BUFOTOXINS AND BUFOGENINS - THEIR EFFECTIVITY IN PROTECTING THEIR PRODUCER AND THEIR POTENTIAL AS AVERSIVE CONDITIONING AGENTS.

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INTRODUCTION

Knowledge of the toxicity of toad venom goes back to ancient times and toad secretions were included in the mediaeval physician's pharmacopoeia. Even today the dried venomous secretions (known as *Ch'an Su* or *Senso*) of the Chinese toad are still used for treating various ailments and are marketed in large quantities in places such as Hong Kong and Taiwan (Meyer & Linde 1971).

The production of toxic secretions has evolved in prey organisms such as toads (*Bufo* spp.) as a chemical anti-predator device which is intended to inhibit attacks by potential enemies. The bufogenins and bufotoxins are produced and secreted by granular glands situated in the skin, and the most prominent are usually the parotid glands. The products of these glands are generally thick and creamy in appearance, and they are sticky to the touch (Lutz 1971). The bufogenins (bufoadienolides) and their derivatives, the bufotoxins, are complex hydrocarbons or steroids.

As far as the author is aware, no work has been published on the toad venoms of South African toad species, although Bharucha, Jager, Weiss and Reichstein (1961, from Meyer & Linde 1971) have analysed the skin secretions of "*Bufo regularis*". The origins of the animals used in their tests are unfortunately not known.

Why do some predators find toads acceptable while others do not?

Five species of hedgehog (Erinaceidae) and one of the Madagascan hedgehog tenrecs (*Echinops* sp.) are known to utilize the toxic skin secretions of toads to lick or rub onto their spines as an additional irritant to deter potential predators (Brodie 1977). When a hedgehog attacks a toad the parotid glands are usually the first to be bitten and chewed (these contain the greatest concentration of skin toxins); the resultant frothy mixture of toad toxin and saliva is then rubbed onto the spines. The toad is frequently eaten after "self-anointing" (Brodie 1977). It is a well-known fact, however, that domestic dogs find toad venom extremely distasteful and noxious. FitzSimons (1962) noted 15 species of snake known to eat toads, and Grobler (1972) recorded toads being eaten by immature bullfrogs (*Pyxicephalus adspersus*).

METHODS

A survey of the southern African literature dealing with the diet of mammalian carnivores revealed a number of species recorded as having included toads in their diet. These are listed in Table 1.

In order to test the palatability of *Bufo rangeri*, *B. gariepensis* and *B. pardalis* (one only), six species of carnivore (domestic dog, black-backed jackal, Cape fox, caracal, suricate and water mongoose) were offered these toads under captive conditions. The results are presented in Table 2.

It is, of course, possible that in nature a hungry predator would eat the most distasteful of toads. It is also possible that certain predators have evolved an innate avoidance reaction to certain colours or patterns.

TABLE 1: PREDATORY MAMMAL SPECIES RECORDED AS HAVING EATEN TOADS (*BUFO* SPP.) IN SOUTHERN AFRICA

PREDATOR	SOURCE
Viverra civetta (civet)	Smithers (1971) Smithers & Wilson (1979)
Paracynictis selousi (Selous' mongoose)	Smithers (1971)
Bdeogale crassicauda (bushy-tailed mongoose)	Smithers & Wilson (1979)
Cynictis penicillata (yellow mongoose)	Stuart (pers. obs.)
Herpestes ichneumon (Egyptian mongoose)	Rowe-Rowe (1978)
Ichneumia albicauda (white-tailed mongoose)	Rautenbach (1978) Smithers & Wilson (1979) Rowe-Rowe (1978)
Atilax paludinosus (water mongoose)	Stuart (1981) Smithers & Wilson (1979)

This has been demonstrated in the reaction of two avian predators towards coral snakes (Smith 1975, from Brodie *et al.* 1979; Smith 1977). Brodie, Nowak and Harvey (1979) feel that innate avoidance by avian predators could account for the greater survival of both the red-legged and red-cheeked morphs in comparison with a black population in the salamander *Plethodon jordani.*

RESULTS

Canis familiaris domestic dog

The animal used in the tests was a golden labrador. In all cases the dog barked and touched the proffered toad with the forepaws in a scratching motion. No biting was attempted. On each occasion the dog eventually lost interest after a few minutes. These four tests were spread over a period of 18 days. The reaction of domestic dogs to toad toxins is well-known.

Canis mesomelas black-backed jackal

Three adult jackals were offered toads on three separate occasions and one on two occasions. All three cautiously sniffed the toads but only one licked a *B. gariepensis* and two licked a *B. rangeri.* This caused them to lick their lips and shake their heads. The toads were left in the cages overnight but were unharmed by morning. Thereafter the toads were ignored.

