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SHORT COMMUNICATIONS

Some Specific Features of Tail Regeneration in the Sand Lizard (*Lacerta agilis*)

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Some species of reptiles are capable of casting away their tails in case of danger, the tails being regenerated in part afterwards. Natural populations of these species almost always include individuals with autotomized tails. One of the principal factors that govern the proportion of individuals with regenerated tails is the predator pressure. As a rule, for most predators, reptiles serve as an additional (secondary) prey, to which they turn only in years when their main prey are rare. Specialized saurophagans are likely to hunt their prey more successfully, whereas "unskilled" (with respect to reptiles) predators perform a great number of unsuccessful attacks, some of which cause the loss of the tail of the prey. In any case, under experimental conditions, all lizards attacked by predators managed to escape by casting away their tails (Medel *et al.*, 1988). Hence, it may be considered that, in the reptile populations, the proportion of individuals with autotomized tails is governed by inefficient predators, i.e., unspecialized saurophagans.

However, we often failed to reveal the relation of the proportion of individuals with autotomized tails to the degree of prey presence in the diet of predators. Thus, in Australia, a comparison of southern and northern populations of *Chemidophorus marmoratus* differing in the duration of the period of high activity did not reveal any distinctions between these populations in the frequency of occurrence of animals with regenerated tails (Hendricks and Dixon, 1988). It has been suggested that, in some species, the casting away of the tail and, hence, the proportion of individuals with autotomized tails in the population depend both on intraspecific antagonistic interactions and specific features of ecology rather than on the intensity of predator attack. The point is that, in populations with a high population density, dominant individuals force other animals out into suboptimum habitats, where the latter become more vulnerable and subject to the effects of adverse factors (Brand and Volkl, 1988). It may be assumed that some animals lose their tails as a result of natural catastrophes (floods, landslides, fires, etc.).

The consequences of tail loss are diverse. These may include a serious wound on the site of the break, energy expenses for its healing and tail regeneration, change in social status, etc. Thus, the experimental tail removal in *Uta stansburiana* decreased the status of males and females. When the tail was regenerated artificially (adhesion of the removed part preserved in a frozen state), the social status of females was recovered, but not that of males. Thus, the social role of the tail is more strongly pronounced in *Uta* females (Fox *et al.*, 1990), which poses the problem of studying sexual distinctions in the frequency of autotomy in natural populations. Tail loss may significantly change the behavioral stereotype of the injured animals. For instance, in a *Scincella lateralis* with an autotomized tail, a reliably smaller rate and a greater distance covered during escape from a potential model predator were recorded, and a decrease in the total activity and the dominance of a cryptic behavioral strategy were observed (Formanowicz *et al.*, 1990). *Sphenomorphus quoyii* with autotomized tails ran faster but swam worse (Daniels, 1985a). In populations of *Lacerta monticola* in Spain, animals with autotomized tails preferred to use habitats where their chances to escape predator attack were greater, although food was less readily available (Jose and Alfredo, 1993).

Thus, tail loss in an individual entails fairly significant adverse consequences. Reptiles naturally try to protect their tails to the utmost, reacting to danger by other means; for instance, they try to hide, and if this is not possible, they manifest demonstrative–defensive behavior: hissing, imitation biting, body wriggling, enlarging the posterior part of the head, etc.

Nevertheless, autotomy in natural populations is a rather common phenomenon. Thus, in populations of *L. agilis* in the European part of the former USSR, the proportion of individuals with an autotomized tail varies from 4.5% in the Stavropol region to 39.0% in the Crimea (*Prytkaya yashcheritsa* ..., 1976), and in populations of *Tarentola mauritanica* in Spain, it may reach 54.2% (Jose and Alfredo, 1993). Therefore, the study in nature of the ability of lizards to cast of their tails, reasons for the significant variability of the relative number of traumatized individuals in the populations, the relation of this index to the sex and age of the animals and its dependence on the habitat type, etc., are undoubtfully of interest both in the theoretical respect and for applied purposes, in particular, for the monitoring of the state of biotic complexes with anthropogenic

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effects. The study of the specific features of the tail regeneration processes is likewise of interest. Thus, in some geckos (genera *Ailuronyx* and *Geckolepis*) the outer layer of the skin contains so-called "fracture zones" along which the break occurs. In animals that have lost this site of skin cover, no recovery of the fracture zone occurs at regeneration (Bauer and Russell, 1992). There are data on the emergence of the so-called tail multiplicity. Since it is widely known that the regenerated part of the tail does not contain vertebrae and is not capable of autotomy, the task of elucidating the importance for the population of the partial injury of the caudal vertebrae that did not result in tail loss assumes great importance. The task of studying the occurrence and role in populations of repeated autotomy, which as is known, is only possible in the uninjured part of the tail, is equally significant.

This paper contains preliminary results of our studies on particular aspects of tail autotomy and regeneration in a population of *L. agilis* from the Bashkir Pre-Ural region (Ufa and Al'sheev districts of the Republic of Bashkortostan). The material was collected in June and July of 1997 and 1998. The total number of studied animals was 51 ind.; of these, 11 were adult males, 21 were adult females, and 19 were juveniles (animals with a body length up to 60 mm and weight up to 5.5 g). All captured reptiles were weighed, and the body and tail lengths were measured. In animals with injured tails, I measured the length of the regenerated part and the distance from the site of breakage to the anterior edge of the cloacal slit. Only instances of genuine autotomy (intervertebral fracture, presence of regeneration) were taken into account.

