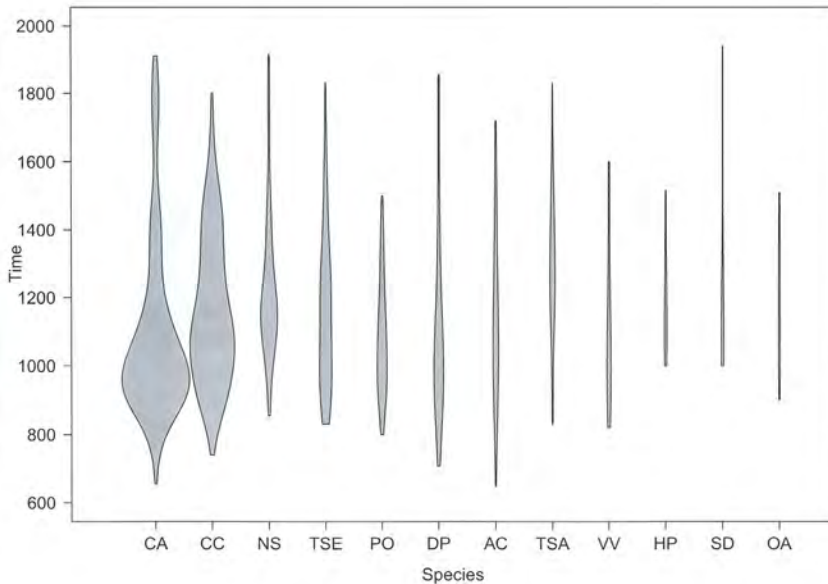
Internal body temperature was recorded by means of cloacal temperature (BT) to 1°C with a Schultheis quick-reading thermometer. Corresponding air (AT), and surface (ST) or water temperatures (WT) were recorded to 1°C with a mercury thermometer. Also noted were the location; habitat; snake activity: basking (B), under cover (C), foraging/feeding (F), hibernating (H), moving (M, crawling on land, climbing, or swimming in water), and reproductive (R) (courting, mating, gravid female). All snakes were released at the point of capture. Snakes were considered active if they moved when touched. It was not always possible to take a snake's BT, as some escaped or were too small. Such events were recorded as observations, but the environmental temperatures (ETs) were recorded immediately after the observation at the snake's exact position.

## RESULTS AND DISCUSSION

*Annual Activity Period.* North American snakes experience different seasonal periods of annual activity due to elevation and latitude, with peaks



**Figure 1.** Annual snake activity by months (AC, *Agkistrodon contortrix*; CA, *Carphophis amoenus*; CC, *Coluber constrictor*; DP, *Diadophis punctatus*; HP, *Heterodon platirhinos*; OA, *Opheodrys aestivus*; PO, *Pantherophis obsoletus*; SD, *Storeria dekayi*; TSA, *Thamnophis sauritus*; TSE, *Thamnophis sirtalis*).



**Figure 2.** Daily snake activity by 24-hour (military) clock (AC, *Agkistrodon contortrix*; CA, *Carphophis amoenus*; CC, *Coluber constrictor*; DP, *Diadophis punctatus*; HP, *Heterodon platirhinos*; OA, *Opheodrys aestivus*; PO, *Pantherophis obsoletus*; SD, *Storeria dekayi*; TSA, *Thamnophis sauritus*; TSE, *Thamnophis sirtalis*).

of surface abundance occurring at different times of the year. Except in the more southern states, and especially in Florida, snakes are least surface active during the period December-February, with more northern species hibernating then (Ernst & Ernst, 2003). With the onset of spring, ETs rise, daylight increases, and snakes become correspondingly active.

Ectothermic snakes do have some control of BT selection through behaviour. A number of factors are involved in the maintenance of snakes' annual activity cycles: size (possibly age), attainment of maturity (adult, juvenile/immature, neonates), female and male hormonal cycles, prey availability, and microhabitat needs (Gibbons & Semlitsch, 2001; Ernst & Ernst, 2003).

*Heterodon platirhinos* was the only Mason Neck snake that exhibited a unimodal activity pattern (Figure 1); Platt (1969) reported a bimodal activity pattern in Kansas. At Mason Neck it was most often encountered in late spring and early summer during its mating season, and when its prey (toads, *Anaxyrus americanus* and *A. fowleri*; salamander, *Ambystoma maculatum*) were most available (Ernst and Laemmerzahl, 1989; Ernst &

Ernst, 2003).

The other Mason Neck snakes with sufficient encounters had bimodal patterns, being active over the summer with a first peak beginning in late spring and continuing into early summer (associated with emergence from hibernation, basking, courtship/mating, and onset of feeding), diminished activity during the warmest summer months (July-August), and a second peak (involving some courtship/mating, but mostly parturition or hatching; diminished prey availability and cessation of feeding; and later movement to hibernacula) in late summer and early fall (mid-September through October). The earliest and latest dates of capture or observation are listed in Table 1; and the annual activity periods of some Mason Neck snakes are shown in Figure 1. Collectively, Mason Neck snakes were active from April through October, with a few outliers in March and November, and the two species of *Thamnophis* and *Agkistrodon contortrix* on warm days in December and early January. All species sought hibernacula in October, and by mid- to late-November all were only found at such sites. The majority of individuals did not arise again until April. Most annual activity occurred

Species (N)	Earliest Date	Latest Date
<i>Carphophis amoenus</i> (328)	March 30	October 18
<i>Coluber constrictor</i> (194)	March 25	October 25
<i>Nerodia sipedon</i> (73)	April 25	September 20
<i>Thamnophis sirtalis</i> (54)	January 5	November 9
<i>Pantherophis obsoletus</i> (43)	January 1	December 26
<i>Diadophis punctatus</i> (42)	April 15	October 12
<i>Agkistrodon contortrix</i> (25)	April 24	December 7
<i>Thamnophis sauritus</i> (23)	January 5	December 23
<i>Virginiae valeriae</i> (18)	March 25	October 20
<i>Heterodon platirhinos</i> (11)	March 5	June 19
<i>Storeria dekayi</i> (11)	April 6	August 26
<i>Opheodrys aestivus</i> (7)	May 3	October 7
<i>Lampropeltis calligaster</i> (6) (recent hatchlings)	August 16	-
<i>Lampropeltis getula</i> (2)	April 18	May 31
<i>Regina septemvittata</i> (2)	April 23	May 14
<i>Lampropeltis triangulum</i> (1)	March 15	-

**Table 1.** Earliest and latest dates on which active snakes were encountered.

Species (N)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
<i>Carphophis amoenus</i> (328)	-	-	C	C, R	C, R	C, R	C, M	C	C, M, R	C	-	-
<i>Coluber constrictor</i> (194)	-	-	C, M, B	C, M, B, F, R	C, M, B, F, R	C, M, B, F	C, M, B, R	C, M, B, F	C, M	C, M, B	-	-
<i>Nerodia sipedon</i> (73)	-	-	B	C, M, B	M, B	M, B, F, R	M, B	M, B	F	-	-	-
<i>Thamnophis sirtalis</i> (54)	R	-	C	M, B, F	C, M, B	C, M, B, F, R	C, M, B	M, B	C, M	C, M, B, R	M	-
<i>Pantherophis obsoletus</i> (43)	H	-	H, M, B	C	C, M, B, F	C, M, B	C, M, B	C, M	C	H, C, M	H	H
<i>Diadophis punctatus</i> (42)	-	-	-	C	C, M	C, M	C	C	C	C	-	-
<i>Agkistrodon contortrix</i> (27)	-	-	-	R	C, M, B	C, B	C, B	C	C	C	B	B
<i>Thamnophis sauritus</i> (23)	B	-	-	M, B	M, B	M	-	B	M	-	-	B
<i>Virginia valeriae</i> (18)	-	-	C	C, M	C	C	C	C	C	C	-	-
<i>Heterodon platirhinos</i> (11)	-	-	C	C, F	C, M	M, B, F	-	-	-	-	-	-
<i>Storeria dekayi</i> (11)	-	-	-	C, M	C	C, B	-	C, M	-	-	-	-
<i>Opheodrys aestivus</i> (7)	-	-	-	-	M	M	-	-	-	M	-	-

**Table 2.** Snake behavior by months: B = basking, C = cover, F = forage/feeding, H = hibernaculum, M = move (crawl on land, climb, swim), R = reproductive (court, mate, gravid female).

during April-June, and noticeably slowed from July through September; most species were less surface active and under cover after June. This was particularly true of the smaller snakes (*Carphophis*, *Diadophis*, *Storeria*, *Virginia*); perhaps as daylight hours became too hot and dry, they shifted to a more crepuscular or nocturnal activity cycle. Such a time shift was also evident in the pitviper *A. contortrix*. Summer heat and drier conditions affected the larger *Coluber* and *Pantherophis* less, although there were fewer surface captures after June. Aquatic and semiaquatic snakes (*Nerodia*, *Thamnophis sauritus*, *T. sirtalis*) that could cool themselves in water, were also less active and usually found only in aquatic microhabitats after June. This annual cycle was expected, and fills an eastern mid-latitude data gap.

