Population Management, ZOOKEEPING (Part 4, Chapter 20)

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Introduction

Populations are dynamic, responding to influences such as environment, disease, and demographic fluctuations. So in zoos and aquariums, why is it important to manage populations rather than leave them to their fate? The answer is that generally speaking, zoos and aquariums manage a limited number of individuals for every species, and population problems become magnified in small populations. For a species to survive, it is important that it contains the genetic diversity to be "evolutionarily flexible". The most famous example of evolutionary flexibility is the rise of the mammals in terrestrial communities following the mass extinction in the late Cretaceous period 65 million years ago. It is likely that a catastrophic event occurred, such as an asteroid colliding with the planet, and that the mammalian species were able to adapt to the changed environment whereas the dinosaurs were not. Even today, the word "dinosaur" is synonymous with a failure to adapt to a changing environment.

The primary focus of this chapter is to give a very general overview on the concepts of population management. After studying this chapter, readers should understand

- the hazards associated with small populations
- the idea that a critical number of animals is required if a population is to be sustainable
- the definition of a founder animal
- the role of demographics in population management
- different tools that managers may use to manage populations

Hazards of Small Populations

Loss of Genetic Variability

A critical number of individuals are required for species of animals or plants to maintain genetic diversity. Without this number, negative effects on the population become magnified. This is because heritable differences (traits passed down from parents to offspring) between individuals will influence how they interact with the environment and within the ecosystem. These differences allow a species to cope with environmental changes, reduce the chances of harmful (deleterious) genes becoming expressed in the population, and confer a flexibility to adapt to future environmental uncertainty. For example, the highly contagious disease rinderpest, known to have killed up to 90% of ruminants in Africa in 1885, is described as the "Great Pandemic." However, a handful of animals were resistant to the disease and survived it. If all the species had similar genes, they all would have responded to the disease in exactly the same way, and thus 100% would have succumbed. A lack of genetic diversity in a population can result in a downward cycle of its reduced ability to withstand environmental pressures and novel conditions, which in turn can result in further reductions in population size and further loss of genetic diversity. This is described as an "extinction vortex" (see below).

A landmark study (Shaffer 1981) showed that a critical (absolute minimum) number of animals were required for a population to be self-sustaining for a long time into the future (beyond 100 years). The Minimum Viable Population (MVP) size is the smallest number of individuals required to withstand the various pressures that affect individual persistence over time. If the population number dips below the MVP, the chances of extinction increase. The tendency of small populations to decline towards extinction has been compared to a vortex (like a spiraling tornado or whirlpool), whereby faster-spiraling events occur closer to the center of the vortex. At the center of the "extinction vortex" is extinction (Gilpin and Soule 1986). Captive populations in zoos and aquariums are derived from initial groups of animals, many of which may have been imported from their native range countries decades ago. Those individuals are referred to as "founders". Any new animals brought into the population that are not related to animals produced from the original group are similarly referred to as founders. If the population is large enough and is managed correctly (i.e., in accordance with studbook recommendations), a population can be self-sustaining with little need for the introduction of new founders. This type of population is referred to as "closed" because animals do not flow in and out of it as they might do in a wild population. Because of the finite number of animals and plants maintained in zoos and aquariums, it is quickly apparent why each individual needs to be genetically represented in the population: to maintain maximum genetic diversity. With an insufficient number of animals reproducing, there is a risk that deleterious genes will be expressed, resulting in health and reproduction problems—or that heterozygosity (genetic variation) will be insufficient to allow some animals to survive a disease epidemic or other catastrophe. This situation is referred to as an "inbreeding depression". In contrast, outbreeding effects occasionally may be seen, such as when two subspecies are bred but are not genetically compatible, and the offspring have reduced fertility or are even sterile. This has been described in the Kirks dik-dik (Madoqua kirkii; Howard *et al.* 1989).

Demographic Fluctuations

Demography is the scientific study of populations, especially with regard to their size, sex ratios, births,

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deaths, and so on. A balanced demographic population would include all age groups, and the average birth rate would equal the average death rate. In reality this seldom occurs; and for certain species, demographic fluctuations may greatly influence the population, making it more susceptible to extinction than it would be by chance alone. For example, in species that reproduce slowly like the elephant, early infant loss or a failure to produce offspring may have dramatic effects on the demographic age structure. Similarly, the overproduction of male or female offspring in a given year may result in a sex skew that over time can have detrimental population effects. In captive settings, although the percentage of production of offspring (at least in mammalian species) is usually 50:50, there are times when chance can result in a different ratio of anywhere from 100:0 to 0:100. When considering the sex ratio of an entire population, it is important to remember that these ratios may occur by chance and may not necessarily represent a sex skew. It is prudent to review the birth ratio over an extended period of time and for a minimum of, say, 10 years to check whether a sex skew is actually occurring. For example, production of a significant majority of male versus female antelope in a single year is alarming for animal managers who only require one breeding male for a herd of females, and may seem like a "sex skew," but production of a majority of female antelope in a given year doesn't usually generate comment.

Recently, facultative parthenogenesis (asexual reproduction, possible under certain conditions) has been reported in Komodo dragons (Watts et al. 2006) and hammerhead sharks (Chapman et al. 2007). Since the reproduction was parthenogenetic, however, these offspring would be genetic copies of their mothers. If not managed appropriately, parthenogenesis in captive populations could result in unexpectedly high inbreeding, loss of genetic variation, and changes in founder contribution (Hedrick et al. 2007), and thus would be important to consider in the overall population.

