Breeding Nine-Banded Armadillos *(Dasypus novemcinctus)* in Captivity

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Abstract | Armadillos (*Dasypus* sp.) are a natural host of a number of protozoal and bacterial pathogens of medical and veterinary importance. To date, it is the best experimental host of leprosy caused by *Mycobacterium leprae* and can be naturally infected with this organism. Poor survival-rate of armadillos under conventional housing conditions, however, has proved a major obstacle in breeding *D. novemcinctus* in captivity. Encouraging results are reported for the breeding and survival of this xenarthran in a walled-off area of forest offering an environment similar to the armadillos' natural habitat. One female raised 2 consecutive litters of 2 and 4 offspring, respectively, to adult age. Increased production is anticipated after preparation of a number of these delimited areas of natural environment for breeding purposes.

Armadillos (Xenarthra: Dasypodidae) are the natural hosts of *Trypanosoma cruzi* (1, 2), *Toxoplasma gondii* (3), species of *Sarcocystis* and *Eimeria* (4,5), a piroplasm (2), *Leptospira* sp. (6), *Salmonella* sp. (7), and *Mycobacterium leprae* (8). Because they are natural hosts of several organisms and because of the interest of geneticists in an animal that reproduces by polyembryony to produce from 4 (*D. novemcinctus*) to 12 (*D. hybridus*) identical offspring, researchers might have sufficient reasons for the establishment of laboratory-bred colonies of armadillos. However, it was the discovery that *D. novemcinctus* was unique among research animals for developing lepromatous leprosy when inoculated with *Microbacterium leprae* (9-12), that evoked the major incentive to breed this xenarthran in captivity. Achieving captive breeding would open the door to numerous biomedical studies in which the armadillos would be used. In particular, armadillos would be a rich source of antigen for the preparation of *M. leprae*/ BCG mixtures for use in immunotherapy of human beings with hanseniosis (13).

Largely motivated by this possibility, a number of studies has been made on the capture, biology, and maintenance of armadillo species, notably *D. novemcinctus* and *D. sabanicola* (14-19). To our knowledge, there has not been a major break-through in the breeding of armadillos in adequate numbers for long-term experimental use, and heavy reliance is still placed on the use of wild-caught animals, with the rare bonus of offspring produced in captivity by females that were pregnant when captured. An unpredictable source of armadillos, their poor survival-rate in captivity, and complications arising from the use of wild-caught armadillos infected with various organisms (in particular, *M. leprae*), remain serious obstacles to their use in biomedical research. In addition, armadillos are a highly prized source of meat in many developing countries, and this, together with man's continual destruction of their natural sylvatic habitat, has severely depleted the population of many species. Furthermore, excessive capture for experimental purposes is likely to place these inoffensive and interesting animals even more firmly on the list of endangered species.

We report here the preliminary results of methods that have led to considerable success in adapting *D. novemcinctus* to captivity and that have resulted in the production and survival of 2 consecutive litters from one captive pair of armadillos.

Materials and Methods

To initiate the studies, a small number of armadillos was purchased from hunters, who had captured them in secondary or primary forest in Pará State, northern Brazil. The building in which they were housed was constructed especially for this project and had space for 40 armadillos. It was a rectangular, concrete building divided into 18 pens, each of which was 2.50 x 2.50 x 1.20 m (Figure 1) with a floor of ceramic tiles, a roof of earthernware tiles, and walls 1.20 m high. The upper half of the outer walls of the pens was of fine, insect-proof wire mesh.

Nearby, but separate from the animal house, an area of natural secondary forest measuring 256 m^2 was surrounded by a concrete wall that extended into the soil to a depth of 1.50 m. Above the soil, this wall was 1.20 m high. Stout wire netting was placed on top of the concrete wall, so that the total structure had a height of 1.50 m. There was not any overhead enclosure.

The protocol we used was to separately quarantine armadillos in pens of the animal house for 2 months. During this period of adaptation to captivity, they were scrutinized for signs of external or internal injuries, and females were examined for signs of pregnancy. The date of entry and other observations were recorded for each armadillo, which received the following diet: 200 to 250 g of dog chow daily, moistened with water; approximately 50 newborn laboratory mice, twice a week; 5 adult

FIG. 1. An animal house designed for the quarantine and maintenance of adult armadillos *(Dasypus novemcinctus)*, which were then used for experimental purposes.