Some species' annual activity may have been at least partially controlled by their preys' cycles. *Coluber* and *Pantherophis* feed mostly on small mammals which are active throughout the year and their annual activity periods show this (Figure 1), while *Nerodia* and the two *Thamnophis* feed on fish, amphibians, small mammals (*T. sirtalis*), or earthworms throughout their annual activity period (Ernst & Ernst, 2003). Contrastingly, *Carphophis*, *Diadophis*, and *Storeria*, which feed predominately on earthworms (Ernst & Ernst, 2003; Orr, 2003, 2006) decreased in numbers after June, and

possibly become more crepuscular or nocturnal to match the active times of earthworms.

Smaller individuals of each species became active later in the spring than did larger, more mature ones. The only small snakes found active in March were the single captured *Lampropeltis triangulum*, a juvenile on 15 March; an adult male *Virginia* on 25 March; and an adult male *Carphophis* on 30 March; all were under cover. Males also dominated in April, with females and smaller individuals becoming more active after the 15th. In contrast, captures from late September to mid-November were about even between the adult sexes and immatures.

*Daily Activity Period.* The daily activity cycle indicates the time of day in which the snakes' major surface activities occur (Gibbons & Semlitsch, 2001). Such patterns are usually determined by the time the best ranges of AT and ST are available for normal surface activity (including basking), times correlated with rainfall events, their prey activity cycles, the hours when the opposite sex is most active (during the mating season, or during the female's time of oviposition or parturition), and the time of appearance of neonates (Figure 2, Table 3).

Daily activity at Mason Neck was categorized as either diurnal (active during the daylight hours), crepuscular (active during the transition between day and night when days become warmer in late

Species (N)	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
<i>Carphophis amoenus</i> (188)	C	C	C	C, M, R	C, R	C	C	C	C	C	-	C, M, R	C	C
<i>Coluber constrictor</i> (156)	-	C	C, B	C, M, B, F, R	C, M, B, R	C, M, B, R	C, M, B, F	C, M, B, R	C, M, B, R	C, M, B, F	C, M, B	C, M	C	-
<i>Nerodia sipedon</i> (65)	-	C	C, M	B, R	M, B	M, B, F	M, B	M, B	M, B	-	B	M	B	-
<i>Pantherophis obsoletus</i> (39)	-	-	C, M	C, M, H	C, M, B	C, M, B, H	C, M, F	C, M, B	M, B	M	-	-	-	-
<i>Thamnophis sirtalis</i> (34)	-	-	B	C, M, B	C, M, B	C, M, F	M, B, R	M, B	M, B	C	C, B	-	M	-
<i>Diadophis punctatus</i> (31)	-	-	-	C, M	C	C	-	C, M	C	B	B	-	C, M	-
<i>Thamnophis sauritus</i> (23)	-	-	B	C	B	M	M, B, H	M	M, B, H	B	B	-	M	-
<i>Agkistrodon contortrix</i> (24)	M	-	C	C, B	C	C, B	B	B, R	C, M, B	-	C	-	-	-
<i>Virginia valeriae</i> (11)	-	-	C	C	C	C	-	C, M	-	-	C	-	-	-
<i>Heterodon platirhinos</i> (11)	-	-	-	C	C, M, F	C, M, F	B	B	-	F	-	-	-	-
<i>Storeria dekayi</i> (10)	-	-	-	-	C, M	C	B	-	-	-	-	C	-	M
<i>Opheodrys aestivus</i> (7)	-	-	M	M	M	-	M	M	M	-	-	-	-	-

**Table 3.** Daily snake behavior by 24-hour (military) clock: B = basking, C = cover, F = forage/feeding, H = hibernaculum, M = move (crawl on land, climb, swim), R = reproductive (court, mate, gravid female).

spring and summer and a reverse of this pattern in the autumn), or nocturnal (active after nightfall). Diurnal snakes included *Coluber*, *Heterodon*, *Nerodia*, *Pantherophis*, and *Thamnophis*. *Carphophis*, *Diadophis*, *Storeria*, *Virginia*, and *Agkistrodon* were crepuscular/nocturnal. This simplistic approach causes overlap in some species because of increasing or decreasing hourly AT and ST during the year. Diurnal surface activity at Mason Neck became earlier in the day as spring advanced and later with the progression of autumn. In summer, some species (*Agkistrodon*, *Carphophis*, *Nerodia*) became active earlier in the dawn hours, went under cover during the hottest mid-day period, and again became active during the late afternoon and dusk hours as AT fell.

Unfortunately, nocturnal research at the refuge was not permitted, and the refuge was locked as darkness approached. Therefore, we were dependent on previous literature reports of nocturnal activity in some species present (see Ernst & Ernst, 2003) and the fact that some species were almost exclusively found under cover during the daylight hours (*Carphophis*, *Diadophis*, *Storeria*, *Virginia*).

*Annual and Daily Behaviour Cycles.* Behaviour of Mason Neck snakes changes during its annual activity period (Table 2). The snakes' behaviour is

most dependent on the ET with which it is most in contact (AT, ST, WT); but also by their reproductive hormonal cycles, and the most advantageous time to find prey (Ernst & Ernst, 2003); and once Spring ATs become warm enough to bring them to the surface, they first begin to bask for more body heat. Then, as AT and ST allow other surface activities, the snakes begin to move about and search for mates and prey. Most species oviposite in June.

Because of excessive daytime ETs in July and August, most snakes remain under cover during the warmest hours and are active in the early morning, late afternoon or evening when ETs do not stress them. A second, lesser period of reproductive activity occurs in September-October (Table 2). Late August-October is also the time when neonates first appear. Activity slows in the autumn as ETs fall with few snakes surface active after October, and all essentially in hibernacula in late November through February (Figure 1, Table 2).

Data in Table 3 indicate that courtship/mating activity may occur anytime during 0900-1700 hours when the two sexes meet, and the ETs are suitable. In the smaller, nocturnal *Carphophis* reproductive behaviour was only noted when the two sexes were found situated side by side or in close proximity under cover together; however, this does not preclude such nocturnal activity when

the species is moving over the surface (Barbour et al., 1969).

As stated in the introductory remarks, this study provides valuable comparative information for possible future studies on the effects of climate change on reptiles in the Middle Atlantic states. Increased environmental temperatures may already be affecting the herpetofauna of the region. In the latter years of our research at Mason Neck, we have observed possible signs of this in the turtle *Kinosternon subrubrum*. A survey of many nesting records reported by Ernst and Lovich (2009) indicates that the turtle normally nests during late May and June, although scattered observations of nesting have been reported from farther south and west on 31 March (a single record; Richmond, 1945) to September. Prior to 2000, nesting at Mason Neck had only been observed in late May and June (Gotte, 1988). Since then we have found female *K. subrubrum* either excavating a nest cavity or ovipositing on four earlier dates: 30 March (ovipositing; Orr & Ernst, 2002), 15 April (excavating; Ernst et al., 2001), 24 April (excavating), and 1 May (ovipositing). If female Mason Neck *K. subrubrum* have been affected by warming climate change, so possibly have the refuges' snakes; thus making the data we present very important for future studies in this region of North America.

