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Nutrition as a Major Facet of Reptile Conservation

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The importance of nutrition has not received much recognition in conservation biology. However, captive breeding is possible only if nutritional requirements of animals are met, and effective habitat management requires an evaluation of nutritional resources. Three examples involving reptile conservation are presented. The formulation and testing of experimental meal-type diets proved essential for the large-scale rearing of green iguanas *(Iguana iguana)* in Panama and Costa Rica, thousands of which have been released into the wild. Survival and growth of captive land iguanas *(Conolophus subcristatus)* in the Galapagos Islands was markedly improved by development of a complete feed based on locally available ingredients; this was essential to continuation of the conservation program in which juvenile iguanas were repatriated to islands where populations had previously been exterminated. Research on the desert tortoise *(Gopherus agassizii)* in the Mojave Desert has identified nutritional constraints that may limit utilization of potential food plants. Thus, nutritional status of wild tortoises may depend more on availability of plant species of high nutritional quality than on overall amounts of annual vegetation. Federal and local agencies involved in the conservation and management of tortoise habitat have recognized the need to fund research on tortoise nutrition. We contend that nutrition should be given a central role in conservation programs for reptiles and other animals.

Key words: diet, husbandry, iguana, tortoise, Galapagos

INTRODUCTION

Many zoological parks and societies support conservation programs for rare and endangered species, both through captive breeding and through direct involvement in conservation efforts in the field. Scientists at zoos have also been instrumental in the development of knowledge and methods for the conservation of small populations, particularly with regard to genetic diversity, behavioral repertoires, and reproductive

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performance. However, it is only in recent years that the importance of nutrition has been recognized.

It used to be assumed that traditional zoo diets were nutritionally adequate, and that animals in the wild would be in good nutritional condition if sufficient food was available. The quantity of food might be of concern, but rarely the quality. There was an underlying expectation that animals would choose what was best for them, whether in captivity or in the wild [Oftedal and Allen, 1996].

The first zoos to hire professionally trained animal nutritionists were the Metro Toronto Zoo (1975), the National Zoological Park (1978), and the Chicago Zoological Society/Brookfield Zoo (1980). In the intervening years, nutritionists at these and other zoos have devoted much effort to the evaluation and improvement of diets. However, most diets for reptiles still reflect tradition and trial-and-error rather than scientific judgment. This is a poor foundation for a conservation program, and places animal health and reproduction at risk.

We will briefly discuss the role of nutritional studies in three large-scale programs targeted at reptile conservation. Scientists overseeing these programs perceived the need for nutritional problem solving, and encouraged applied research. We hope the positive results of these programs will stimulate further interest and research in reptile nutrition.

ALTERNATIVES TO DESTRUCTION

Green iguana *(Iguana iguana)* populations in many parts of Central and South America have plummeted due to deforestation, human encroachment, and overhunting of iguanas for food by local peoples. The initial incentive for starting a green iguana breeding project was to find a way for poor, rural peoples to benefit from forested areas without destroying the forests. In 1983, a multiyear grant was awarded by the Alton Jones Foundation to the Smithsonian Tropical Research Institute (STRI) in Panama to seek "Alternatives to Destruction." Among its goals was the development of small-scale iguana farming. If inexpensive rearing methods could be perfected, farmers might be trained to raise iguanas in multiuse forest patches which the farmers would be committed to protecting.

Dr. Dagmar Werner was appointed to oversee the green iguana project. She developed methods for obtaining eggs from wild iguanas and for breeding iguanas in captivity. Egg incubation methods were tested and improved, and substantial numbers of hatchlings obtained. However, Dr. Werner was not satisfied with the rates of growth of the hatchlings, and in preliminary studies found that growth of iguanas provided meat and bone meal on a freechoice basis was superior to that of animals fed rice, locally collected vegetation, and fruits and vegetables purchased from local markets. She asked us to assist her in diet formulation and testing.

As Dr. Werner had demonstrated that iguanas would eat a meal-type diet, an obvious approach was to develop nutritionally complete diets that could be manufactured as a dry meal. Our objective was to produce diets that (1) would require minimal labor, (2) would be relatively easy to store and handle, (3) would not attract insects of other nuisance animals (such as raccoons), and (4) would not contain exotic or hard-to-get ingredients so that local feed companies could manufacture the diets. We also wished to have diets that could be manipulated to alter the levels of such constituents as protein, fiber, and minerals.

Hatchlings and juveniles fed a nutritionally complete artificial diet as the sole food were robust, vigorous, and grew more rapidly. Growth rate was found to be related to dietary protein, with more rapid growth on diets containing 28% protein (dry matter basis) than on lower protein diets [Allen et al., 1989]. Animals were able to adjust to various fiber levels, although growth rate was reduced on high-fiber diets [Baer, 1992].

