Wild Tigers in Captivity: A Study of the Effects of the Captive Environment on Tiger Behavior

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ABSTRACT

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Humans maintain wild animals in zoological parks for the purposes of education, conservation, research, and recreation. However, abnormal behaviors may develop in animals housed in human-made environments, if those environments do not allow them to carry out their natural behaviors (such as swimming, climbing, stalking, and predation). Captive environments in zoological parks often do not provide for natural behaviors due to spatial constraints and negative public reaction. Tigers (*Panthera tigris*) present a difficult case; they have large home ranges in the wild and natural predatory hunting behaviors that are difficult to provide for in captivity.

As the numbers of wild tigers decline, captive breeding programs have become a major focus of the zoo community, which magnifies the importance of research on tiger husbandry. A body of research exists on small felids, but little, if any, has focused on tigers. This thesis presents an analysis of the effects of the captive environment on the behaviors of 18 captive Bengal and Siberian tigers in four zoological parks in Virginia and Pennsylvania. Certain animal characteristics (such as subspecies, and age) were also related to behavior. Several characteristics of the captive environment had statistically significant effects on stereotypic and exploratory behaviors of tigers: shade availability, the presence of a body of water, cage size, the presence of a conspecific, vegetation, environmental enrichment, and substrate type. There were significant differences in the behaviors of the two subspecies studied, but the reason for the differences are unclear.

The results of this study showed clearly that tigers kept in more natural and complex enclosures performed less stereotypic pacing (unnatural behavior), and more exploratory (natural) behaviors than those housed in less natural enclosures. Reducing the stress level in captive tigers will enhance the animals' overall physical and psychological well being, which will in turn increase the success of captive breeding programs. These results suggest that captive tigers should be housed in large enclosures containing natural substrate and vegetation, water pools, ample shade, a variety of resting locations, and a variety of enrichment items.

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CHAPTER 1

INTRODUCTION

Humans maintain wild animals in zoological parks for the purposes of education, conservation, research, and recreation (Mench and Kreger, 1996; and Shettel-Neuber, 1988). However, abnormal behaviors may develop in animals where the captive, human-made environment is not suitable for them to carry out their natural or instinctive behaviors (Carlstead, 1996). Felids generally have extensive natural home ranges in the wild and carry out "hide, stalk and chase" hunting behaviors. The captive environments of most zoological parks do not, and can not, provide for these behaviors due to spatial constraints and negative human reactions to predatory behaviors (Mellen et al., 1998).

In the past 30 years, a number of zoological parks have implemented major changes in the management of felids to enhance their lives (Law et al., 1997). Environmental enrichment is the process in which animals' captive environments are manipulated to provide various items and spaces that will stimulate their psychological and physiological well being (Sheperdson et al., 1998). However, enrichment plans for felids are notoriously difficult to develop due to their natural hunting behaviors and spatial requirements. Further research on the effects of enrichment on felid well being is needed (Mellen et al., 1998).

General Study Objectives

Zoological parks depend on the expression of "normal" behaviors by the animals displayed to successfully achieve their goals (Baldwin, 1991). Normal behaviors can be defined as "the exhibition of a phenotypic trait within the environmental context for which primary selective forces have shaped it, the outcome of which being maximal, inclusive fitness" (Eisenberg, 1981). In captivity, these "normal" behaviors are often replaced by abnormal, or "stereotypic" behaviors such as pacing (Carlstead, 1996). The following questions regarding the human-animal-environment relationship stimulated this study:

- Are human-made environments suitable for "wild" animals?

- How do animals adapt and adjust to human-made environments and the constant presence of humans?
- How do various factors of exhibit design, such as vegetation, substrate, and enclosure size, influence tiger behavior?
- Can changing elements of the tigers' captive environment reduce stereotypic pacing behaviors?
- Do tigers in more natural exhibits perform less stereotypic behaviors than those in less natural exhibits?

The primary objectives of this study are the following:

(1) To determine the frequency of occurrence of resting, exploring, and stereotypic behaviors in captive Bengal and Siberian tigers.

(2) To determine the amount and quality of enclosure space that my study animals utilized.

(3) To examine the relationship between behaviors and two sets of variables: animal variables and environmental variables.

(4) To provide a series of recommendations developed from the findings of this study to enhance current enrichment and management programs for tigers in captivity.

Tigers (*Panthera tigris*) were chosen as the research animals in this study for two reasons. First, within the human-animal-environment literature available on felids, almost none was focused specifically on tigers. By completing this study, I hope to add more species-specific information to the literature. Second, through personal observations of this species performing stereotypic behaviors in captivity, I felt that this project could provide specific recommendations for enriching and managing captive tigers.