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# Body temperatures of *Sceloporus anahuacus* from a montane zone of northeastern Estado de México, Mexico.

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Information on the thermal ecology of lizards is important because our ability to understand the potential for climate change to affect the future distributions of species depends in part on our understanding of current relationships of species with their thermal environments. Given that a recent study has suggested the potential for major negative impacts of climate change on the abundance and distribution of Mexican lizards (Sinervo et al., 2010), the more information we can gather on temperature relationships of lizards the better we might be able to predict such changes. The body temperatures and temperature relationships of lizards in the genus *Sceloporus* are among the best studied of any genus of lizards, and information on numerous species has been published. However, there are still species for which no published information on body temperatures and temperature relationships are available. One such species is *Sceloporus anahuacus*. *S. anahuacus* is relatively unstudied, but it has been observed perched on rocks or the ground along road sides or near forests (Smith & Lemos-Espinal, 2005) and it is found in pine forests between 2800 and 3600 m in the mountains around Mexico City (Ramírez-Bautista et al., 2009). Here we report on the body temperatures of *S. anahuacus* from Isidro Fabela, Estado de México, Mexico. In particular, we consider the effects of environmental temperatures,

body size, sex and reproductive condition, and microhabitats on body temperatures.

## MATERIALS AND METHODS

We conducted the study in Isidro Fabela (19° 32' 41" N, 99° 29' 20" W and 3200 m elevation), northeastern Estado de México, Mexico. Mean annual temperature and precipitation are 12°C and 800 mm, respectively. Plant species include *Pinus montezumae*, *Pinus* sp., *Stipa ichu*, *Muhlenbergia* sp., *Festuca* sp., *Outeloa* sp., *Bachaeris conferta*, and *Senecio praecox*, principally (Rzedowski, 2006).

We captured lizards by hand or noose between 0930 and 1330 h. Once captured, we recorded sex, reproductive condition in females (by abdominal palpation), snout vent length (SVL, to the nearest 1 mm), body ( $T_b$ ; cloacal temperature, to the nearest 0.2°C), air ( $T_a$ ; bulb in the shade, 3.0 cm over the substrate occupied by the lizard, to the nearest 0.2°C), and substrate temperature ( $T_s$ ; bulb in the shade on the substratum occupied by the small lizard, to nearest 0.2°C) using a quick-reading thermometer (Shultetheis, Miller Weber Inc., interval 0-50°C, 0.2°C precision). We also recorded each lizard's position with regard to solar insolation as being completely exposed to sun, in shade, or cloudy day. Lizards that needed a major effort to capture (> 1 min.) were excluded from

	T <sub>b</sub> (°C)	T <sub>a</sub> (°C)	T <sub>s</sub> (°C)
Males (N = 36)	30.50 ± 0.18	20.48 ± 0.35	20.31 ± 0.40
Non-gravid females (N = 50)	30.32 ± 0.20	20.16 ± 0.36	19.40 ± 0.35
Gravid females (N = 33)	32.13 ± 0.26	20.81 ± 0.47	20.72 ± 0.41

**Table 1.** Mean body temperature (T<sub>b</sub>), air temperature (T<sub>a</sub>), and substrate temperature (T<sub>s</sub>) of male, non-gravid female, and gravid female *S. anahuacus*. Means are given ± 1 SE.

	T <sub>b</sub> (°C)	T <sub>a</sub> (°C)	T <sub>s</sub> (°C)
Sunny (N = 79)	31.07 ± 0.18	20.88 ± 0.24	20.47 ± 0.24
Sun/Shade Mosaic (N = 30)	30.63 ± 0.23	19.61 ± 0.52	19.29 ± 0.56
Shaded (N = 10)	30.06 ± 0.51	19.48 ± 0.84	18.92 ± 0.61

**Table 2.** Mean body temperature (T<sub>b</sub>), air temperature (T<sub>a</sub>), and substrate temperature (T<sub>s</sub>) of *S. anahuacus* found in sunny, sun/shade mosaic, and shaded microhabitats. Means are given ± 1 SE.

temperature records. We used only one observation for each lizard.

**RESULTS AND DISCUSSION**

Mean T<sub>b</sub> was 30.88 ± 0.14 °C (N = 119). Mean T<sub>a</sub> was 20.44 ± 0.22 °C (N = 119). Mean T<sub>s</sub> was 20.04 ± 0.23 °C (N = 119). Body temperature was significantly related to T<sub>a</sub> (N = 119, r<sup>2</sup> = 0.18, P < 0.0001; T<sub>b</sub> = 25.47 + 0.26T<sub>a</sub>). Body temperature also increased with T<sub>s</sub> (N = 119, r<sup>2</sup> = 0.14, P < 0.0001; T<sub>b</sub> = 26.24 + 0.23T<sub>s</sub>). It thus appears that environmental temperatures are important in the body temperatures of *S. anahuacus*; however, the relatively low amounts of variation in body temperature that were explained by environmental temperatures suggest that these lizards may be able to regulate their body temperatures to some extent.

Body temperature was not related to SVL (N = 119, r<sup>2</sup> = 0.017, P = 0.15). Our results are consistent with the failure of all previous studies that have examined the potential effects of lizard size on T<sub>b</sub> in *Sceloporus* to find such an effect (*S. horridus*, Lemos-Espinal et al., 1997b; *S. jarrovi*, Smith & Ballinger 1994; *S. malachiticus*, Vial 1984; *S. ochoteranae*, Lemos-Espinal et al., 1997; *S. siniferus*, Lemos-Espinal et al., 2001). It thus

appears that body size likely plays little, if any, role in body temperatures in *Sceloporus*, but additional studies are needed to confirm this.

Body temperature differed among males, non-gravid females, and gravid females (Table 1; F<sub>2,116</sub> = 20.06, P < 0.0001), with gravid females having significantly warmer T<sub>bs</sub> than both males and non-gravid females (Tukey HSD, P < 0.05). However, mean T<sub>a</sub> did not differ between these three groups (Table 1; F<sub>2,116</sub> = 0.70, P = 0.50), but T<sub>s</sub> did (Table 1; F<sub>2,116</sub> = 3.26, P = 0.042). Our observation that gravid females had a higher mean T<sub>b</sub> than males or non-gravid females is different from previous studies that have found that pregnant or reproductive females had lower mean T<sub>bs</sub> (*S. grammicus*, Andrews et al., 1997; *S. jarrovi*, Smith & Ballinger, 1994) or did not have a different mean T<sub>b</sub> than males or non-reproductive females (*S. bicanthalis*, Andrews et al., 1999; *S. gadoviae*, Lemos-Espinal et al., 1997c). Taken together, these results suggest that reproductive condition can influence body temperatures in *Sceloporus*, but that the nature of this influence varies among species, but our database is too small to draw any conclusions as to why.

Most lizards were observed in sun microhabitats

(79; 66.4%), followed by mosaic microhabitats (30; 25.2%). Relatively few of the lizards were observed in shaded microhabitats (10; 8.4%). Microhabitat did not affect  $T_b$  (Table 2;  $F_{2,116} = 2.50$ ,  $P = 0.09$ ). However, mean  $T_a$  was highest in sunny microhabitats (Table 2;  $F_{2,116} = 3.89$ ,  $P = 0.026$ ), as was  $T_s$  (Table 2;  $F_{2,116} = 0.20$ ,  $P = 0.82$ ). *Sceloporus* can thermoregulate by shuttling (Bowker et al., 1986), which may help explain the constant  $T_{bs}$  and variable  $T_a$  and  $T_s$  among microhabitats in *S. anahuacus*.

