

## Influence of Toe-Clipping on Running Speed in *Eulamprus quoyii*, an Australian Scincid Lizard

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**ABSTRACT.**—Toe-clipping has been widely used for individual identification of amphibians and reptiles. It is costless and easy to apply and read. An animal's locomotor speed may affect its ability to acquire food, to avoid predation, and to achieve a high social status. Thus, it is of interest to determine whether toe-clipping affects the running speed of lizards. Wild caught Eastern Water Skinks (*Eulamprus quoyii*) were run in a race track in three consecutive sessions. In the first session, all animals were run with their toes intact. Half of the animals had their toes clipped between the first and second session, whereas the other half were toe-clipped between the second and the third session. Neither the average or maximum running speeds of lizards were affected by toe-clipping.

To address questions in ecology and evolution, it is often necessary to be able to identify individual animals for long periods of time. A wide variety of techniques have been used for this purpose in reptiles (e.g., Boone and Larue, 1999; Ferner, 1979; Hudson, 1996; Rodda et al., 1988). The choice of a suitable technique depends on the study species (e.g., size, habits, skin type), the characteristics of the study (e.g., captivity or natural environment, number of animals involved, duration of the study, distance at which the animals are to be identified) and budget.

Radio transmitters have the advantage of allowing localization and remote measurement of additional variables such as temperature (e.g., Reinert, 1992). Although their size has been considerably reduced and their useful life and capabilities have increased in the last decade, they are still too large for most reptile species. Passive integrated transponder (PIT) tags are practical alternatives when remote sensing is not required. However, both PIT tags and radio transmitters are expensive, require the use of readers or receivers to identify the animals, and involve invasive procedures for implantation. Painting is inexpensive and easy to use and read but lasts for only a short time and can cause secondary problems (Jones and Ferguson, 1980; Boone and Larue, 1999). Toe-clipping has been widely used for individual identification of amphibians (e.g., van Wijngaarden and van Gool, 1994; Ryser 1996) and reptiles (e.g., Huey et al., 1990; Marco and Perez-Mellado, 1998).

Ideally, a marking technique should not interfere with the biology of the animals under study. A number of studies have tested the effect of toe-clipping on amphibian survival and behavior. Abundant and sometimes conflicting information suggests that the effects of toe-clipping can vary widely among different amphibians (e.g., Clarke, 1972; Stanford, 1996; Auburn, 1999; and references therein). Surprisingly, studies on potential secondary effects of toe-clipping on lizards are scarce, despite the frequent use of this technique for such animals.

Running speed is commonly used as a whole-body performance measure in reptiles (e.g., Huey et al., 1990; Sorci and Clobert, 1997; Elphick and Shine, 1998). An animal's locomotor speed may affect its ability to acquire food, to avoid predation, and to achieve high social status (e.g., Christian and Tracy, 1981; Garland et al., 1990; Huey et al., 1990; and references there in). Speed is also potentially useful as an index of physiological and morphological capacities. Thus, it is of interest to determine whether toe-clipping affects the running speed of lizards. Here, we report the results of such a test on adult Eastern Water Skinks (*Eulamprus quoyii*).

The *E. quoyii* belongs to a species complex of four morphologically similar species that differ mainly in size and geographic distribution (Cogger, 1992). *Eulamprus quoyii* is a medium-size viviparous lizard with a mean ( $\pm$  SD) snout-vent length (SVL) of  $112 \pm 9$  mm (this study,  $N = 44$ ). It is found on the coast and ranges of eastern Australia, from northern Queensland to southern New South Wales, extending via the Darling River system to western Victoria and southeastern South Australia (Cogger, 1992). They live mainly along water bodies, although larger individuals are sometimes found on ridges far from water (Swan, 1990).

*Eulamprus quoyii* is a shuttling heliotherm, depending strongly on basking to thermoregulate. Voluntary minimal and maximal temperatures (those within which activity has been recorded in the field) are around 24° and 34°C, respectively, with a mean of 28.5°C (Veron and Heatwole, 1970; Spellerberg 1972). They are commonly seen basking on top of rocks, in the vicinity of holes or crevices where they run for shelter when threatened (pers. obs.).

