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Invertebrate research overview: 2. The endemic land snails

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Among the terrestrial invertebrates, the Galapagos malacofauna occupy a special position. Compared to the arthropods, they are represented by much fewer species, the total amounting to probably about one hundred different species or taxa. They are dominated by the Bulimulidae, an endemic group of gastropods forming about 90% of the existing species of land snails.

They are often unnoticed by visitors because of their dull brown colour and small size (the biggest species only reach 25 mm in length, the smallest barely 5 mm), but also because they live in hiding places under heavy dead logs or stones, or within shady and thick undergrowth, and only experienced eyes know where to look for them.

A few specimens of Galapagos bulimulids were collected by Charles Darwin, but the first extended review of this group of land snails was made by DALL and OCHSNER as recently as 1928. Although many species were collected and described during the second half of the 19th century (ALBERS, 1850) other main contributions to the knowledge of this group are more recent (SMITH, 1966, 1972; VAN MOL, 1972; VAGVOLGYI, 1977 ; BREURE & COPPOIS, 1978). They were made possible by the development of the Charles Darwin Research Station on the island of Santa Cruz. Longer stays were then possible in the archipelago, and field research was focused more on the ecology, the distribution of the species, and conservation problems these land snails have to face (COPPOIS, 1984; COPPOIS & WELLS, 1987).

All Galapagos bulimulid land snails are endemic and belong to the same genus, *Bulimulus (Naesiotus).* They underwent a spectacular speciation process within the archipelago: 65 species with several subspecies or forms were described, totalling 93 taxa. The morphological diversity shown in the Galapagos bulimulids is surprising; the general shape of the shell, the shape of the aperture and of the umbilicus, the sculpture of the shell surface, its colour and size vary from one species to another.

They adapted to a wide range of climatic conditions and habitats: some species live in near-desert conditions, others are found only in humid forests with more temperate climates. With few exceptions, they are present on almost all sizeable islands of the archipelago. Species generally differ from one island to another and few species are found on more than two or three islands. Usually there is a higher diversity on the elevated islands where a marked vegetal zonation parallels the climatic gradient from the arid coastal zones to humid highlands where habitats are more diversified. For instance, Santa Cruz has the greatest diversity with 25 bulimulid species, which correlate with a great variety of habitats and with the highest variety of vegetal associations.

The distribution of bulimulid species is sometimes limited to very small areas (such as a valley in the highlands, or an isolated hill) characterised by a special microclimate or a special type of vegetation. Bulimulid land snails are often very sensitive to microclimatic changes and are therefore good ecological markers for checking the good health of habitats or to estimate ecological changes.

Lands snails are endangered, and many species are already extinct

Bulimulid specimens represented in museum collections are abundant, with many having been collected alive during the 19th century. A careful examination of these collections and recent visits to the original sampling sites show that distribution ranges are often much smaller now than before, and that many species have already disappeared from these areas or are now extinct. This extinction process has increased in recent years, and many of the remaining species are now endangered.

The process of land snail extinction is a recent one. A correlation can be made between the extension of human colonisation to the different islands of the archipelago and a shrinking of the endemic snails' distribution. About 200 to 300 inhabitants were already present in the Galapagos in 1835, when Darwin made his visit. The first inhabited islands were Floreana and San Cristobal, where settlers moved mainly after 1847. Transformation of the habitat started rapidly as men cleared the land for cultivation and cattle breeding.

As a result, many bulimulid species described from these two islands were no longer found alive by subsequent expeditions during the beginning of the 20th century and some species were already wiped out. Many species disappeared at the end of the 19th century, but the process is faster now and more than a third of the species became extinct during the last half century.

Santa Cruz was neglected for a long time, and was only colonized after 1920. Habitat destruction began later and 25 bulimulid species were still found on this island before 1973 (when a road crossing the island was completed). Human colonisation of the island increased, and more destructive activities occurred as a consequence. Since then, the number of species is reducing rapidly and possibly only half a dozen survive in 1998. Although human colonisation cannot explain all the disappearances (as will be discussed later) it is one of the main reasons.

Threats and main areas of concern

The human population settled in four islands, first in a village on the coast as the only access was by boat. Then they moved inland to find suitable areas for farming. These areas extended in the highlands where proper soil and enough water were available, and resulted in the clearance of huge stretches of native forest. This situation was legally recognised in the seventies when the ''colonised zones'' were created and the limits of the National Park established. As they are excluded from the National Park, legislation relating to environmental protection does not apply in these colonised zones devoted to human activities. Destruction or modification of the natural habitats in the colonised zones were highly detrimental to many species of land snails and many other species of invertebrates which used to live in the *Scalesia* forests and the forests of the transition zone.