#### ACKNOWLEDGMENTS

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**Reproduction in *Lygisaurus curtus* (Scincidae) from Papua New Guinea**

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*Lygisaurus curtus* occurs throughout the Papuan Peninsula of Papua New Guinea where they inhabit disturbed areas in montane rain forests from sea level to 1540 m elevation (Kraus, 2007). It appears *L. curtus* may have an annual lifespan, lasting about fifteen months with eggs hatching in the early months of the year; adult males in breeding colours were collected in October (Kraus, 2007). In this note we provide additional information on the reproduction of *L. curtus*.

A sample of 49 *L. curtus* from Papua New Guinea consisting of 27 males (mean SVL = 35.7 mm ± 3.0 SD, range = 31-41 mm), 18 females (mean SVL = 35.1 mm ± 2.8 SD, range = 30-40 mm) and 4 subadults (mean SVL = 24.0 mm ± 1.6 SD, range = 22-26 mm) was examined from the herpetology collection of the Louisiana State University, Museum of Natural Science (LSUMZ). Lizards were collected under licence in 2006 and 2009 in Milne Bay Province: LSUMZ 92682-92693, 92698-02700, 94099, 94506, 94509-94511, 94517-94519, Northern Province: LSUMZ 94100, and Gulf Province: LSUMZ 94523-94526, 94528-

94530, 94538-94551, 94553-94556.

The left gonad was removed for histological examination and embedded in paraffin. Enlarged ovarian follicles (> 3 mm) or oviductal eggs were counted. Histological sections were cut at 5µm using a rotary microtome and stained with Harris hematoxylin followed by eosin counterstain. Histology slides were deposited in LSUMZ.

Two stages were observed in the testicular cycle; spermiogenesis in which the lumina of the seminiferous tubules are lined by sperm or clusters of metamorphosing spermatids and recrudescence in which there is a proliferation of spermatocytes to be utilized in the next period of spermiogenesis. Seventeen males from August, eight of nine from September and one of one from October all exhibited spermiogenesis. The epididymides were not histologically examined but they were enlarged and convoluted in all males undergoing spermiogenesis indicating the likelihood they contained sperm. The smallest mature male (spermiogenesis in progress) measured 31 mm SVL (LSUMZ 94517). One male (31 mm SVL, LSUMZ 94543) from September exhibited recrudescence. It is not known when spermiogenesis would have commenced but it would appear 31 mm SVL was near the minimum size of maturity for males of *L. curtus*.

Clutch size for 9 females was an invariant 2.0. The presence of two females (LSUMZ 94519, 94548) containing oviductal eggs and concomitant yolk deposition in smaller follicles for a subsequent clutch (Table 1) indicated females of *L. curtus* produce multiple clutches. The smallest reproductively active females measured 33 mm SVL (LSUMZ 92693, 94549, 94556, early yolk deposition; LSUMZ 92692, 2 oviductal eggs).

Month	N	No yolk dep.	Early yolk deposition	Enlarged follicle (> 3 mm)	Oviductal eggs	Oviductal eggs and yolk dep.
August	12	1	4	3	3	1
September	6	1	4	0	0	1

**Table 1.** Monthly stages in the ovarian cycle of *L. curtus* from Papua New Guinea.

The size of hatchlings is not known, however, the four subadults (August  $n = 3$ , September  $n = 1$ ) may have been born in the early months of the year as reported for *L. curtus* (Kraus, 2007).

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### First country records for *Urotheca decipiens* and *Urotheca pachyura* and range extensions of *Urotheca guentheri* in Nicaragua

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Although the number of amphibian and reptile species reported for Nicaragua is lower when compared to other Central American countries, efforts to revert this situation have been increasing during the last decade. Here, we report the first country records of the collared glass-tail snake (*Urotheca decipiens*) and the Costa Rican glass-tail snake (*Urotheca pachyura*), as well as range extensions for the striped glass-tail snake (*Urotheca guentheri*). These findings confirm the suspected presence of the former two species and increase the country distribution of the latter.

The herpetofauna from Central America has

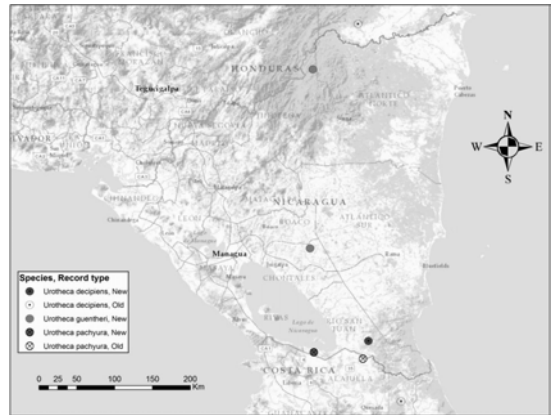


Figure 1. Map of Nicaragua showing the location of new and closest, old records for three species of *Urotheca*.

attracted the attention of many biologists since the 1950's, making this a well explored area. However, exploration in Nicaragua has proven difficult, causing the number of amphibian and reptile species reported for this country to be lower when compared to neighboring countries (Khöler, 2001; Savage, 2002; Ruiz & Buitrago, 2003). Although many species are suspected to occur in Nicaragua, their presence has not yet been confirmed (Sunyer Mac Lennan, 2009) or only a few records are available (HerpNet, 2011). This is the case for snakes of the genus *Urotheca* (Squamata, Colubridae, Dipsadinae), which is composed of 10 species (Savage, 2002), with only two having been recorded in Nicaragua (*U. guentheri* and *U. euryzona*) and two more expected to occur there (*U. pachyura* and *U. decipiens*). Here, we report the first records of the Costa Rican glass-tail snake, *U. pachyura*, and the collared glass-tail snake, *U. decipiens* for Nicaragua. We also report two further records that extend the distribution of the striped glass-tail snake, *U. guentheri*, within Nicaragua.

On 12 August 2005 an adult individual of *U. pachyura* was found at Los Guatuzos Ecological Centre (11°01'50" N, 85°03'12" W, 41 m a.s.l.), Municipality of San Carlos, Río San Juan Department, Nicaragua (Figure 1). This individual (Figure 2a) was found by Marco D. Barquero during a field course and later released at its point of capture. Photographs were deposited (as



**Figure 2.** Adult specimens of: (A) *U. pachyura* observed at Los Guatuzos Ecological Centre; (B) *U. decipiens* found at El Quebracho Wildlife Reserve; and *U. guentheri* found at Bosawás Biosphere Reserve, Jinotega Department (C) and Santo Domingo, Chontales Department (D), Nicaragua.

vouchers) in the collection of the Smithsonian National Museum of Natural History (catalog numbers USNM Herp Images 2744-2749). This specimen represents the first country record for this species, which extends its distribution 60 km to the northwest from the closest Costa Rican record (Museum of Zoology, University of Costa Rica, catalog number UCR-5933).

On 08 September 2009 an adult female of *U. decipiens* was found at El Quebracho Wildlife Reserve (11°09'58" N, 84°24'21" W, 60 m a.s.l.), Municipality of El Castillo, Río San Juan Department, Nicaragua (Figure 1). The snake (570 mm snout vent-length [SVL], Figure 2b) was

collected during a field trip sponsored by Fundación del Río and deposited in the herpetological collection of the Museum of Vertebrate Zoology at Berkeley (catalog number MVZ-267438). This specimen represents the first country record for this species, which extends its distribution 100 km northwards from the closest Costa Rican record (Smithsonian National Museum of Natural History, catalog number USNM-219971) and 450 km southwards from the nearest known locality in Honduras (McCranie et al., 2003).