High rates of growth were deemed important because small iguanas are subject to high predation, and thus the age at which they could be safely released into forest patches was dependent on the size of the animals. More rapid growth permitted earlier release, reducing overall cost and effort, and making iguana rearing more economically feasible for poor farmers.

Animals reared on the meal-type diets retained a preference for them, and would return to feeding stations in the trees even after they were released into forest patches. We were surprised when some native iguanas that had hatched and survived in the wild were also observed to use the feeding stations containing meal-type diets (D. Werner, personal communication). The fact that iguanas returned to feeding stations facilitated relocation and censusing of the released animals.

The iguana rearing and release project is ongoing on a much larger scale under the auspices of the Pro Iguana Verde Foundation in Costa Rica. Hatchling iguanas imported to the National Zoo from the project have been used in several research projects, including Ph.D. dissertations [Baer, 1992; Bernard, 1995]. Among the discoveries is the observation that iguanas maintained on diets containing about 3,000 IU vitamin D_3 per kg developed frank vitamin D deficiency; fluorescent lights emitting ultraviolet light of the appropriate wavelengths (280 - 3 20 nm) for vitamin D synthesis alleviated the problem [Bernard et al., 1991; Bernard, 1995; Allen et al., 1996]. In the meantime, a number of pet food manufacturers have recognized the feasibility of artificial diets for green iguanas, and now market specialty feeds for these animals. While all such diets may not be nutritionally complete, it is a step forward that manufactured diets are now available for green iguanas in the pet trade.

THE RESCUE OF THE GALAPAGOS LAND IGUANA

In 1976 Dr. Werner made another major contribution to reptile conservation. She had been asked by the Charles Darwin Research Station (CDRS) and the Galapagos National Park Service to investigate the cause of widespread mortality in land iguanas *(Conolphus subcristatus)* on the Galapagos Islands. Recognizing that introduced mammals (especially feral dogs and cats) were in the process of exterminating the remaining land iguanas on several islands, she captured as many iguanas at these sites as possible. Some were translocated to a small island (Venezia) where predators were absent, and the remainder were brought to the CDRS. These were to serve as the nucleus of a breeding program, with the objective of repatriating captive-bred animals to their original islands once the introduced predator problem had been tackled. This program saved populations on several islands from certain extinction.

Initial activities at the CDRS by Howard and Heidi Snell were directed at the need to establish viable breeding groups in suitable cages, and the need to determine suitable incubation conditions for land iguana eggs. The first hatchlings were produced in 1979. In the 1980s, substantial numbers of hatchlings were produced but juvenile mortality proved problematic. Many juveniles died with their stomachs or intestines destended by fibrous mats of vegetation, suggesting digestive disorders. Reproductive females also appeared to be very thin after egg laying, and did not recover condition for prolonged periods thereafter.

In 1989 one of us (O.T.O.) accepted the invitation of CDRS herpetologist Dr. Linda Cayot to evaluate the diets fed to the land iguanas. The nutrient composition of food plants eaten by wild iguanas was compared to that of plants harvested by CDRS staff for feeding of the captive iguanas. Among the recommended changes in management practices were (1) an increase in the frequency of feeding, especially in the cool season (locally termed "garua") when mortality was highest, (2) removal of dominant juveniles from group pens, (3) greater selectivity in plant collection, and (4) incorporation of a meal-type manufactured diet into the overall feeding program. A test of a mealtype diet demonstrated that juveniles fed this diet grew more rapidly and appeared more vigorous than those fed only vegetation. Overall, juvenile mortality dropped from nearly *25%* per year in 1988 to less than 3% per year in 1990 - 1991 [Cayot and Oftedal, 1996].

Several factors limited the type of diet that could be developed for the land iguanas: (1) animal feeds and feed ingredients were not available in the Galapagos, (2) specially ordered supplies from the Ecuadorian mainland could not be relied upon due to the unpredictability of supply ships, and (3) there were no feed manufacturing facilities in the Galapagos. It was apparent that diets would have to be made by hand using locally available ingredients. We tested the feasibility of grinding various locally available grains and legumes in a manual food grinder, and assayed these grains and legumes for nutrient composition. As primary ingredients for the diet, we selected an Andean grain (quinoa) and lentils, both of which were relatively high in protein and relative easy to grind by hand. As a calcium source we used a very fine, white coral sand, collected from the Tortuga Bay beach near the CDRS. The sand contained 40% calcium. Salt and vegetable oil were added, but the vitamin and mineral premixes had to be air freighted from the U.S. The ingredients were mixed in a custom-built V-mixer at CDRS.

The quinoa-lentil diet is mixed on a weight basis with locally collected plants that are the primary fiber source. The amount used is calculated to provide 50% of the dry matter intake of the iguanas. The vigor, condition, and activity of the adult iguanas has improved dramatically, and the hatchlings and juveniles grow rapidly, are muscular, and have continued low mortality. Repatriation of the juveniles to the wild, suspended in the 1980s due to juvenile mortality in the captive population, was reinstituted. For the first time, land iguanas were repatriated to the island of Baltra, on which they had become extinct about 45 years earlier [Cayot and Menoscal, 1992].

