Proposal

Effects of Zoological Enclosures on Rhinos and Tapirs

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Introduction

Environmental conditions and resources affect an organism's growth, reproduction, health, and survival (Begon *et al.* 1990). In zoological parks, enclosures provide this environment in which captive animals live. Only under optimal conditions will an organism be able to maximize its fitness. To some degree, fitness is anthropogenically controlled in zoos. Yet, even if captive animals are fed well, they may still have lower productivity due to other factors, such as inadequate living conditions and space requirements (Hediger 1965, Mellen 1991, Smith & Read 1992). However, few data exist on the relationship between enclosure attributes and individual fitness. As a consequence, curators have little scientific information on how to optimally design enclosures for captive species (Carlstead 1999).

Zoological exhibits, as well as the philosophy on the role of zoos, have undergone many changes in recent decades (Gibbons *et al.* 1995, Seidensticker & Doherty 1996). Historically, enclosures basically consisted of square, kennel-like cages (Hediger 1950, Seidensticker & Doherty 1996). Little consideration was given to the animals' well-being or ex-situ conservation. Today, there is greater emphasis on conservation research, education, endangered species management, standards of animal care, and enclosure design (Hutchins & Conway 1995, Hutchins *et al.* 1995). The typical square cages have transformed into more naturalistic exhibits (Gibbons *et al.* 1994, Forthman *et al.* 1995, Kleiman *et al.* 1996). Unfortunately the redesign of enclosures is usually based on assumptions and aesthetics, rather than on empirical data concerning the biology and behavior of the organism (Carlstead 1999). This lack of knowledge has led to numerous problems for the care of captive animals, including inadequate reproduction, health problems, and mortality. For example, captive breeding of the black-footed ferret (*Mustela nigripes*) was largely unsuccessful until the U. S. Fish and Wildlife Service learned how to properly manage ferrets in captivity (Seal *et al.* 1989, Balmford *et al.* 1996). Similarly, captive management of rhinoceros remains problematic, with productivity levels below demographic and genetic sustainability, for unknown reasons (Smith & Read 1992, Carlstead 1999, Carlstead *et al.* 1999).

Enclosures contain many different features that could affect the captive animal. At the basic level, the enclosure must contain at least food, water, shelter, and space. Debate currently exists on whether enclosure size or complexity is more important for captive animals. Hediger (1950) asserted that enclosure size should be based on flight distances of the wild animal in captivity, but that tame animals only need enclosures that are several times the length of their bodies to satisfy their physiological needs. Interestingly, this philosophy is still being used by zoos to determine minimum enclosure sizes, despite the general lack of data. The quality of space, rather than quantity, is assumed to be more important for the management of captive species (Hediger 1950, Besch & Kollias 1994). Fueling the debate between enclosure size and complexity are discrepancies between research results; several studies have found that enclosure size is insignificant (Wilson 1982, Mellen 1991, Kreeger 1996, Lyons *et al.* 1997), while others have found it to be correlated with reproductive success and mortality (McCusker 1978, Miller-Schroeder & Paterson 1989, Roberts 1989, Carlstead *et al.* 1999). The differences in enclosure size significance may be due to species perceptions and mobility. Species that are able to climb, such as gorillas, would tend to view a more three-dimensional, rather than two-dimensional surface. For these species, volume might be a more appropriate measure for enclosure size. For species whose locomotory abilities restrict them to the ground, enclosure area might be important for determining their fitness.

Other enclosure attributes and husbandry practices also may affect captive animals. The combination of factors, such as density, diet, climate, and sanitation maintenance, define the environment within the enclosure. The interaction between environmental factors and the response of the animal ultimately determine its health, reproduction, and survival. For large animals, usually only a few individuals are kept at a single zoological institution. Consequently, individual variation plays an important role in the management of captive animals, yet population management is also required for the conservation and management of species in captivity. Developing general guidelines for the management of captive species is critical for successful species conservation programs. To improve the reliability of these guidelines, a scientific and empirical basis needs to be established by measuring environmental factors across multiple zoos and determining species response.

Perissodactyls, specifically tapirs and rhinos, were selected for this study due to their worldwide threatened and endangered status, presence in zoological institutions, locomotory abilities, and size, being among the largest herbivores. Captive management of tapirs, especially the Malayan (*Tapirus indicus*) and lowland (*T. terrestris*), has been fairly successful in recent years, despite their threatened and endangered status in the wild (Barongi 1993, Barongi 1997). The worldwide captive population of Baird's tapir (*T. bairdii;* $n \approx 43$) remains low though, compared to the Malayan ($n \approx 175$) and lowland ($n \approx 200$) tapirs (Barongi 1993). Reproduction among tapirs, however, is fairly commonplace, despite medical and behavioral problems that occur mainly due to lack of experience and knowledge (Barongi 1997). Conversely, rhinos have experienced numerous problems in captivity, resulting in the lack of self-sustaining populations for several species (Smith & Read 1992, Carlstead 1999, Carlstead *et al.* 1999, AZA Rhino Advisory Group 2002). Reproduction is a major problem for white rhinos (*Ceratotherium simum*), whereas mortality and skewed natal sex ratio towards males are the main problems for the black rhino (*Diceros bicornis*) in captivity (AZA Rhino Advisory Group 2002). The captive population of Indian rhinos (*Rhinoceros unicornis*) has fewer demographic problems, but its genetic diversity is low and many individuals are afflicted with foot problems (AZA Rhino Advisory Group 2002). The environment provided for each of these species may have a significant effect on reproduction, mortality and health and needs to be further examined.