Finally, on 03 December 2008 an adult specimen of *U. guentheri* (Figure 2c) was observed at the Bosawás Biosphere Reserve (14°21'46" N,

85°03'48" W, 283 m a.s.l.), Jinotega Department, Nicaragua (Figure 1). Another adult specimen (female, 700 mm SVL, Figure 2d) of *U. guentheri*, however, was found on 21 July 2011 at Santo Domingo (12°15'39" N, 85°05'50" W, 375 m a.s.l.), Chontales Department, Nicaragua (Figure 1). Both specimens were found by Milton Salazar S., with the latter deposited in the herpetological collection of the Museum of Vertebrate Zoology at Berkeley (catalog number MVZ-267439). These specimens extend the distribution of this species to central (200 km) and northern (400 km) areas of the country, since the species was previously reported unambiguously from only one southeastern locality (Cerro El Gigante, Río San Juan Department, see Khöler, 2001).

This report contributes to confirm the presence and expand the distribution of secretive species such those of the genus *Urotheca*; for which only a handful of specimens are available (HerpNet, 2011), increasing both the number of reptile species and individuals collected in Nicaragua. Recent efforts to explore different areas of the country (Sunyer Mac Lennan, 2009; Barquero et al., 2010) have been adding to the number of species of herpetofauna, although many sites remain poorly or completely unexplored. Therefore, more exploration is still required to complete a species list for the country; very basic information that can be used by conservationists and decision-makers.

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### Distributional range of the poorly known *Liolaemus tacnae* (Shreve 1941)

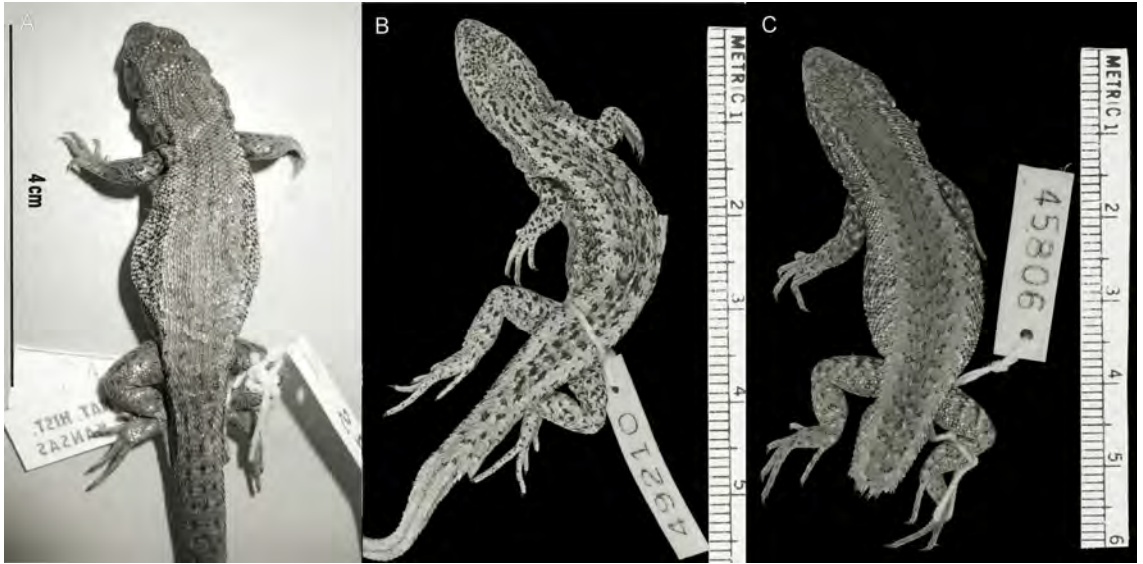
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*Liolaemus* is a large genus of lizards, subdivided into two subgenera: *Liolaemus* (sensu stricto) and *Eulaemus* (Laurent, 1983), each of which has been divided into several groups. *L. tacnae* Shreve 1941 was described based on three specimens



**Figure 1.** Dorsal view of specimens: a) *Liolaemus* sp. female (SDSU-1924 from Chapiquiña); b) The only known female of *L. tacnae* (MCZ R-49210 from Cujajone); c) *L. tacnae* male (holotype, MCZ R-45806 from Toquepala).

(MCZ R-45806, R-45807 and R-45808; three males) from Toquepala Mine, Tacna department (Perú). This species belongs to the subgenus *Liolaemus* and the group *alticolor-bibronii* (Lobo et al., 2010). Thereafter, Lobo & Espinoza (2004) indicated the existence of two more specimens (MCZ R-49210 (male) and R-49211 (female)) from Cujajone Mine, Moquegua department (20 km to NW from Toquepala, Perú). However, in a recent review of the Chilean species of *Liolaemus*, Pincheira-Donoso & Núñez (2005) included *L. tacnae* that had been recorded earlier from Chile by Lobo & Espinoza (1999), which was an important distributional expansion (160 km).

The record of *L. tacnae* reported from Chile by Lobo & Espinoza (1999) was based on a female specimen (SDSU 1924) labeled “Chapiquiña, 4.080 m, 3 km east of Portezuelo, Tarapacá, unknown collector.” However, after examining the type series of *L. tacnae*, the authors stated that “a recent examination of the type series of the *L. tacnae* (MCZ 45806–08) indicates that the *L. tacnae* examined in our previous study (SDSU-1924) is not referable to this species” (Lobo & Espinoza, 2004). Nevertheless, Pincheira-Donoso & Núñez (2005) included *L. tacnae* as a Chilean species, based on the same specimen (SDSU-1924), and

provide a redescription. Later, this species was also listed for Chile by Pincheira-Donoso et al., (2008).

We examined the female specimen SDSU-1924 and photographs in several views from known specimens of *L. tacnae*, including the holotype (with the exception of the MCZ R-45808). Also, we include data for scale counts around midbody and neck for *L. tacnae* from the literature (Lobo & Espinoza, 2004). The same scale count data were taken for the SDSU-1924 specimen from Lobo & Espinoza (1999) and confirmed in the laboratory.



**Figure 2.** Distributional map. Pentagon: *L. tacnae* (Moquegua & Toquepala). Square: *L. alticolor* (present in Putre, Parinacota & Caquena (Donoso-Barros, 1966)). Triangle: *Liolaemus* sp. SDSU-1924 (Chapiquiña). Circle: *L. puna* (present in Chiapa (Lobo & Espinoza, 2004)). The main cities are indicated.



We conclude that there is insufficient evidence to support the identification of SDSU-1924 from Chile as *L. tacnae*, because: 1) The female SDSU-1924 (Figure 1a) differs in its dorsal color pattern compared to the only known female specimen of *L. tacnae* (MCZ R-49210, Figure 1b), since MCZ R-49210 has spotted dorsolateral stripes, a spotted head and the absence of a vertebral field lighter than the paravertebral field, 2) the dorsal body scales of *L. tacnae* terminate more sharply than those of SDSU-1924, and 3) both species differ in counts of the scales around midbody (58 in SDSU-1924, but 44-47 in *L. tacnae*) and the neck scales (41 in SDSU-1924, but 28-34 in *L. tacnae*).

Moreover, *L. tacnae* has been collected at the Toquepala Mine and the Cuajone Mine, both from Perú. Toquepala Mine is approximately 160 km (straight line) from Chapiquiña (Chile). However, Pincheira-Donoso & Núñez (2005) mistakenly listed the type locality of *L. tacnae*, as “Tacna, Perú”, which is approximately 80 km from Chapiquiña (straight line). In the section “material estudiado” the authors mention the SDSU-1924 specimen as collected in Chapiquiña, but in the legend of the photograph is mentioned as collected in Perú.

The SDSU-1924 specimen exhibits a combination of characters that do not coincide with those found in the other known species of the *alticolor-bibronii* group that occur near Chapiquiña (Figure 2). In fact, *Liolaemus* sp. (SDSU-1924) has a greater number of midbody scales (58) compared with *L. alticolor* (39-51) (Quinteros, 2012) and *L. puna* (43-54) (Lobo & Espinoza, 2004). Additionally, *Liolaemus* sp. (SDSU-1924) differs from *L. alticolor* and *L. puna*, due to the absence of paravertebral dark stripe (females of *L. alticolor* and *L. puna* have paravertebral dark stripes).