In the studied sample, 19.6% of the lizards had autotomized tails. This value is close to the average value of the variability range of the proportion of individuals with traumatized tails in the population of *L. agilis* of the former USSR mentioned above. In our opinion, this is likely to testify to the average intensity of the effects of traumatic factors leading to tail loss, irrespective of their nature. Animals with autotomized tails were distributed according to sex–age groups as follows: of 11 adult males, tail breakage was recorded only in one (9.1%); of 21 adult females, in 5 (23.8%); and of 19 juveniles, in 4 individuals (21.1%). Thus, the smallest degree of tail traumatization was observed in the group of adult males, and the greatest, in the group of adult females. In juvenile lizards, this index was smaller than in the group of adult females, but the differences were insignificant. The latter probably means that adult females and young are affected by traumatic factors close in their spectra and intensity, whereas adult males, due to their greater mobility, may more successfully avoid the impact of these factors. Note that, among adult animals of both sexes, the proportion of individuals with autotomized tails was 18.8%, i.e., somewhat less than in the young of the year. This fact suggests that juvenile lizards with injured tails perish more often than animals of the same age that were not traumatized. They grow more slowly and do not (on average) reach those sizes and weights that are characteristic of the latter. The following observations provide additional support for this hypothesis. First, the largest studied reptiles had uninjured tails. Second, the comparison of lizards of the same sex and age (with similar or almost similar body lengths) with uninjured ($n = 13$) and traumatized ($n = 7$) tails indicated that the weight of the former was, on average, 16.2 g greater than the weight of the individuals from the second group.

Tail breakage in lizards may occur at different distances from the tail base. According to our observations, this distance (from the anterior edge of the cloacal slit to the site of breakage) varied from 6 to 68 mm and averaged 22.6 mm, or 27.1% of the body length, i.e., autotomy largely occurred closer to the tail base, in the first third. However, these indices differed rather strongly in different sex–age groups. Thus, in one traumatized male, the break occurred 68 mm away from the cloacal slit that made up 98.6% of its body length. In adult females, the average distance of the site of breakage from the cloacal slit was 19.6 mm, or 25.2% of the body length. In juvenile lizards, the site of breakage was 14.0 mm away from the anterior edge of the cloacal slit, i.e., it is 18.9% of the body size. Thus, in the absolute expression and in relation to the body length of the animal, the tail breakage occurred nearer to the tail base in juvenile individuals. In adult females it was slightly further from the base, and the greatest distance away was recorded in an adult male. The latter fact was singular, but it may still indicate the importance in the localization of the breakage site of sexual distinctions in the anatomical structure of the caudal section, as in males, it is likely that the proximal part of the tail is hardly susceptible to autotomy due to the presence here of the hemipenis and the accompanying musculature.

The variety of distances of the site of breakage from the tail base is likely to be associated with a variety of factors causing a traumatic effect (more than a predator attack). Thus, when the tail tip of *Phyllodactylus marmoratus* geckos was grabbed, they only cast it away entirely in 23.0% of cases, whereas during a predator attack, tail breakage occurred near its base in all individuals irrespective of the site of bite (Daniels, 1985b). Note that tail grabbing is a kind of anthropogenic effect on *L. agilis*, the kind producing sometimes rather intense effects, particularly, in sites used for recreational purposes. In the Southern Urals, lizards are the most common and widespread reptiles. They are often within sight of people, thus provoking people to attempt to catch them. In this instance, man plays the role of a strongly unspecialized predator. In periods of high activity, sand lizards are rather mobile and escape from danger, and if a man captures his prey, it is usually just a cast-away tail.

To elucidate the significance of anthropic factors in the distribution of caudal traumatism in populations of

L. agilis, we collected material in three habitats that were originally similar but now are subject to different types of anthropogenic pressure. The first is located near a resort and is often visited by people, i.e., is under a significant recreational load. In the second, regular cattle grazing takes place; i.e., this biotope has a high pasture load. In the third, there is no cattle grazing, and it is rarely visited by people. This biotope served as a control for comparison with the former two. All three habitats are nearly equal in area.

As it turned out, the highest proportion of individuals with an autotomized tail was in the habitat with the pasture load (25.0%). This proportion was slightly lower in a biotope used for recreation (23.1%). At the control site, the proportion of traumatized lizards was two times lower than the former values (11.8%). Thus, anthropogenic factors are likely to play a significant role in the occurrence in natural populations of *L. agilis* individuals with autotomized tails. Taken alone, this result is not a surprise for a site with a recreational load. Of greater interest is the fact that in the biotope used for cattle grazing, the proportion of traumatized lizards was slightly higher than in the biotope often visited by people. It is hardly probable that the pasture load is related to a high predator concentration. Therefore, there are grounds to believe that caudal traumatism is largely accounted for by some mechanisms generated by a nonspecific factor of anthropogenic origin, such as an anxiety factor that is present both at the pasture site and at the recreation site. The specific mechanisms that provoke tail autotomy have yet to be determined.

As for the processes of regeneration of the tail section, the available material revealed (in comparing animals of the same sex and age) that the length of the regenerated tail did not exceed 79.9% of the length of the uninjured tail.

Hence, the problem of tail autotomy and regeneration in natural populations of lizards includes several ecological aspects, in particular, those associated with anthropogenic effects that are of both theoretical and practical interest and require further research. The degree of occurrence in populations of individuals with autotomized tails may turn out to be a good indicator of certain forms of anthropogenic loads.

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