Vulpes chama Cape fox

Apart from an initial sniff, the toad was completely ignored and was not touched over a period of 2½ days.

Felis caracal caracal

Apart from initial sniffing the toads were left unharmed. One toad remained in the cage for several weeks before it was eventually removed.

Suricata suricatta suricate

A large *B. pardalis* was placed in an enclosure with four suricates. The suricates moved quickly to the toad and each animal clawed and bit the amphibian, predominantly in the region of the head. The reaction in all cases was vigorous head-shaking, with open mouth and copious frothing and salivation. The animals attemped to remove the irritation by frequent rubbing of the mouth with the forepaws; this included wiping the tongue. The mouth was also rubbed against the floor of the cage. The reaction to the toxin lasted for 15-20 minutes.

TABLE 2: REACTION OF SOME MAMMALIAN PREDATORS TO TOADS UNDER CAPTIVE CONDITIONS

PREDATOR	PREY	TIMES OFFERED
Canis familiaris (domestic dog)	*B. gariepensis*	2
	B. rangeri	2
Canis mesomelas (black-backed jackal)	*B. gariepensis*	3
	B. rangeri	2
Vulpes chama (Cape fox)	*B. gariepensis*	1
Felis caracal (caracal)	*B. gariepensis*	2
Suricata suricatta (suricate)	*B. rangeri*	2
	B. gariepensis	1
	B. pardalis	1
Atilax paludinosus (water mongoose)	*B. gariepensis*	2

Footnote In all cases, with the exception of the domestic dog, no other food was given on the days when toads were offered.

Similar reactions were noted when a single *B. gariepensis* was placed in the enclosure, although only two of the suricates actually bit the toad. Continuous head-shaking lasted for approximately 60 seconds. In the case of the *B. rangeri* four of the suricates lightly licked the toads and three touched them with their forefeet but after light salivation and head-shaking the toads were left alone. Despite the fact that the suricates had not had food that day, and the toads were left in overnight, no harm appeared to have been done to the toads. It is possible that by this stage the suricates had learned that toads were not suitable dietary items.

Atilax paludinosus water mongoose

An adult, wild-caught, female water mongoose was given a *B. gariepensis* on two occasions. On the first occasion the mongoose flipped the toad onto its back and held the neck region with one forepaw and ripped open the ventral surface with its teeth. Only the head and part of the dorsal skin were not eaten. On the second occasion the toad was entirely consumed.

TO TOADS

RED

DISCUSSION

Although these tests are far from conclusive, in that only small samples were tested, it would appear that five of the captive species rejected toads as food items, some without contact and others after contact with the venom. There is no way of knowing whether these animals had previous experience of toads or not. Only the water mongoose ate the toads offered.

A number of points emerge from these brief observations:

1. It would appear that some predators (e.g. black-backed jackal and caracal) are inhibited from biting or eating toads whereas others are not (e.g. suricate and water mongoose). What factors are involved in this? Two common ranids (*Rana fuscigula* and *R. grayii*) were selected for feeding to the wild carnivores, in order to test whether all amphibians were dealt with in the same manner. Only the caracal rejected all amphibians as food items.
2. The majority of southern African toads are cryptically coloured, unlike several of the so-called "poison-arrow" frogs (Dendrobatidae) and the coralline frog (*Leptodactylus laticeps*) of South America. These New World amphibians provide a classic example of bright warning colouration combined with extreme danger to a potential predator. In the case of the cryptically coloured toads, which presumably cannot afford to be easily seen, their toxins are not so efficient as to keep off all or most predators.
3. What is the potential for the artificial production of the chemical components of the bufogenins, as aversive conditioning agents in the management of South African problem predators such as the black-backed jackal and caracal? Large numbers of caracal and black-backed jackal stomach contents have been examined (Stuart 1981) and no toad remains have been found. Preliminary tests undertaken in captivity show an aversion to toads by these two predators.

Footnote: In a test undertaken approximately two years prior to the above experiments, Cape grey mongoose (*Herpestes pulverulentus*) were offered, amongst other food items, *Bufo gariepensis* and *Bufo rangeri*, of which both species were rejected. However, the stomach content of a recently collected (October 1981) male *H. pulverulentus* contained remains of a *Bufo gariepensis*.

At present mammalian predator control in South Africa is carried out for the most part unselectively. Aversive conditioning is a potential tool for flock protection rather than predator destruction and I believe it warrants research in South Africa. If the artificial production of toad toxins should prove to be practical proposition, perhaps we would be able to go some way to introducing a more enlightened approach to predator management in this country.

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