Functionality of the blue tongue in blue-tongued skinks (*Tiliqua* sp.)

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The lizard tongue is part of a complex integrated system (hyolingual apparatus) that can be used for a variety of functions. Its structure and use have always fascinated biologists. In the early 20th century the tongue structure was considered an important characteristic in the classification of lizards. Consequently, the first comprehensive classification of lizards (CAMP 1923) was primarily based on exactly such differences in tongue structure and use in lizards: while the more primitive groups have a fleshy, broad tongue that is mainly used during feeding (Ascalabota, mainly chameleons, agamids, iguanids, geckos), the more derived groups have a narrow, elongated tongue that is predominantly used for chemoreceptive purposes (Autarchoglossa, see also UNDERWOOD 1971, SCHWENK 1988). Although scincid lizards are generally considered to be autarchoglossans, they do not show the extreme specializations of the tongue for chemoreception observed, for example, in varanids.

Even nowadays the tongue is sometimes used as a systematic character, one example being the case of the genus *Tiliqua*. Lizards of this genus are characterized by a dark, often blue tongue (hence the vernacular name bluetongues). One species of the genus clearly forms an exception. The pink tongued skink *(Tiliqua gerrardii)* has, as indicated by its common name, generally a pink tongue as an adult (GREER 1989). Still the young animals are born with a dark tongue (BARNETT 1977, ROBERTSON 1980) which gradually looses its color in the adults (STEPHENSON 1977). However, some confusion exists as these lizards are sometimes also characterized as belonging to a separate genus (*Hemisphaeridion,* GREER 1989, COGGER 1992) or to the genus *Cyclodomorphus* (SHEA in COGGER 1992). All the other lizards of the genus are born with a darkly colored tongue and keep this color for the rest of their life.

One of the most frequently asked questions related to bluetongues is what the function of the blue tongue color in these lizards might be. One of the most important functions of the tongue in lizards in general is its assistance in feeding. Lizards of the genus *Tiliqua* do not only use their tongue to transport prey through the buccal cavity (GANS et al. 1985), but also to pick up food items (GANS et al. 1985, KIENE et al. 1996, pers. obs.). Similarly, the tongue is of prime importance for drinking, where it is used to lap up water. During both drinking and prey prehension, the tongue is extended from the mouth, makes contact with the food item or water and is subsequently withdrawn. Still, as tongue prehension is only used while capturing stationary or immobile food items, the coloration of the tongue seems trivial in this respect. One other important function of the

tongue in scincid lizards is chemoreception (COOPER 1994). In order to sample chemicals from the environment the tongue is elongated, extruded from the mouth, flicked through the air and withdrawn. Still, no plausible explanation for the blue coloration of the tongue during tongue flicking can be identified.

Apart from its function during foraging, feeding and drinking, the tongue (actually the whole hyolingual apparatus) is also used for behavioral purposes. The best known examples in this respect are the extension of a brightly colored dewlap as in *Anolis* lizards (GREENBERG 1977) and the flying dragons (*Draco* sp.) from Southeast Asia, and the frill erection of bearded and other dragons (CARPENTER & FERGUSON 1977, THROCKMORTON et al. 1985, BELS et al. 1994). Both types of display are mediated by the action of the hyolingual apparatus which causes an extension of the throat region. Usually such display behavior is used in social interactions with conspecifics, as in anoles, or for defensive purposes as in the case of the bearded dragons.

Most explanations for the blue coloration of the tongue in *Tiliqua* are of a similar nature. Generally, a defensive function is attributed to it, as the tongue is used in display actions during defensive behaviors. Most accounts indicate that the defensive display of *Tiliqua* skinks is very characteristic and stereotyped. Usually the animals flatten the body, and face the intruder. Next they open the mouth widely, extrude the tongue and start hissing loudly (CARPENTER & MURPHY 1978). During such defensive display, the animals may even lunge at a predator, attack and bite.

Two functions of this behavior are provided in literature. Firstly, by the fierce hissing, and the orientation of the animal towards the predator, the latter may confound the lizard (partially due to the crossbanded color pattern) with a death adder (*Acanthophis* sp., GREER 1989). However, this explanation can only be validated for those species with a crossbanded pattern (e.g., *T. occipitalis* or *T. scincoides*). Secondly, by turning towards the threat, opening the mouth and sticking out the bright blue tongue (contrasting vividly with the pink mouth), the predator might simply be scared off (SHEA 1998). Clearluy, whereas the first explanation does not provide any explanation for the blue coloration of the tongue, the second one does. Some support for the second hypothesis can also be found by examining the functional characteristics of the threat behavior. During such threat display, the leaf shaped lingual pad of the flexible tongue can be lifted by pulling the hyoid apparatus forward. Next the tongue is tilted over and past the mandibular symphysis (GANS et al. 1985, pers. obs.). As during these actions the tongue is actively flattened, spread out, and protruded from the mouth, its visibility is greatly increased. Additionally, with blue and red being complementary colors, the contrast and visibility are increased further.

