


Stress and distress: evaluating their impact for the well-being of zoo animals

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Are “well-being” and “stress” 2 mutually exclusive terms? Let us consider the bungee jumper who leaps willingly off a 100-foot bridge or the popularity of roller coaster rides at one of the many amusement parks around the nation. Drastically different experiences, such as the thrill and excitement of a roller coaster ride and the much less desirable stress of a daily commute during rush hour or giving a public speech, can elicit very similar physiologic and hormonal reactions that have been summarized under the term “stress response.” The wide range of occurrences that can evoke such a response highlights the complexity surrounding the term “stress” and its assessment. Across mammals and, more generally, across vertebrates, the neuroendocrine and physiologic responses to stressful stimuli appear to be quite similar and have been preserved through evolutionary history. What, then, is stress, how does it impact the well-being of animals, and how can we measure it?

Stress and Distress—Concept and Definition

Since the early 1970s, stress has become an increasingly popular and widely applied term in our everyday language and usually conjures up negative images. Disagreements about a clear definition of the term have caused some researchers to doubt the general usefulness of the stress concept, while others struggle with changing the original definition and meaning. The term “stress” originated in the engineering field to describe certain properties of metals and glass and was introduced into the biological field in the late 1930s by Canadian physician and stress researcher Hans Selye. Selye defined stress as a general syndrome occurring in response to any stimulus that threatens or appears to threaten the homeostasis (or the physiologic and physical integrity) of an individual. He called such stimuli “stressors” and the syndrome “stress” or “general adaptation syndrome.” A very general concept of the stress response had already been described almost a decade earlier as the “fight or flight” syndrome by Walter B. Cannon. This general physiologic stress response appears to have evolved as an adaptive mechanism that allows organisms to adjust to and cope with less predictable circumstances in their environment and to respond rapidly to a wide variety of stimuli. Thus, stress represents an important part of life and should not be considered as inherently bad. Some researchers have recently argued that the term stress should only be used for events that are considered detrimental to an individual. However, we are still in the process of establishing what distinguishes the normal and adaptive response from the one that leads to negative effects. Although we can clearly identify some of the negative effects, we are not yet able to distinguish positive and negative stressors and associated responses reliably. The term “distress,” applied by some to label the already identified detrimental effects of stress responses and certain stressors on animal health and well-being, appears to represent a more appropriate subcategory of stress. As we continue to expand our knowledge in the area of stress research and gain a better understanding of its mechanisms and consequences, we may be able to establish more appropriate definitions in the future.

The Stress Response and Its Consequences

Once a stressor has been perceived by an organism, the hypothalamus is stimulated and responds by synthesizing and releasing corticotropin-releasing factor, among other hormones. Corticotropin-releasing factor is one of the primary factors activating the pituitary...
Defining animal well-being and welfare has been fraught with much difficulty, and no clear consensus has been reached. One problem is that welfare cannot be seen solely as a scientific concept, since it also reflects political and ethical views of societies. In assessing welfare, we are not only concerned with the physical needs but also with psychologic and emotional aspects of well-being. However, defining psychologic well-being and assessing mental states of animals are clearly very difficult. It requires us to view the world from the animal’s perspective rather than our own, usually anthropocentric viewpoint guided by our limited sensory capacities. Even though we may never be able to establish what constitutes perfect well-being for individual animals, we most certainly can establish what leads to a lack of well-being. It is via the process of elimination that we can identify the prerequisites necessary for both physical and psychologic well-being of species and individuals to the best of our abilities.

The following basic “freedoms” were established as minimum standards for the welfare of farm animals in the UK after much political controversy: “Freedom to display most normal behavior patterns, freedom from thirst, hunger and malnutrition, freedom from physical and thermal discomfort, injury and disease, and freedom from fear.” Although quite vague, these freedoms can offer a starting point for identifying some of the prerequisites necessary for improved well-being.

Minimum requirements have already been established for many zoo-held species and are being improved upon or newly established for others (eg, under the supervision of the American Zoo and Aquarium Associations [AZA] Animal Welfare Committee, AZA members are working on compiling and revising mammal and avian standards based on currently available scientific information). Successful reproduction, lack of disease and pain, absence of abnormal or detrimental behaviors, normal weight range and blood values, food consumption, and longevity have all been used as indicators of well-being. Zoos have made tremendous progress over the past decades in the areas of veterinary care, nutrition, population genetics and management, animal husbandry, and exhibit design and have greatly contributed to our understanding of individual animal and species-specific needs. Recent advances in stress research have now lead to the realization that certain preclinical and clinical symptoms may be resulting from physical and psychologic distress experienced in the captive environment. Freedom from distress thus represents another essential component for the establishment of overall well-being.