With respect to the pattern of coloration, Lobo & Espinoza (2004) and Quinteros (2012) indicate that *L. tacnae* does not have a vertebral line nor dorsolateral stripes. However, examination of digital photographs of the specimens shows that dorsolateral stripes may be present (spotted or immaculate) or absent. The vertebral line may be fragmented (Figure 1c) or inconspicuous. The coloration of the throat and belly is melanistic in the male. In the female, the throat is spotted and the

coloration of the belly is grey.

In conclusion, we find no evidence to support the existence of *L. tacnae* in Chile and it must be considered endemic to Perú. Specimen SDSU-1924 differs from all known species of the *alticolor-bibronii* group that occur near Chapiquiña, and for the present must be designated as *Liolaemus* sp. Further research and collection of more specimens is needed to clarify the identity of the populations of *Liolaemus* sp. from Chapiquiña.

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## NATURAL HISTORY NOTES

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**PHYLLOMEDUSA IHERINGII:** EGG PREDATION. *Phyllomedusa iheringii* Boulenger (1885) is a tree frog that occurs in the Pampa biome of Uruguay and state of Rio Grande do Sul, Brazil (Langone et al., 1985; Frost, 2011). The reproductive period of this anuran species extends from October to December (Achaval & Olmos, 2007). *P. iheringii* uses vegetation to vocalize and to spawn. Eggs of this species hatch into exotrophic tadpoles that drop into lentic water (mode 24 sensu Haddad & Prado, 2005).

Two events of clutch predation of *P. iheringii* were observed. In the first event (15 December 2011), the snake *Liophis jaegeri* Günther (1858) (Colubridae) was recorded consuming the clutch in a swamp edge in Santa Maria municipality, Rio Grande do Sul, Brazil (29°43'15.68"S, 53°43'35.58"O, 92 m). The clutch was deposited at 120 cm height, on leaves of *Eupatorium imulaefolium* (Asteraceae) in the water-body edge. The observation occurred during the night period (at 20:00 h) and there were no adult individuals of *P. iheringii* around the clutch. The snake was wrapped in the vegetation and was eating the clutch with its head into the leaf nest containing the eggs (Figure 1). With observer arrival the snake escaped into the water. We did not find any more clutches on the same vegetation. On the next day (16 December 2011), the snake was found in the same place at about 20:30h, coiled on exactly the same plant.

Clutch predation of *Phyllomedusa* spp. by snakes were reported for *Leptodeira annulata* and *Liophis miliaris* (Castanho, 1996; Martins & Oliveira, 1998). *Liophis jaegeri* occurs in southern Brazil and is associated with flooded environments



**Figure 1.** *L. jaegeri* eating the clutch of *P. iheringii*. The head of the snake is into the leaf nest containing the eggs, at 120 cm height, in a swamp edge in Santa Maria municipality, RS, Brazil.



**Figure 2.** Ants (*Camponotus* sp.) attacking eggs of *P. iheringii* in the leaf nest. The nest was in an herbaceous plant, at the margin of a pool, municipality of São Sepé, Rio Grande do Sul, Brazil.

(Lema, 1994). The diet of this snake is composed essentially of anurans (Achaval & Olmos, 2007). However, there is only one case of an anuran clutch predation by *L. jaegeri*, which was on the underground nests of *Leptodactylus plaumanni* (Solé & Kwet, 2003), since *Liophis jaegeri* occupy semiaquatic habitats and is not expected to be found suspended at 120 cm above the vegetation.

The second event of egg predation of *P. iheringii* was observed at 16:00 h on 5 November 2011, in the edges of a pool in the municipality of São Sepé, Rio Grande do Sul, Brazil (30°15'03.9"S, 53°35'05.1"W, 198 m). At least three clutches of *P. iheringii* were found in leaves of *Vernonia tweediana* (Asteraceae), about 20 cm above the water surface. The nests were partly open and the eggs were being attacked by ants (*Camponotus* sp.). The capsules of the eggs were broken and the ants were eating the yolk (Figure 2). The genus *Camponotus* belongs to the subfamily Formicinae and it is a very diverse group (Vittar, 2008). Species of this genus forage in the late afternoon and at night, feeding mainly on nectar and liquid substances (Alsina et al., 1988; Vittar, 2008). Most of the time, they are opportunistic, of a medium to large size and some species have arboreal habits (Silvestre & Silva, 2001; Vittar, 2008).

Amphibian reproductive modes with non aquatic eggs probably reduce predation by aquatic invertebrates, but they expose the eggs to attack from a variety of other predators (e.g. crabs, spiders, beetles, wasps, crickets, and dipteran larvae) (Wells, 2007). In fact, species of beetles, flies and mammals were observed preying on the eggs of two species of *Phyllomedusa* at Floresta Amazônica, where about 77% egg mortality was caused by phorid fly larvae and staphilinid beetles (Neckel-Oliveira & Wachlevski, 2004). These are the first records of clutches predation of *P. iheringii*. We do not know the real impacts of these predations in population dynamics, however ants of *Camponotus* sp. and the snake *L. jaegeri* can be important egg predators where these species coexist.

#### ACKNOWLEDGEMENTS

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**Figure 1.** Predation on *H. mabouia* by *C. ani*, observed at Açailândia municipality, Maranhão state, northeastern Brazil. Photo by A. L. Silveira.

**HEMIDACTYLUS MABOUIA** (Tropical House Gecko): PREDATION. The gekkonid *Hemidactylus mabouia* (Moreau de Jonnés, 1818) has been historically introduced into the New World, establishing itself in many countries of South and Central America (Howard et al., 2001; Anjos & Rocha, 2008), and southern United States (Meshaka, 2000). It presents nocturnal habits, and is often found in anthropic environments (Anjos et al., 2008). Despite its wide geographic distribution, few works have been done on the natural history and ecology of *H. mabouia*, according to Howard et al. (2001). The latest published records of predation of this lizard species were published by Wojnowski & Selempo (2005), which reported the predation of *H. mabouia* by the bat *Cardioderma cor* Peters, 1872, and Diniz (2011), which reported the predation of *H. mabouia* by the spider *Nephilengys cruentata* (Araneae: Nephilidae). This paper reports the predation of *Hemidactylus mabouia* by the bird *Crotophaga ani* Linnaeus, 1758, observed in an urban area.

The observation took place on 06 December 2011, at 13:00 h, within the municipality of Açailândia (4°57'22" S, 47°29'39" W; 248 m), Maranhão state, northeastern Brazil. An adult

individual of *C. ani* was perched on a wall located on a vacant lot, when it flew to the ground, captured the lizard with the beak and flew back to the wall, and after to a tree, where predation occurred (Figure 1).

*C. ani* is known for feeding mainly on invertebrates, such as insects and arachnids (Repenning et al., 2009; Ramos et al., 2011). Nevertheless, Repenning et al. (2009) reported the predation of a bird by *C. ani*, indicating that this species can occasionally forage on vertebrates.

We suggest that *H. mabouia* could be an unusual item on the diet of *C. ani*, once this bird presents diurnal habits, contrariwise to this lizard species, which is nocturnal. Thus, the predation event related on this paper should be taken as opportunistic.

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**GYMNODACTYLUS GECKOIDES** (Naked-toed Gecko): PREDATION. The use of pitfall traps is extremely efficient in the sampling of vertebrates such as amphibians, reptiles and small mammals (Mengak & Guynn, 1987; Condez et al., 2009; Sousa et al., 2010). Several studies have reported the effectiveness of this method (Greenberg et al., 1994; Cechin & Martins, 2000), and others studies have exposed problems (Crosswhite et al., 1999) including mortality of animals inside the traps (Enge, 2001) by desiccation (Jenkins et al., 2003), predation by vertebrates (Ferguson et al., 2008) and invertebrates (Bocchiglieri & Mendonça, 2010). Predation events within pitfall traps are rarely published and until now there are no reports of predation of *Gymnodactylus geckoides* by giant ants inside these pitfall traps.