Still, although the explanation that the blue coloration of the tongue serves to deter predators seems plausible, evidence to support it is purely circumstantial. One contradicting argument is the absence of the dark coloration of the tongue in one of the *Tiliqua* species (*T. gerrardii*). If the coloration has a positive effect on predator deterrance, then the predation on *T. gerrardii* should be greater than on congeneric species. An alternative explanation might be that this is only of importance in juvenile lizards which are clearly more vulnerable, and for which predation pressures are usually higher. As the defensive display is even present in near term, but not yet born, young (WAKEFIELD 1956), this indicates that the behavior is innate and not learned. It supports the hypothesis that defensive display might be more crucial for newborn and young animals. If the blue tongue coloration is predominantly functional in juveniles, then *T. gerrardii* also

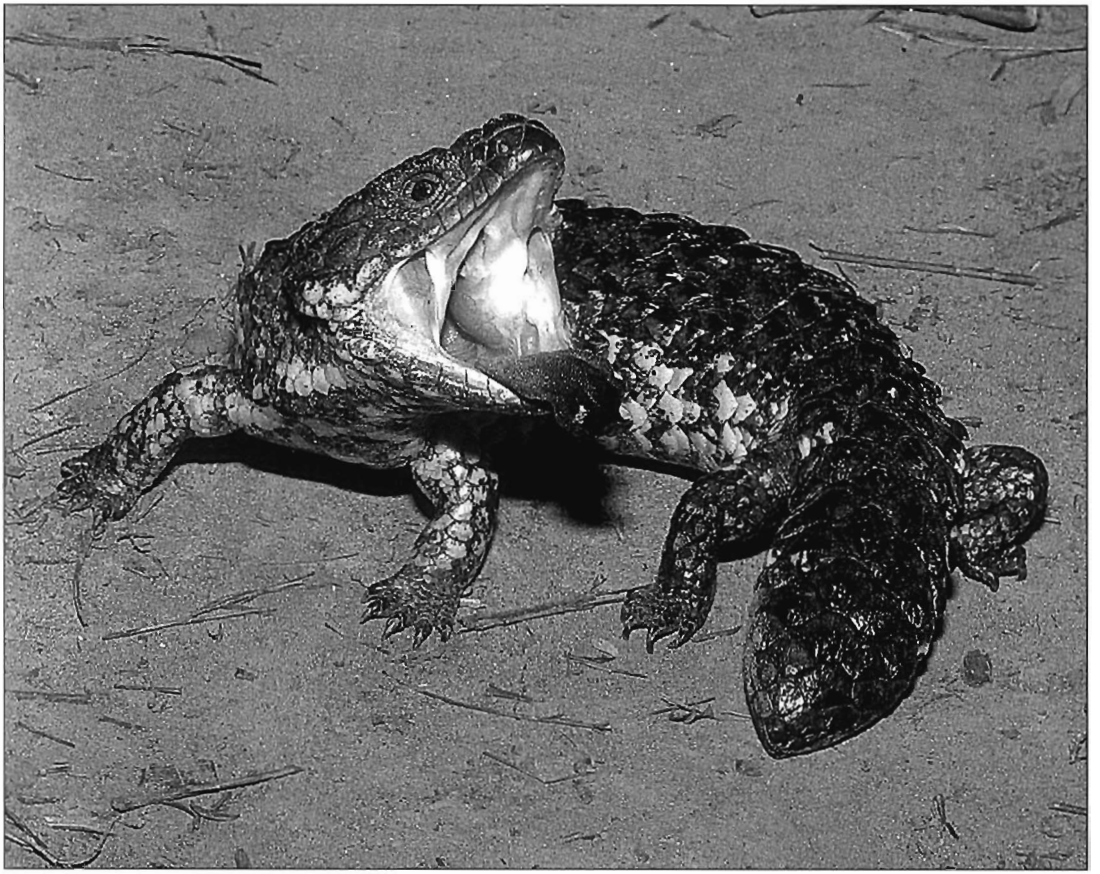

Fig. 1 *Tiliqua rugosa aspera* from Dalby / QLD. Photograph: Raymond Hoser

fits the general *Tiliqua* pattern, which gives further support for the hypothesis. Nevertheless, to test this hypothesis the effect of the tongue coloration on the predation rate should be quantified in the field for both adult and juvenile lizards by experimental manipulation of the tongue coloration.

An alternative hypothesis might be that the blue tongue and the typical display behavior serves a role during the mating season when male-male combat is usually fierce (in *T. rugosa* this is the result of their mate guarding strategy; BULL 1994). If the tongue coloration and display can be used to judge the "quality" of conspecifics, actual combat might be avoided. Again this hypothesis should be tested by field observations of mating and combat in several species of *Tiliqua*.

One last hypothesis is that the blue coloration is due to simple phylogenetic inertia. This implies that the blue tongue color arose in the predecessor of the whole genus (by accident or not) and just persisted throughout the further evolution of the lineage.

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