The success of this project demonstrated to CDRS staff the importance of nutrition in reptile breeding programs. An effort is currently underway to improve the diets used for breeding and rearing Galapagos tortoises *(Geochelone elephantopus)* at the CDRS. This rearing program, like that for land iguanas, proved necessary due to predation, poor survivorship, and low population numbers on many of the Galapagos Islands; hundreds of juveniles have been repatriated. In 1995, plants used for feeding of captive tortoises were collected for nutritional analysis, and a test of the quinoa - lentil diet was initiated with hatchlings and yearling tortoises. Although juvenile mortality is not a problem at present, we hope that growth and condition of juveniles may be improved by use of a formulated diet.

NUTRITION OF THE THREATENED DESERT TORTOISE

Faced with evidence of precipitous population declines of desert tortoises *(Gopherus agassizii)*, the U.S. Fish and Wildlife Service made an emergency ruling in 1989 listing this species as endangered in the Mojave Desert; a subsequent final ruling designated the Mojave Desert population as threatened. High adult mortality was associated with a widespread upper respiratory tract disease (URTD), and some scientists believed that the susceptibility of tortoises to this disease was linked to poor nutritional status. The fear was that overgrazing by livestock had altered plant communities and reduced nutritional resources to an extent that tortoises had become debilitated, opening the way for infectious agents. A consensus emerged that research was needed on the nutritional needs of desert tortoises, and in 1991 the Smithsonian Institution (National Zoological Park) was awarded a 2 year research contract by the Nature Conservancy to that end. Collaborative research on tortoise nutrition was initiated by P.S. Barboza, D.E. Ullrey, and us. Subsequent research funding has been provided by the U.S. Bureau of Land Management (BLM), and via the Habitat Conservation Plan for desert tortoises in Clark County, Nevada.

A Desert Tortoise Conservation Center (DTCC) was built near Las Vegas in 1990 - 1991 to house displaced tortoises and to permit research studies. The BLM also constructed a small rearing facility that would permit year-round nutritional studies. The DTCC holds about 1,000 tortoises, of which up to 250 are used in nutritional research.

Initial research focused on the responses of young tortoises to various levels of dietary protein and fiber, as well as the digestive function of tortoises fed natural foods [e.g., Barboza, 1995]. However, in a broad survey of the nutritional composition of potential food plants for tortoises in the Mojave desert, it became apparent that many food plants are characterized by high potassium levels, as noted by Mmnich [1979]. This was of concern because tortoises do not have salt glands that can excrete excess potassium, in contrast to other reptilian herbivores in the Mojave desert such as chuckwallas *(Sauromalus obesus)* and desert iguanas *(Dipsosaurus dorsalis)* [Minnich, 1970; Nagy, 1972]. Reptiles are also unable to produce osmotically concentrated urine, since the reptilian nephron is relatively short and simple. We reasoned that tortoises consuming diets high in potassium must excrete the excess as potassium urates, but since uric acid is about one-third nitrogen, the consequent losses of nitrogen must be great.

In our studies of the effects of potassium, we have demonstrated (1) that tortoises can select among diets varying in potassium concentration, and invariably choose the diet lower in potassium, (2) that when fed a single diet, the voluntary food intake of tortoises is negatively correlated to dietary potassium concentration, (3) that this negative effect of potassium on food intake is more pronounced when a low nitrogen (1.6% N or 10% crude protein) diet is fed, and (4) that even a high nitrogen diet (3.2% N or 20% crude protein) will not permit positive nitrogen balance in young tortoises if the diet also contains 3.8% potassium [Oftedal et al., 1994, 1996].

We now hypothesize that tortoises in the wild may be constrained in plant selection by the ratio of nitrogen to potassium (N:K), and that certain plants of high N:K (including legumes) may be of particular nutritional importance to tortoise populations. If further studies confirm these hypotheses, land managers and conservation biologists may be able to assess habitat quality more accurately, and be better able to evaluate the potential conflicts for food between grazing livestock and desert tortoises. Given the political fervor surrounding attempts to restrict grazing in the West, decision makers are eager for scientific information that can document the effects of grazing on the environment.

CONCLUSIONS

It is clear that the nutritional needs of reptiles and other animals must be considered in conservation programs, whether in regard to the health and performance of captive animals or with respect to the evaluation of natural populations. We have given examples of a rural development program, a population rescue program, and a habitat conservation program in each of which nutrition proved important. How many conservation programs are there in which strong effects of nutrition fail to be recognized? It is imperative that this message reaches beyond the confines of the zoo community, and touches the conservation community at large.

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