Free-ranging animals may often experience stress and distress on a daily basis; for example, hunting, being hunted, mating, fighting, establishing and maintaining social hierarchies, finding shelter, diseases, parasites, sudden changes in weather, and anthropogenic influences can all represent significant stressors. However, stress reactivity can vary greatly across species and individuals according to sex, age, genetics, nutritional status, overall health, and early rearing environment (including prenatal experiences). Therefore, animals born and raised in captivity may react very differently compared with their wild counterparts, even when faced with the same stressors. In captivity, many of these original stressors have been removed, and the lack of stimulation can itself present a source of distress due to animal boredom. Environmental enrichment, now car-

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![Image](attachment:animal_welfare_forum_the_welfare_of_zoo_animals_javma_vol_223_no_7_october_1_2003_974.png)
ried out by many zoos for a wide variety of species, can provide necessary and beneficial stimulation. Depending on an animal’s temperament, some individuals may require more stimulation than others. Several studies on animal temperament have shown that, similar to humans, some individuals may seek novelty and excitement, whereas others prefer routines. A variety of studies employing quantitative behavioral observations or measures of reproductive success already indicate the beneficial effects of environmental enrichment, exhibit changes, and provision of behavioral choices. However, very little research has yet examined physiologic stress responses and preclinical and clinical signs of distress in combination with changes in captive management and environment of zoo animals. The challenge is to identify appropriate measures that can be applied to zoo animals for the assessment of distress and well-being.

Measuring Stress and Distress

No single biochemical or behavioral measure can be used to assess animal well-being or stress. While behavioral observations may frequently provide a first indicator of distress, they can also be misleading. Individual variation in stress reactivity, variation in coping styles, and our lack of understanding of the causal mechanisms underlying observed behavioral changes do not make them a reliable indicator of distress. Similarly, measures of reproductive success, growth rate, and general health, although important for examining certain aspects of animal well-being, usually cannot provide reliable early indicators of distress when examined by themselves. Only through a combination of factors, including physiologic measures, can we begin to examine the influence of stress and distress on animal well-being.

The recent development of fecal hormone monitoring has provided us with a new tool for such investigations. Measuring glucocorticoid concentrations in blood samples has long been used as an indicator of stress in mammals, however, the invasive nature and inherent stress of collecting blood samples have limited its usefulness for studies on many captive and wild animals. Fecal cortisol monitoring can be used in combination with behavioral observations and other measures of overall health in longitudinal studies without additional stress to the animal. One has to be aware, though, that careful biochemical and physiologic validation is necessary for the application of this technique, and resulting measures cannot provide a litmus test for distress. Increases in fecal glucocorticoids may be a result of negative (ie, nonadaptive) or positive (ie, adaptive) stress responses. Furthermore, glucocorticoid concentrations may decline because of intrinsic hormonal control and negative feedback mechanisms, rather than elimination or decrease of the external stressor. In addition, although a wide variety of stressors stimulate the HPA axis, not all types of stressors will affect an increase in glucocorticoids. Nevertheless, the combined use of all available measures can help us better understand the impact of various stressors on animal well-being and make significant advances in our assessment of distress.

Examples of Zoo Studies on Animal Stress

Recent studies on wild and captive animals are beginning to investigate the effects of various environmental and social variables on stress responses using noninvasive physiologic measures in combination with behavioral and other measures. Application of such measures to zoo animals has already shown promising results. A study on urinary cortisol in leopard cats found that concentrations were significantly reduced and pacing behavior decreased when additional hiding spaces were added to the enclosure and enrichment was provided. A study on capuchin monkeys using fecal cortisol and behavioral measures indicated a positive effect of enrichment on stress responses with a decline in cortisol. Another study employing the use of salivary corticosterone measures and behavioral observations on several mammal species, including rhinos, found no significant effect of zoo visitors on cortisol levels. An ongoing study on cheetahs combines a health measure, the development and severity of gastroenteritis, with fecal cortisol concentrations and environmental and husbandry factors.

In a recent study on clouded leopards, Wielebnowski et al examined 74 individuals at 12 North American zoos and correlated fecal cortisol concentrations with extensive behavioral and husbandry information. Results showed significant correlations between observed behavioral problems (eg, fur plucking, extensive pacing, and hiding) and mean fecal cortisol concentrations, potentially indicating chronic stress. Furthermore, several husbandry variables, including enclosure height, number of keepers, and keeper-time spent with animals, also correlated significantly with mean fecal cortisol concentrations. For example, the higher the enclosure, the lower the cortisol concentrations. Also, animals on display or visibly exposed to other large cats appeared to have increased cortisol concentrations. These results can provide us with first indicators of potential problems. However, further experimental manipulation of enclosure features and husbandry variables is needed to establish causality. Therefore, an ongoing follow-up study is currently investigating the impact of enclosure height and hiding spaces on a subset of the study population by experimentally manipulating enclosure features. Longitudinal behavioral and hormone monitoring, together with keeper and health records of individual clouded leopards, are used to assess the effect of these environmental changes on animal well-being.