### MATERIALS AND METHODS

All animals used in this trial were adults caught in wild areas around Sydney, either by noosing or with the help of sticky traps (Downes and Borges, 1998). Forty four adults (nine males and 35 nongravid females) were randomly allocated to two groups of 22 individuals each (group 1 and group 2). All animals were run a total of six times in three consecutive sessions of two runs each. We allowed the animals to rest for a minimum of 10 min between runs in the same session and a minimum of 20 min between sessions. The trials were performed in a temperature-controlled room at 28°C

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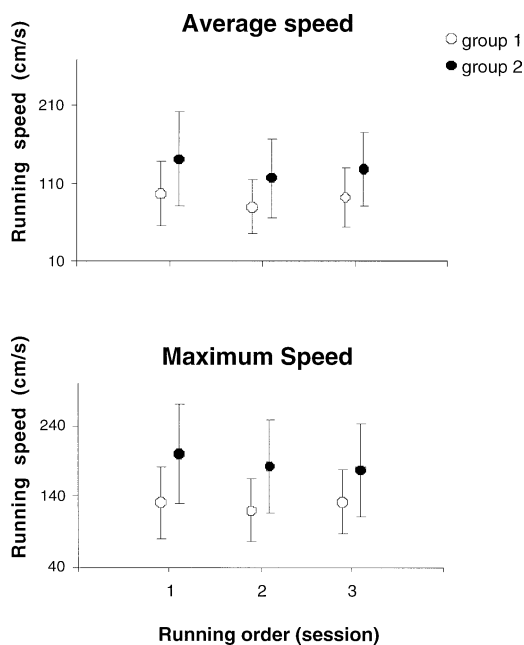


FIG. 1. Effect of toe-clipping on average running speed (over 1 m) and maximum running speed (over 25 cm) in the lizard *Eulamprus quoyii*. Animals in group 1 had their toes clipped between the first and second sessions, whereas animals in group 2 were toe-clipped between the second and third sessions. The lack of a significant interaction between session and group indicates no effect of toe clipping on running speed. Datapoints represent the average ( $\pm 1$  SD) of 22 animals for each session.

( $\pm 1^\circ\text{C}$ ). Before the trial, the animals were allowed to equilibrate to room temperature for an hour. In the first session, all animals were run with their toes intact. Animals in group 1 had their toes clipped between the first and second session, whereas animals in group 2 were toe-clipped between the second and the third session. A toe was clipped by removing the distal one-third of it with sharp scissors. A total of three toes were clipped from each animal with no more than one toe clipped per foot. The particular combination of feet and toes for each individual was chosen randomly with the only restriction of using a unique combination for each animal.

Running speed was measured in a 1 m long, 4 cm wide race track with sand glued to the running surface. The race track was previously equilibrated at the trial temperature. The animals were placed at the beginning of the race track and collected at the end. If necessary, we chased the lizards with a paintbrush to encourage them to run. Photocells connected to a stopwatch enabled us to record the speed of the animals every 25 cm. The speed over 1 m ("average speed" hereafter) and the speed over the fastest 25-cm section ("maximum speed" hereafter) were recorded in each run. The mean of the two runs in a session was used as the value for average and maximum speed for that session.

We used a two way repeated-measure ANOVA with session as the repeated factor and group as the other

factor. If toe-clipping affected running speed, differences in trends between the two groups should generate a significant interaction between session and group. This design allowed us to control simultaneously for individual differences and time effects. Data were checked to meet the assumptions of all statistical tests. Homogeneity of variance was tested using Cochran's test (Underwood, 1997), and normality was checked through visual inspection of the residuals. All tests were run at a level of significance of 0.05 using SuperAnova 1.11 and Statview 5.0 (Abacus Concepts, Incorporated, Berkeley, California) with the exception of the Cochran tests which were performed by hand.