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crickets (*Gryllus* sp.) and approximately 50 mealworms (*Tenebrio molitor*), provided alternately every 5 days. Methods for keeping and breeding the insects were similar to those reported by Zimmermann (20). A constant source of water was provided, and the floor of each pen was strewn with a relatively thick bedding of forest-floor litter of fresh and dry leaves, which was changed when necessary.

After 2 months of quarantine and adaptation to captivity, an adult male and female were housed together in a pen, and the male was changed each year. When pregnancy of any female was confirmed, the pair of armadillos were then transferred to the enclosed area of forest, where conditions were similar to their natural environment. In addition to any food that they found themselves (e. g., insects, worms, roots,), armadillos housed in the forest environment were provided with the aforementioned animal-house diet.

Due to its open nature, the outdoor pen had climatic conditions similar to those of the neighboring tropical rainforest of the Belém area. Distinct wet (December through April) and dry (May through November) seasons were recognizable, with mean monthly rainfall for the two seasons in 1991 being 305 and 68 mm, respectively. Temperature and relative humidity in the forest range from about 28°C and 80% during the day to 25°C and 95 to 100% at night.

Results

Initially, we purchased adult armadillos, but these adapted poorly to the conditions of our indoor animal house, and there was a high death rate. Later, we accepted only young, half-grown armadillos, which tolerated captivity far more readily and had almost a 100% survival-rate.

On January 9, 1992, we received a pregnant female *D. novemcinctus* that gave birth to 4 female offspring on February 25, 1992, while still in quarantine. Unfortunately, none survived for more than a few weeks, doubtless due to the unnatural conditions of the indoor pens. That same female and an adult male were released into the enclosed area of forest on February 25, 1993. Apart from the daily provision of food and water, all contact with the 2 armadillos was strictly avoided. One year and three months later (May 1994) the female of this couple was seen accompanied by 2 female offspring (Figure 2), and on November 24,1995, she produced 4 more young, again all females. At the time of this report, all these young armadillos have survived in excellent condition.

FIG. 2. A portion of secondary Amazonian forest enclosed by a wall that extended 1.5 m into the forest floor. This area served as an external breeding area for *D. novemcinctus*. A female is pictured with 2 of her offspring.

Discussion

In nature, armadillos are largely insectivores, and termites and ants figure extensively in their diet. In addition to other insect life such as the larvae of many beetles found in fallen and rotting tree-trunks, they will eat a wide variety of small vertebrates, including bird nestlings and eggs, carrion, and, sometimes, plant material such as roots and fallen forest fruits. The maintenance of *D. novemcinctus* in captivity does not, therefore, pose great dietary problems, especially when laboratory-bred insects such as *Gryllus* and *Tenebrio* sp. are at hand. In our study, commercially available dog chow and an abundance of baby laboratory mice, bred for use in other biomedical research, formed an important additional source of protein. Consequently, we have reached the point at which we are reasonably confident in the survival of *D. novemcinctus* for periods adequate for most experimental purposes, once they have passed quarantine and adaptation to captivity.

The major obstacle severely limiting the use of armadillos as laboratory animals is breeding them in captivity in sufficient numbers. Other researchers (21) kept 3 pair of *D. novemcinctus* in wire-fenced pens in natural surroundings, and 1 of those females produced 4 offspring after 10 months and 11 days of captivity. Delayed implantation, however, can obscure the actual gestation period of armadillos, and it remains uncertain whether this female was mated prior to capture. We are unaware of anyone who has a record of successful breeding of *D. novemcinctus* under controlled conditions in captivity that can rival that reported for our study.

Although we have had a good survival-rate for adults in our conventional animal house, conditions did not favor the survival of a litter born in this highly artificial environment, and only continued observations will indicate whether those conditions will permit adequate mating. Both problems were resolved, however, by the use of an enclosed area of secondary forest into which a single pair of adults can be released before or after mating. In that environment, they can construct their natural burrow and would be protected from predators - clearly much more conducive to the successful raising of offspring than the conditions of an indoor pen. Although the armadillos will initially supplement their artificial diet with insects and other foods they obtain for themselves, the natural source may soon be depleted, and the animal-house diet as well as water must be continually provided.

Territorial requirements of *D. novemcinctus* will clearly limit the number of breeding pairs allotted to an enclosed area of forest. We anticipate, however, that this problem can be overcome by the preparation of numerous outdoor quarters of this nature, but that are smaller than those used in the study reported here. Continuing efforts will be made to increase the production of armadillos in a closed colony.

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