Objectives

The main objectives of this research are: (1) to assess the relationship between enclosure attributes and reproduction, mortality, and health; (2) to determine the optimal enclosure size that maximizes breeding success and minimizes mortality and disease frequency, and; (3) to compare optimal enclosure design between species. The enclosure attributes that are correlated with breeding success and mortality rate may vary among species, but the following variables ranked in order of importance are predicted to be biologically significant: exhibit size, density, the percentage of public access along the enclosure perimeter, climate, and the number of years that the zoo has maintained rhinos and tapirs. As exhibit size increases, breeding success should theoretically increase, and mortality should decrease, until a threshold is met. Density may also influence reproduction and mortality, since the total enclosure area may not be as significant as the relative amount of space for each individual within the enclosure. Since tapirs and rhinos, excluding the white rhino, are primarily solitary, multiple males or females may lower breeding success and increase mortality. Carlstead *et al.* (1999) found that zoos with a single black rhino female had a higher reproductive rate compared to zoos with multiple females, and that the mean age of first reproduction was significantly lower for those single female rhinos. Carlstead *et al.* (1999) also found a correlation between mortality and the percent public access. Increases in the amount of public access along the enclosure perimeter may increase fear and stress for individuals in the enclosure, resulting in lower reproduction success and higher mortality. Climate also may have an effect considering that seasonal variation could influence the timing for reproduction. Furthermore, the amount of time that the animals are kept in the indoor enclosure will most likely be correlated with climate, with the zoos in the higher latitudes unable to provide outdoor access during the winter months. Lastly, differences in breeding success and mortality may be due to difference in experience in managing these species. The number of years that the zoo has kept these species should serve as a measure of the zoo's level of experience.

In addition to reproduction and mortality, health of rhinos and tapirs also will be examined. The average number of medical treatments per year or the frequency of certain diseases as a response variable may actually provide a more sensitive measure of the effect of enclosure attributes on these species, considering that individuals in poor health are less likely to reproduce and more likely to die. Thus, the variables that are significant for reproduction and mortality are likely to be significant for health as well. However, substrate, water pools, shade, diet, and number of feedings per day are also predicted to be significant. For instance, the substrate of the enclosure could possibly influence the occurrence of foot problems, parasitic infections, and colic for both rhinos and tapirs. The number and size of pools of water might be especially important for the fitness of tapirs. Pools may lower the risk of rectal prolapse, because of tapirs' preference to defecate in water, and may reduce the incidence of skin problems (Barongi 1993). Shade is also considered an important factor for reducing the incidence of eye problems for tapirs (Barongi 1997). The importance of shade for the health of tapirs will most likely depend on the climate of the zoo and species, since eye problems are more prevalent in Malayan tapirs and in zoos at lower latitudes (Barongi pers. comm.). The diet provided to rhinos and tapirs is also critical for their health. In fact, the diet of black rhinos is suspected of attributing to the problem of hemolytic anemia and other disease syndromes afflicting this species due to possible iron overload and phosphate depletion (AZA Rhino Advisory Group 2002). In addition to having an adequate diet, the number of feeding times may also influence the health and well-being of rhinos and tapirs. Seitz (2001) found that several outdoor feedings and the availability of natural vegetation increased the activity budget of tapirs and reduced resting periods during the day. The maintenance of normal, natural behavior in captivity could impact health, reproduction, and mortality for these species. Finally, various other attributes that define the environment for these species, such as barrier height, topography, number of trees and shrubs, shelters, average time on exhibit, and maintenance conditions, may show a correlation with reproduction, mortality and health.

Optimal enclosure design will depend on the relationships found between the enclosure attributes and reproduction, mortality, and health. For example, optimal enclosure size would be the size that minimizes mortality and disease frequency and maximizes reproduction, given that a positive and negative relationship exists between these factors. The optimum could possibly be defined in terms of phase space, providing a range of enclosure sizes that achieve the same goal of optimization. Identifying the combination of enclosure features that are associated with increased reproduction and health and decreased mortality will facilitate enclosure design for these species.

However, variation between and within the species can influence optimal enclosure design for attaining captive management goals. For example, optimal enclosure area may scale allometrically with species size. If this is the case, then the white rhino may require a larger enclosure than the black rhino, which would require a larger enclosure than the Malayan tapir. Differences also might exist between captive and wild-born individuals within a species. One might expect increases in mortality and disease frequency among wild-born animals, especially in smaller enclosures. Sexual differences are also expected to occur due to physiological and behavioral differences between males and females. The data collected will be used to evaluate each of these hypotheses.