Here we report the moment that a species of giant ant *Dinoponera quadriceps* (Hymenoptera, Formicidae: Ponerinae) was observed preying adults individuals of *G. geckoides* (Squamata, Phyllodactylidae) in an area of Caatinga in northeastern Brazil. The observations occurred on May 16, 2010 at 08:54 h and January 21, 2011 at 04:35 h in Monumento Natural Grota do Angico (9°39'50"S, 37°40'57"W; 200 m above sea level; Datum SAD-69) between the municipalities Poço Redondo and Canindé do São Francisco, Sergipe, Brazil. One of the lizards was dead inside the pitfall trap (Figure 1) and the other had its tail predated by ants. *D. quadriceps* is a typical queenless ponerine, a carnivore and solitary, occurring in biomes such as Caatinga, Cerrado and Atlantic Forest (Paiva & Brandão, 1995; Fourcassié & Oliveira, 2002). *G. geckoides* is a small lizard that occurs in the Caatinga biome, has diurnal habits and feeds primarily insects (Vanzolini, 2004; Vitt, 1995). The distribution of *D. quadriceps* contrasts with the distribution of *G. geckoides* and can probably occur in interspecific encounters triggering the predation of this lizard by this ant in nature.

Predation of lizards by giant ants have already been reported by Sousa & Freire (2010) who observed that *Coleodactylus natalensis* had been



**Figure 1.** *G. geckoides* killed by giant ants in pitfall trap (Photo by CBD-Carvalho).

predated by *D. quadriceps* in an Atlantic Forest. Two other species of lizards, *Cnemidophorus ocellifer* and *Hemidactylus brasiliensis*, have also been predated by this ant in a pitfall trap in the Caatinga region (Ribeiro et al., 2011). However many other invertebrates can prey on lizards within pitfall traps. Bocchiglieri & Mendonça (2010) report predation of *Tropidurus oreadicus* by *Lycosa erythrognatha* inside pitfall trap in the Cerrado region. This is the first record of predation of *G. geckoides* by giant ants to Caatinga and the state of Sergipe, Brazil.

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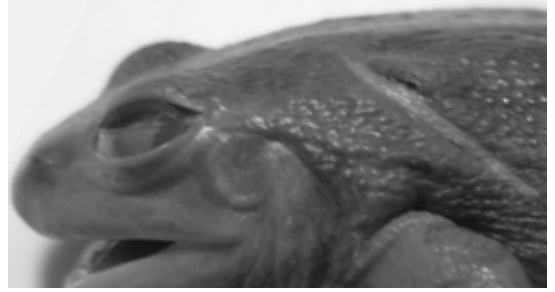
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**PSEUDACRIS STRECKERI ILLINOENSIS** (Illinois chorus frog): LARGE WOUND IN HOLOTYPE. Injuries to anurans are relatively common and thus are now seldom reported in the literature. However, I found a healed wound of such a large magnitude in the holotype of *Pseudacris streckeri illinoensis* Smith, I feel it is worth reporting. This small, muscular frog is distributed in relictual populations in sand areas of the central Midwest, USA (Conant & Collins, 1998; Phillips et al., 1999). It is highly fossorial and makes exclusive use of its enlarged forelimbs in forward burrowing (Brown et al., 1972). The holotype (INHS 5982, deposited in the Illinois Natural History Survey) is a sexually mature male collected in the Pleistocene sand area near Meredosia in west-central Illinois, USA in 1950 (Brown & Rose, 1988). The wound is evident by a light yellow scar extending obliquely from behind the left forelimb dorso-anteriorly toward the midline (Figure 1). The scar is not mentioned in the lengthy holotype description by Smith (1951)



**Figure 1.** Holotype of *P. streckeri illinoensis* (INHS 5982) showing wound evidenced by long scar (pale gray) extending obliquely from behind forelimb dorso-anteriorly toward the midline. Photo by T. Cheung.

even though it is quite obvious. The scar is long (8.7 mm) and nearly straight with an opening (2.1 mm in length) where the wound had not completely healed adjacent and somewhat posterior to the anterior region of the scar. Scar tissue lines the sides of this opening and the scar is widest in this area. The integument is quite swollen on the posterior side of the opening. Considerable alcohol emerged from the opening when slight pressure was applied, suggesting that the wound extends into the coelom, at least in this area. The frog otherwise appears quite normal externally and is not emaciated. Its SVL is 39 mm which is near the mean of 37.3 mm for 37 sexually mature males of *P. s. illinoensis* reported by Brown & Means (1984). The length of the wound of the holotype is 22.3% of its SVL. Many vertebrates would probably not be able to survive a wound of this magnitude.

I thank: Tak Cheung for Figure 1; Jill Brown, Angelo Capparella, Edward Mockford, and Chris Phillips for critically reading the ms; and Chris Phillips for loan of the holotype.

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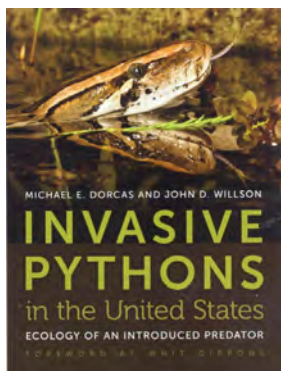
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### *Invasive Pythons in the United States: Ecology of an introduced predator*

Michael E. Dorcas and John D. Willson  
Georgia University Press  
ISBN-13: 978-0-8203-3835-4



The US State of Florida and its famous Everglades wetlands are no strangers to exotic residents. Not only does Florida's climate make it a favourite retirement destination, but the sub-tropical temperatures made it a logical hub for the reptile and exotic pet industry. As a consequence, many imported animals have escaped and become established in the area. One of the most infamous of these is the Burmese Python (*Python molorus bivittatus*) which have established sizeable breeding populations. The large size and public reaction of pythons have garnered a great deal of media attention.

In an undeniably attractive volume, Dorcas and Willson have given an informative overview of the python problem and the difficulties facing those scientists, enthusiastic amateurs and agencies trying to address the issue. A professor of biology and graduate research student respectively, they are clearly well-informed and passionate about their subject. The issue is placed firmly within the context of invasive species, and sections included for non-herpetological specialists. These sections include "About Pythons", "Scientific research on Pythons" and "Pythons in the pet and skin trade". Indeed, given the focus of the book it is very even-

handed toward the pet industry, acknowledging the role snake-keeping can play in educating the public and thus conserving wildlife. Overall this is an affordable, readable and very informative book for specialist and interested general readers alike.

Perhaps the only serious criticism that can be levelled at this book, or rather, some of the work it reports relates to an experiment conducted with 10 Burmese Pythons which were housed in an outdoor facility in South Carolina in 2009 in an effort to establish whether or not the animals could become established in other parts of the USA, particularly the more temperate regions. The book explains the shortfalls inherent in many of the climate-matching studies which this might have underpinned, but did not acknowledge the problems identified in the Rodda (2009) paper on which they based the experiment. Given that the distribution map printed in this book demonstrates a dramatic drop in numbers immediately north of "Alligator Alley" the main road which bisects the Everglades.

Other than this I would recommend this to anyone interested in snakes, reptiles, the Everglades or, and perhaps especially, those interested in the impact of introduced species and the exotic pet-trade. Of course, since this book has been written there have been significant changes to the US legislation regarding the keeping of these snakes in Florida (it has been banned) and there are stringent restrictions on their being moved between states.

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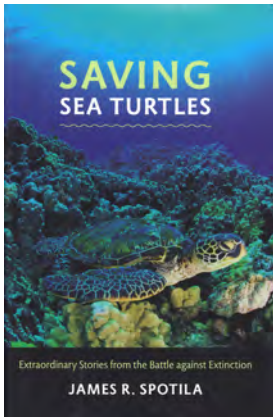
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*Saving Sea Turtles: Extraordinary Stories from the Battle against Extinction*

James R. Spotila

2011, Johns Hopkins University Press. 216pp.