Several similar studies on a variety of species, including okapi, black rhinos, elephants, and polar bears, are currently being conducted. These types of longitudinal and multidisciplinary studies, carried out on a representative sample of various captive populations at multiple facilities, will allow us to significantly increase our understanding of the impact of stress on zoo animals. Ultimately, these concerted efforts can provide us with scientific evidence and quantitative evaluation for management and husbandry adjustments to improve the well-being of the animals in our care.

Future Research

Integration of measures from a wide variety of disciplines, including (but not limited to) veterinary med-
icine, nutrition, genetics, reproductive physiology, behavior, and psychology, will be required to address issues of stress and distress in captive and wild animals. More cross-disciplinary research is urgently needed to address these topics. Furthermore, the development and use of innovative and noninvasive measures of stress responses and assessment of animal psychologic status are needed in combination with the already existing techniques to further improve our understanding. Remote sensing technology, various radiotelemetry devices, and other advances in sampling technology will hopefully provide us with new avenues for these endeavors in the near future.

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Steering the ark toward Eden: design for animal well-being

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Whatever one thinks of capturing wild animals for pets, zoos, aquariums, or research, one may also think of their descendants as refugees of our own species’ global war for dominion over nature. This paper will review the development of zoo design as we seek to improve the well-being of these zoologic refugees.

Stage 1—Physical Survival

During the era of barred cages, there were few long-term survivors. Advances in diet and veterinary care brought in the era of green-tile enclosures and, for many species, greatly increased longevity. In 1950, this success encouraged Edward Hindle, Scientific Director of the London Zoo, to say, “…the vast majority of zoo animals are far healthier…than those in the wild, and also have a longer average life.”

Massa, the popular Philadelphia Zoo gorilla, set the species longevity record of 54 years in such an environment and was well supported by human caregivers.

Stage 2—Emotional Survival and Reproduction

While Massa had close human friends, he usually lived alone. Willie B, Zoo Atlanta’s gorilla patriarch, led a similarly isolated life for his first 27 years. Then in 1988, Willie was joined by 13 gorillas from the Yerkes Regional Primate Research Center. Formed into 3 troops, they soon acclimated to their spacious naturalistic outdoor enclosures. Within this complex social and natural environment that was managed by Dr. Terry Maple, the previously solitary Willie B sired 5 offspring. A total of 13 gorillas have been born at Zoo Atlanta since 1988. Similar breeding successes have been achieved by many zoos for many species when appropriate social grouping is combined with advanced veterinary care. During this same period, zoos in Lincoln Park, Illinois and Howletts, England had great success with gorillas in highly artificial, albeit enriched environments. In Europe, laws were putting building preservation above animal well-being.

Green Space is Not Always Enough

As before, some behavioral problems were treated with medication, and physical and behavioral health problems were often seen as unrelated. Training and behavioral enrichment activities were remedial. Hediger identified problems related to boredom; lack of activity and exercise could lead to loss of physical fitness and long-term health problems. Even highly naturalistic artificial habitats may not meet all animal needs. Stoinski found gorillas at Zoo Atlanta eschewed open spaces, preferring shady retreats near large solid objects. Carlstead suggested some black rhinoceroses suffered chronic stress resulting in diminished longevity and reproduction when kept in small or walled enclosures, however naturalistic they appeared.

Coe and Scheffler demonstrated a relationship between high levels of stress and depressed immune response. Snowdon found that giving captive animals choices lowered stress levels. Larger, lushly landscaped displays modeled on natural habitats emerged in the United States in the 1970s. My recollection of the period was that the same sentiment, which favored nature as the model in display design, favored a more hands-off policy in husbandry. Gone were chimpanzee tea parties. Gone also were mechanical mice as enrichment stimuli. Naturalistic displays were thought by some to be sufficiently stimulating that additional stimulation was unnecessary. While this approach worked well, it did not always prevent problems, such as loss of occupation. Could we do more?

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Coe and Scheffler demonstrated a relationship between high levels of stress and depressed immune response. Snowdon found that giving captive animals choices lowered stress levels. Larger, more naturalistic enclosures offer more choices but still fall far short of the diversity of the wild, and most important choices are made for animals by caregivers. To borrow a computer analogy, large, passive exhibit areas (hardware) also need active husbandry programs (software) to reach their full potential. Nearly 20 years ago, Fortham-Quick summarized the debate between the naturalistic method and the more interventionist approach of Markowitz, who argued for integration of behavioral enrichment and training into the basic design of naturalistic animal displays. Yet, I have found...