## RESULTS

Sex did not significantly influence running speed before toe-clipping (average speed:  $F_{1,20} = 1.37$ ,  $P = 0.26$ ; maximum speed:  $F_{1,20} = 0.69$ ,  $P = 0.42$ ); thus, males and females could be pooled together for the rest of the analyses. Toe-clipping did not significantly affect either the average (interaction term:  $F_{2,84} = 0.21$ ,  $P = 0.91$ ) or maximum running speed (interaction term:  $F_{2,84} = 1.09$ ,  $P = 0.34$ ) of lizards. Unexpectedly, the group that a lizard was randomly assigned to had a significant effect on both average and maximum running speed (average: [ $F_{1,84} = 12.68$ ,  $P < 0.01$ ]; maximum: [ $F_{1,84} = 16.20$ ,  $P < 0.01$ ]); although time (or session) significantly affected average but did not have an effect on the maximum running speed [(average  $F_{2,84} = 3.89$ ,  $P = 0.02$ ]; maximum: [ $F_{2,84} = 1.64$ ,  $P = 0.20$ ]). However, none of these effects could be attributed to toe-clipping (Fig. 1). All wounds caused by clipping were completely healed two weeks after the trial. None of the animals showed signs of infection, inflammation or any other obvious adverse effect.

## DISCUSSION

Our results show that running speed can be reliably measured on water skinks when using toe-clipping as an identification method. All animals were run within the first 30 min after being toe-clipped. If toe-clipping affected running speed, it would be more likely to do so in this period than after the wound had healed completely. The effect of toe-clipping on other variables cannot be predicted from data on running speeds. Nevertheless, running speed is more likely to be affected by toe-clipping than most other measurements of organismal performance because of its obvious dependence on the limbs and toes. Although claws are important in water skinks for climbing rocks and logs (pers. obs.), it is unlikely that the removal of one toe per limb would affect this activity. No obvious adverse effects on climbing ability were observed when the animals were released in the field. Nonetheless, more specific studies would be needed to properly address this issue.

As in our experiment, Paulissen and Meyer (2000) clipped a maximum of one toe per limb and used an experimental design that involved examining the interaction effects. They did not find any effect of toe clipping on the ability of the gecko *Hemidactylus turcicus* to cling and run along vertical walls. Dodd (1993) did not find a significant effect of toe-clipping on the running speed of the Six-Lined Racerunner (*Cnemidophorus sexlineatus*). Unfortunately, the animals in his study were run once before and once after toe-clipping,

confounding the effects of time and toe-removal. In our experiment, time affected average running speed, but this effect could be separated from potential effects of the marking technique. In studies of the iguanid *Sceloporus merriami*, Huey et al. (1990) did not find a significant association between the number of toes lost (either naturally or by artificial clipping) and running speed (adjusted by sex, weight, and capture site). Hudson (1996) discussed potential implications of toe-clipping based on natural rates of toe loss in several species of Australian skinks. The information is useful by showing that toe loss is frequent in some of those species, and therefore toe-clipping is unlikely to generate effects not commonly found in nature. Nevertheless, it does not imply the lack of important secondary effects. The probability of toe loss in nature may be associated with specific characteristics (e.g., sex, reproductive status, or size). Hudson (1996) found a greater incidence of toe loss in terrestrial than in scansorial species. He also found a trend for females of terrestrial species to be more likely to lose toes in relation to males than their scansorial counterparts. If toe loss is associated with some phenotypes more than with others, its secondary effects could be considered as a component of that phenotype. Toe-clipping is more reliable as a marking technique in species where natural toe loss is rare. Those species should be the main goal of studies on the secondary effect of this marking technique. Very few of the lizards used in our study showed naturally lost toes when captured in the wild.

Carothers (1986), working with *Uma scoparia*, found that the effect of removing toe fringes on running performance was substrate dependent. *Uma scoparia*, a sand dwelling lizard, run faster an achieved higher acceleration with their toe fringes than without them when run on loose sand. The treatment had no effect on a rubber substrate. The running surface used in our trials, sand glued to a wooden plank, simulates very accurately the surface of the rocks along water bodies where the animals usually bask. Therefore, in this respect, our results are likely to be comparable to the performance of the animals in their natural habitat.