James Spotila has been involved in the conservation of marine turtles for over forty years. This book is essentially a personal account of his experiences both in the field, on the beaches of Central America, and when working with colleagues to establish campaigns and progress the cause of turtle conservation in the political sphere, often against bureaucratic obstinacy and self-interested opposition.

However it is more than that. It sits firmly within the genre of popular science and intersperses the personal anecdotes with a raft of information on the biology and behaviour of turtles, uncovering the personalities and the scientific processes that have contributed to our understanding of these animals.

The book is presented in fifteen chapters each tackling a different topic, either on turtle biology, a specific threat to turtles, or a campaign or initiative to promote and conserve turtles. Each chapter is further divided by subheadings into bite-sized chunks of relevant information, making it easy to find particular topics or to refer back if necessary, but also making it easy to dip in and out. Occasionally I found the writing style a little irritating, sometimes becoming uncomfortably moralistic and emotional in tone. However, the

book is easy reading and it moves along at an engaging pace.

When I sat down to read the book I was expecting a review of turtle conservation initiatives across the world, but that is not what this is. It is set almost entirely in Central America and, whilst some work outside this region gets a passing mention, it is not discussed in much detail. Europeans may find this a little disappointing, but it succeeds in giving the book a more personal feel than it might otherwise have had as the author draws almost exclusively on his own extensive experience.

The book explores each of the myriad of threats to turtles and describes the exhaustive search for solutions. I remember some of the campaigns described here, such as the efforts to ensure that all shrimp trawlers fit Turtle Excluder Devices (TEDS) to their nets. But what I found completely compelling was discovering the inside story to these campaigns and gaining an appreciation of just how difficult it can be to implement simple common sense solutions.

This book also emphasises the importance of local involvement in conservation initiatives, demonstrating how egg poachers have, on occasion, been successfully turned into conservationists by providing the right incentives. Where local people have been excluded, initiatives have usually failed. While this is now conventional wisdom in any conservation programme, Spotila's involvement covers a long period of time so this book provides a microcosm of the evolution of such ideas.

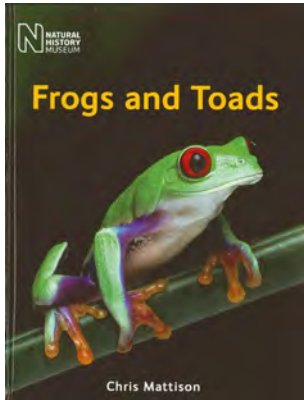
Being involved in conservation is often a frustrating business, but probably never more so than when sea turtles are your subject. Oscillating between the fundamentally depressing and the surprisingly optimistic, this book reveals the sheer determination and persistence required to achieve anything against official obfuscation and inertia. The people whose stories are told here have all contributed enormously to the conservation of sea turtles and despite the many setbacks both past and foreseeable, the tone of the book remains one of optimism for the future of sea turtles.

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## *Frogs and Toads*

Chris Mattison

2011, Natural History Museum, London. 192 pp.



I didn't read *Frogs and Toads* (Chris Mattison) cover to cover; I dipped in and out of the sections that were of most interest to me and flicked through to look at the pretty pictures. I think it's designed for this kind of use, as it is helpfully divided into broad topics over its ten chapters for relatively quick reference to the various themes. The index also comprehensively allows you to go straight to a species of interest using either the common name or binomial nomenclature.

The book contains hundreds of really beautiful photographs, of some really weird and wonderful anurans. It would serve as an entertaining coffee-table book for the herpetologically minded, though would be a little wasted if only used in that way. I find myself regularly flicking through it if I have a spare moment to discover something new, without even referring to the text. The text is however, very informative and covers a broad range of topics with chapters on origins and classification, morphology, ecology and behaviour. Chapter and sub-section order is logical and means the topics flow quite naturally from one to the next. However, perhaps I would have placed the chapter on Families (Chapter 10) directly after Origins and Classification (Chapter 1) to allow the reader to get a feeling of the immense diversity of frogs and toads really early on. It would also mean that some of the more bizarre photographs could be

revealed sooner, such as the Mexican burrowing frog and the Indian purple frog. It's a shame that at the time that this book was published there had not yet been the description of the tiny frog species (*Paedophryne amauensis*) discovered in Amau, Papua New Guinea (7.7 mm average length) which hit the news in January 2012; as it makes the range in size given for frogs (10 to 300 mm) in Chapter 2, slightly inaccurate.

I really enjoyed reading Chapter 4 Enemies and Defence. I felt the methods of defence were comprehensively covered with sections dedicated to camouflage, toxic secretions and smell, mimicry, feigning death, attack and even finishing with a description of the defence mechanisms employed in eggs and tadpoles. I especially enjoyed the section on crypsis through camouflage, as the accompanying photographs were excellent. I was particularly interested in the content of Chapter 9, Frogs and Man. This chapter contains some general interest pieces as it describes the traditional uses of frogs and toads in medicine but also goes on to touch on conservation issues such as habitat destruction and fragmentation, disease and exploitation. I would have perhaps liked a little more detail in the Conservation section, with description of some other current conservation research.

Overall, I enjoyed looking through this book, it seems well researched and I expect I will continue to return to it every now and then for quite some time. The main strength is in the quality and diversity of the photographs.

I imagine this book will appeal to amateur naturalists and professional herpetologists alike.

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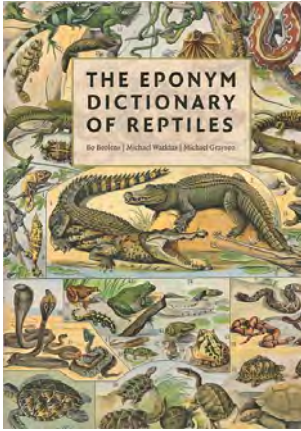
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## *The Eponym Dictionary of Reptiles*

Bo Beolens, Michael Watkins and Michael Grayson

Johns Hopkins University Press

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Few books written on herpetology would initially seem less enticing to the layperson. An unillustrated dictionary written exclusively about the people, places or things after which scientists have chosen to name reptiles. So, we learn that the Helmeted Gecko (*Tarentola chazaliae*) gets its name from the name of the discoverer's yacht, the Chazalia and that Robert Arthur Johnston (after whom the Australian crocodile is named) was a policeman who would tease children by suddenly pulling snakes from his shirt. Each name is followed by the names (common and binomial nomenclature) and the name of the describer and the date, along with a piece of interesting biographical data.

This might seem a collection of rather quaint and amusing anecdotes. Perhaps even the sort of 'QI'/pub quiz brand that may be seen as somewhat frivolous scholarship. Of course, it can inform the interested who are looking up a given species, something those with 'favourites' will do so fairly selectively. In fact, it was whilst looking for species I keep that I found one omission from the book, Ross Allen, the US herpetologist, after whom the stunning Everglades ratsnake (*Pantherophis obsoletus rossalleni*) is named. Others with more specialist knowledge may find further omissions.

Any omissions are perhaps outweighed by the restraint the authors show regarding a well-known Australian snake-keeper and self-styled taxonomist who has, effectively, named several species after himself and caused significant confusion. However, to relegate this book to the 'gift section' as a novelty is to miss the true value of this work. Few books illustrate as clearly the adage that science does not take place in a vacuum. Those earnest workers toiling neutrally in the apparently positivist quest to unlock the secrets of taxonomy are actually themselves the subject of societal pressures and influences. These pressures have changed over time as has the way herpetology has been conducted generally. It gives an insight into the different events and perspectives which have acted upon these workers, as well as provided the sources for many of the specimens. It will not be missed by the reader that many of these reptile species have been named after military explorers and colonialists.

In terms of layout, this book lends itself to being a work of reference or something the more casual reader may wish to dip into. It is not illustrated, which might have made it an even more pleasant read, but this would probably increase the price.

So overall, this is a book highly recommended to the specialist herpetologist, science historian or interested layperson. Hopefully soon the authors will find equally fascinating facts about the amphibians of the world.

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