Methods

Three species of tapirs (lowland, Baird's, and Malayan) and three species of rhinos (black, white, and Indian) were chosen for this study. Studbook data will be used to provide life table information for each species. The studbook data also provides information on whether the animal was captive or wild-born, the number of years housed within a zoo, and the number of transfers between zoos. In addition, a census of all North American zoos housing these species will be performed. A survey instrument will be mailed to these zoological institutions to gather information on enclosure attributes (Appendix A). Some of the variables that will be included on the survey are: age of the enclosure, total enclosure area, shape of the enclosure, enclosure substrate, percent of public access along enclosure perimeter, number and size of water pools, percent shade, number of individuals per enclosure, and amount of time animals are allowed in the outside versus inside enclosures. Though individual behavior is an important aspect to be considered, this research will only address how behavior translates into mortality, health, and reproduction.

Data analysis will be performed for each of the six species. If no significant differences exist, data may be pooled across taxonomic family for the three species of Rhinocerotidae and the three species of Tapiridae. Summary statistics, such as means and standard deviations, will be calculated for each of the enclosure variables. Correlation among variables will be analyzed, with an 80 percent overlap considered significant. A principle components analysis may be used if the variables are highly intercorrelated. Since population data is being obtained, instead of a sample of the population, identifying the model that best describes the data is the primary objective (Gill 2001). The explanatory variables that will be used include exhibit size (S), density (D), the percentage of public access along the enclosure perimeter (P), climate (C), and the number of years that the zoo has maintained rhinos and tapirs (E). Using an information-theoretic approach (Burnham & Anderson 2002), the relationship between these variables and the three response variables, birth rate, death rate, and average number of medical treatments per year, will be evaluated. The following models will be analyzed using Aikake's information criterion (AIC): main effects [S, D, P, C, E]; [Log S]; [Log S, D]; [Log S, D, S*D]; [S, D, P]; [S, D, P, S*D, S*P]; [S, D, P, C]; [P, C, E]; [C, E]. In addition, substrate, shade, water pools, diet, and number of feedings per day will be used as explanatory variables for specific disease frequencies. For example, models of all possible combinations of shade and climate will be analyzed for the incidence of eye problems in tapirs; whereas substrate will be used for frequency of foot problems for both rhinos and tapirs. Akaike weights will be used to rank the models and the relative importance of the explanatory variables. Optimality modeling will then be used to determine optimal enclosure sizes for each of the species. Using regression, allometric relationships also will be assessed. Some post hoc exploratory analysis of the data will be performed to further identify potential relationships between the explanatory variables and reproduction, mortality and health.

Implications

Knowledge of how enclosure attributes affect reproduction, health, and mortality for rhinos and tapirs can be applied to improve captive management, as well as to provide a better understanding of rhinos and tapirs themselves. Human intervention, in terms of health care, keeper experience, enrichment, hand-rearing of young, or other factors that cannot be accounted for, may impact the results of this study. However, identifying the relationship between environmental factors and demographic and health parameters is a fundamental step for further developing successful management programs for rhinos and tapirs in captivity.

The American Zoo and Aquarium Association (AZA) Minimum Husbandry Guidelines recommend standards for the management of species, including specifications for indoor and outdoor facilities, enclosure features, sanitation, diet, social groupings and veterinary care. Unfortunately, few scientific data exist to base these guidelines. For instance, AZA Minimum Husbandry Guidelines recommend that each adult tapir have an outdoor enclosure of at least 18.6 m^2 (Barongi 1997). However, whether this is the optimal size is unknown. Innis et al. (1985) suggest that the appropriate enclosures size can be calculated using the number of animals and the minimum preferred distances between individuals for a particular species. Determining the preferred distance between individuals, however, is unclear, which could lead to potentially erroneous enclosure size calculations. Comparisons between direct observations of the effects of enclosure size and the suggested appropriate sizes could prove useful for developing better guidelines and models for calculating spatial requirements. This approach, using empirical data, could be applied to other enclosure features and husbandry practices to determine overall optimal enclosure design.

One of the primary goals of the AZA Species Survival Plan for Rhinoceros is the "improvement of captive husbandry and management through research in health, nutrition, behavior, and reproduction to facilitate development of viable populations ex situ…" (AZA Rhino Advisory Group 2002, p. 8). The AZA Tapir Taxon Advisory Group (TAG) also has established similar objectives. By acquiring empirical data on husbandry and environmental factors across multiple zoos, this comprehensive study fulfills that objective and provides much needed information for captive management of tapirs and rhinos. Consequently this research is approved by both the Rhino and Tapir TAG (Appendix B). Because the data obtained is observational, only correlations between factors can be demonstrated; yet, this study provides a crucial tool to indicate important trends for reproduction, mortality, and health in the captive environment and to identify possible explanatory factors that need further investigation.

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