Many other aspects of habitat destruction occurring in the National Park areas have resulted from uncontrolled human activities. An example is the destruction of vegetation by goats on many islands where they were introduced or released. Every time it resulted in the destruction of the natural habitats, often involving severe erosion of the soil layer and the loss of many snail species. On some occasions uncontrolled forest fires were also very destructive.

Introduced predators like black rats, *Rattus rattus,* and little fire ants, *Wasmania auropunctata,* have a more direct negative impact on land snail populations as they feed on them or destroy their eggs, preventing any reproduction by the snails.

Curiously, some potential competitors were also accidentally introduced in the past, but with no known consequences as they are often seen in very limited numbers in places where bulimulid land snails occur. This is the case with the tiny pantropical snail, *Subulina octona,* and a small black slug, *Deroceras laeve.* On the other hand, another mollusc was introduced, most probably in 1984, and is very successfull and displacing, the well known pest slug *Vaginulus (Sarasinula) plebeius* (Veronicellidae). It is now frequent in all colonised zones where it seems to have contributed to the elimination of some endemic land snail species.

It must be noted that bulimulid land snails had to face a variety of major natural hazards since their ancestors reached the islands, including volcanic eruptions and extended droughts. But although many species disappeared through natural causes, none of these prevented them from evolving in one of the best example of adaptive radiation among invertebrates. Effects of long-term climatic changes are more puzzling. To what extent will global warming and more frequent El Niño episodes influence the evolution of land snails in the future?

During the 1982-83 El Niño, few big trees remained standing in the Scalesia forests of Santa Cruz. As their closed canopy usually provides continuous shade over the undergrowth where bulimulids live, the herb and shrub layers were exposed directly to the sun once the trees fell down. As a consequence, the habitat became rapidly drier once the heavy rains stopped, and as the years 1984 and 1985 were unusually hot and dry, many populations of bulimulid land snails disappeared from these areas. Snails do not survive rapid and drastic climatic changes. Sometimes relict populations are able to aestivate long enough (inside deep crevasses or under logs) and survive. They may then be the nucleus from which a new population is able to develop once more normal conditions return.

Saving the terrestrial malacofauna for the future

Although it will not be possible to control climatic changes in the future, many of the detrimental factors mentioned above may be reduced if proper actions are taken. One of these will be the strict adherence to a quarantine system to avoid introduction of other new exotic competitors or predators of snails into the islands. An effective control of introduced vegetal plagues is also important, as any modification of the native forests may induce more changes in the microclimates and microhabitats and therefore reduce the ability of snails to survive. Habitat rehabilitation is a key factor, mainly in the humid forests in the highlands. It is possibly the most effective effort that could be taken to save snails and many other invertebrates species for the future. This is obviously not an easy task and may include buying land in well chosen areas of the colonised zones in order to protect and develop remaining patches of native forests.

Present programmes conducted by staff members of the Charles Darwin Station and the Galapagos National Park are promising steps in the right direction: controlling the goats on Isabela will save tortoises from starving, but also allow many species of invertebrates to recover once the vegetation is back to normal.

What needs to be done within a short time is a new evaluation of species loss and a determination of the

present distribution of species. Places where snails are still living must be protected first, and control of adequate conditions of life must be made. Some observations have already been done in the field and will be continued in the future. Captive breeding may be a good solution to preserve some of the species for the future. Although technically difficult to accomplish, it is possible to conduct such conservation programmes as long as adequate and dedicated long term care is provided. For some species of land snails, it will probably be possible to conduct captive breeding programmes in the field where proper conditions are easier to control.

Is there hope?

The collector and shell dealer Hugh Cuming found one live specimen of the species *Bulimulus (Naesiotus) achatellinus* in the early 1830s, just before Darwin's visit to Galapagos. It is so rare that only a few shells are known. Another live specimen was collected by George Baur in 1890. Five other shells, some bleached, were found by L.G. Hertlein during the Allan Hancock Expedition (1931-32). Since then, the species was considered extinct (SMITH, 1971) until I was lucky enough to find two live specimens on San Cristobal Island in 1987. This enigmatic species was still alive.

Who knows if it is still alive now, ten years after my discovery? Does *Bulimulus (Naesiotus) achatellinus* survive after the recent droughts, or following further modifications of its habitat by human activities (the live specimens were found near the Cerro Verde village in the highlands of San Cristobal)?

For many populations of snails, the chances of surviving unusual events like prolonged droughts were certainly reduced by the destruction and changes caused by human colonisation. It resulted in the extinction of many species which might have survived if the ''human factor'' had not been present. Let's hope that at least a few species will be able to maintain viable populations for the future, with a little help from us.

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