The scant number of studies currently available show no secondary effects of toe-clipping on locomotor speed in lizards. Nonetheless, the widespread use of toe-clipping as a inexpensive and easy way to individually identify lizards calls for more research on the reliability and limitations of the information collected when it is used. Appropriate experimental design is indispensable if a valid assessment of the technique is to be achieved.

*Acknowledgments.*—We want to thank E. Herrera, G. Barreto, and V. Sanz for their comments on the original manuscript. People in the Shine lab (University of Sydney) helped in several ways and made the work enjoyable. This research was funded by Fundación Gran Mariscal de Ayacucho (Venezuela) and the Australian Research Council. All experimental procedures were conducted with the approval of the Animal Care and Ethics Committee of the University of Sydney.

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Accepted: 11 April 2003.

*Journal of Herpetology*, Vol. 37, No. 3, pp. 595–602, 2003  
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## Growth and Development of Larval *Rana temporaria*: Local Variation and Countergradient Selection

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**ABSTRACT.**—I raised tadpoles of the Common Frog (*Rana temporaria*) from populations in eight source ponds in southern Sweden, in a common garden experiment at two densities. Tadpoles from different populations differed in development rate; those from source ponds with high tadpole densities developed faster than those from less crowded ponds. Thus, differences among ponds in tadpole performance, which were documented in previous field studies, must have a genetic or maternal component. This result of source pond crowding likely resulted from microevolution and is an example of countergradient selection. In contrast, I found no significant effect of source pond hydroperiod; tadpoles from temporary ponds grew and developed at a rate similar to those from permanent ponds. Tadpoles of *R. temporaria* can respond plastically to pond drying by increasing development rate. I suggest adaptive plasticity in development rate decreased selection by pond drying in natural ponds.

Local character variation is found in many species and arises from direct effects of environment on the phenotype or from underlying genetic variation. Phenotypic variation may be adaptive, which is usually referred to as adaptive plasticity (Via et al., 1995; Pigliucci, 1996), or nonadaptive, having the character of environmental modulation (sensu Smith-Gill, 1983). Similarly, genotypic variation may be adaptive (an effect of microevolution) or the result of nonadaptive processes (i.e., genetic drift or founder effect). In amphibians, two major causes of variation are those related directly to pond quality and those related to differences among eggs from which larvae hatched. The latter includes both genetic and maternal effects, such as egg size (Rossiter, 1996; Bernardo, 1996; Loman, 2002a).

In southern Sweden, growth and development of Common Frog (*Rana temporaria*) tadpoles, differ among ponds (Loman, 2002b). Ponds studied had several environmental gradients that could influence tadpole growth and development rate, including pond hydroperiod. In the study area (and in other parts of its distribution), Common Frogs frequently breed in ponds that regularly dry before or during metamorphosis

(Cooke 1985; Kutenkov and Panarin, 1995; Loman, 1996, 2002b). This may cause catastrophic mortality, but tadpoles of Common Frogs partly counter this (at least under laboratory conditions) by accelerating development when subject to cues suggesting pond drying (Loman, 1999; Merilä et al., 2000a). Another gradient was tadpole density, which varied considerably among ponds (Loman, 1996, 2002c). At high densities, tadpoles tend to develop more slowly and metamorphose later than those growing under low densities (Wilbur, 1977; Loman, 1999; Brady and Griffiths, 2000).

Recently, cogradient and countergradient selection (Fig. 1) have attracted renewed interest from ecologists studying character variation (Berven et al. 1979, Conover and Schultz, 1995). Cogradient selection (Fig. 1A) occurs when selection pushes the reaction norm in the same direction as the trait expression that is plastically induced in that environment. For example, when fish were present, salamander (*Ambystoma barbouri*) larvae reduced activity, thus reducing feeding rate (Sih et al., 1992). Under standard laboratory conditions, reduced activity and feeding were most pronounced for larvae from populations at sites with fish; presumably these