Environmental Fluctuations

In most zoos, many environmental conditions such as temperature, food availability, water, and light can be controlled. However, disease epidemics may be more challenging to contain. The chytrid fungus (*Batrachochytrium dendrobatidis*) in amphibians is a good example of where stringent quarantine methods and animal handling will be required to maintain the health of amphibian populations in captivity. Similarly, the H_5N_1 influenza (bird flu) is highly contagious to birds and remains a serious concern to bird collections and human health worldwide.

Managing Populations

Record Keeping

The International Species Information System (ISIS) is an international database of zoological information, containing information from more than two million animals. Institutions that use ISIS contribute data on age, sex, parentage, place of birth, circumstances of death, and so on to generate a database that is used to manage genetic and demographic populations in animal collections around the world. ISIS software is recognized as the world standard in best practice for zoological record keeping. Accurate record keeping is critical to the success of this system, and is facilitated by the animal keeper's contribution of regular informational updates on animals.

Acquisition and disposition

To appropriately manage animal collections, it is necessary to periodically introduce new animals into a zoo or aquarium's collection. This maybe accomplished by buying, trading, donating, loaning, capturing, breeding, or rescuing an animal. The term for bringing in new animals is "acquisition". Similarly, animals may need to be permanently removed from a population for reasons such as population management, reintroduction, behavioral incompatibilities, sexual maturation, ending of a breeding loan, or death. This process is referred to as "disposition". It is important to remember that animals should be moved, traded, loaned, and donated only to institutions that have the expertise and appropriate facilities to adequately care for the animal.

Contraception, Euthanasia, and Sex Selection

In spite of careful population management, animals surplus to the population are still produced. This is especially true for many herd ungulates, where a single breeding male may be needed for a herd of multiple females. It may also result when an individual has reproduced sufficiently in a population and its genes are well represented, but continues to breed. For example, if males are not separated from females, due to space limitations or other reasons, offspring will continue to be produced. This could have the effect of flooding the population with genes from the overrepresented individual, and it is counterproductive for genetic diversity. Surplus animals can be managed in several ways; they can be treated with a contraceptive that may be permanent or reversible (see chapter 19), sold or donated to institutions outside the managed collection, maintained as a separate population if space allows for zoological research programs, or euthanized. Euthanasia as a management tool is commonly practiced in many countries, depending on social mores, and it has the advantage of keeping a female in more of an active breeding condition. It is widely known, though undocumented to date, that keeping females "open" (unbred) for several years can hamper efforts to get them to reproduce when it is finally desired.

Cutting-edge research is investigating the use of artificial insemination using sex-selected sperm to produce offspring of known sex. This has been particularly effective in the bottlenose dolphin (*Tursiops truncatus*), where 13 female offspring of predetermined sex have been produced (O'Brien et al. 2009; O'Brien and Robeck 2010).
The nucleated blood cells of birds allow sex determination to take place, and some institutions have refined the technique of carefully drilling a hole into a fertilized egg, collecting a tiny amount of blood from a blood vessel, sealing the hole, and continuing incubation. The blood can be used to determine the sex of the embryo, and then a decision can then be made as to whether to hatch the egg.

Tools

Collection planning determines, sometimes on the basis of staff expertise or geographical region, which assortment of species the institution will focus on. In zoological institutions belonging to organized associations such as the Association for Zoos and Aquariums (AZA), the European Association for Zoos and Aquariums (EAZA), the British and Irish Association of Zoos and Aquariums (BIAZA), and the Zoo and Aquarium Association (ZAA) in Australia, captive populations are managed in a more formal and cooperative way. A collection of experts, called a taxon advisory group (TAG), determines which species require formal breeding programs to be self-sustaining. These programs, such as AZA's Species Survival Plans® (SSP) or EAZA's European Endangered Species Program (EEP), will make formal recommendations to breed individual animals in order to ensure the viability of the population. They often use specialized software such as the Single Population Analysis and Records Keeping System (SPARKS) and Population Management 2000 (PM2000) to provide a detailed analysis. Population biologists and studbook analysts work with the SSPs and EEPs to confirm population sizes, meet conservation objectives, and ensure that captive populations do not grow beyond the ability of zoos and aquariums to manage them. Decision-making is facilitated by the use of studbook data including births, deaths and parentage: information essential to determining which animals should breed. Also, husbandry manuals, often written by animal care staff, outline proper care and breeding of a species and can be instrumental in the success of a breeding program. For details on these tools, see chapter 55.

Summary

The zookeeper can play an important role in managing animals by recognizing that individuals may need to be transported to other institutions in accordance with breeding recommendations. Compliance with such recommendations supports the long-term sustainability of the species by ensuring that it remains genetically diverse. Similarly, prompt removal of offspring once they get close to puberty prevents father-daughter or mother-son matings which can result in genetically useless animals that take up space in the institution. For example, a bias of male hoofstock offspring several years in a row should be scrutinized within the context of a 10-year period to prevent a coincidental occurrence being confused with a genuine sex skew. Lastly, keepers wishing to learn more about population management or to become more involved in it are encouraged to take on studbooks and/ or attend various professional training courses supplied by AZA and EAZA.

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