Significance

Stereotypic behaviors are thought to be an indication of stress (Carlstead, 1996). Every effort should be made to reduce stress in captive animals, not only for the general well being of the animal, but also to increase the success of captive breeding. The captive breeding of endangered species for maintaining genetic diversity is especially important for tigers because their numbers are greatly reduced in the wild (Seidensticker et al., 1999). Wild tiger numbers are estimated to be in the range of 5,000 to 7,000 at the global scale (Seidensticker et al., 1999). Five tiger subspecies remain since the recent extinction of the Caspian, Javan, and Bali subspecies. The next subspecies expected to vanish is the South China tiger, which has an estimated population of 30 individuals (Seidensticker et al., 1999). This study focuses on the Bengal (*Panthera tigris tigris*) and Siberian (*Panthera tigris altaica)* subspecies (Figures 1.1 and 1.2). In the wild it is estimated that there are 3,159–4,715 Bengal tigers and 360–406 Siberian tigers (Tilson et al., 2002). Approximately 490 Siberian tigers are in captive breeding programs and there are 333 Bengal tigers in zoos, primarily in India (Tilson et al., 2002).

As captive breeding programs become more important in conservation, the husbandry of captive tigers is also becoming a major focus of the zoo community and gaining prominence in the public eye (Sheperdson, 2002). This study provides information that could be used to improve the lives of captive tigers and increase breeding success.

The study of the relationship between the captive environment and animal well being is an important component of tiger husbandry. This thesis adds to the literature on captive felid enrichment, most of which is focused on smaller cats (Mellen et al., 1998), and provides useful information for zoo exhibit planners and other animal keepers. By considering the relationship between enclosure variables and animal behaviors, designers can attempt to optimize desired behaviors and reduce stereotypic behaviors that are performed by their animals. My recommendations will also be useful for other subspecies of tigers not included in this study, and other large felids such as lions and pumas.

Background on Animal Geography

The results of this study will also add to the limited literature on cultural and ecological animal geography (Bennett, 1960; Davies, 1961; Philo, 1995; Sauer, 1952; Donkin, 1989; Anderson, 1995; and Tuan, 1984). Animal geography is recognized as "the study of animal populations in terms of their spatial distributions and environmental associations" (Philo, 1995).

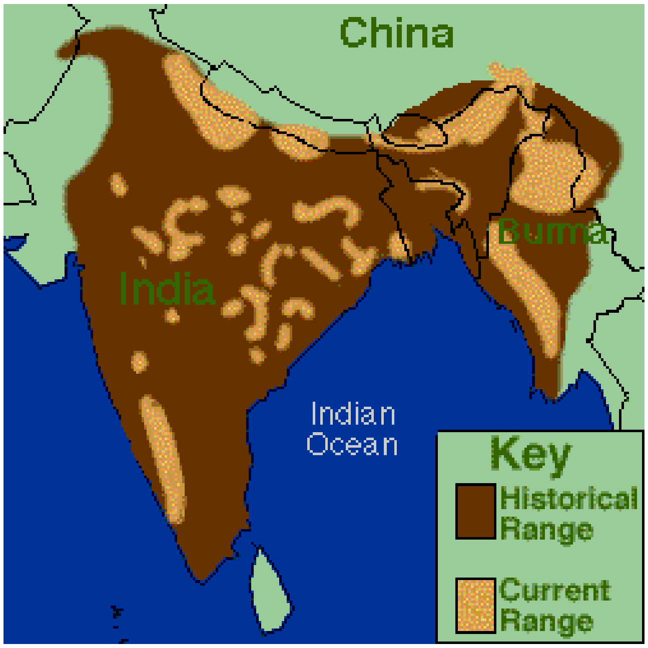
Bennett (1960) defines cultural animal geography as “those aspects of animal geography which accumulate, analyze, and systemize data relevant to the interactions of animals and human cultures”. Ecological animal geography involves an attempt to understand the environmental dynamics which influence animal distributions through time (Bennett, 1960). Bennett (1960) emphasizes that studies in animal geography create “a needed appreciation of animals as an element in the landscape”. Zoological parks consist of a “nature” that has been created by, and for, humans (Anderson, 1995). Sauer (1952) acknowledges that the lives of animals are greatly influenced by humans. In captivity, this influence is even greater.

Tuan (1984) calls attention to the varying ways in which humans think and feel about animals, which shapes our “sociospatial practices” towards different animal species according to Philo (1995). Humans may feel compassion, fear, revulsion, love, and utilitarianism for animals. Animals that display human characteristics, such as apes, or animals that are large and furry, such as panda bears, are known as “charismatic megafauna”, and are highly prized by the general public. Tigers fall into this category, as they are large, attractive, and an endangered species. As tigers comprise one of the most popular zoo exhibits, much information can be shared with the public regarding their conservation status and ecological needs in the wild. Research has shown that displaying wild animals to the public can be an effective education tool, but even more effective when the animals are performing “normal” species-specific behaviors and in naturalistic exhibits (Shettel-Neuber, 1988).

Figure 1.1. Historical and current range of the Siberian tiger (*Panthera tigris altaica*).

Source: 5 Tigers: The Tiger Information Center. 2002. http://www.5tigers.org

Figure 1.2. Historical and current range of the Bengal tiger (*Panthera tigris tigris*).



Source: 5 Tigers: The Tiger Information Center. 2002. http://www.5tigers.org

CHAPTER 2

LITERATURE REVIEW

This literature review is divided into four sections. First, I present the goals of zoological parks in order to understand their value. The second section reviews current exhibit design and the concept of landscape immersion. The third section discusses abnormal behaviors in captivity, and the fourth explores prevention of abnormal behaviors through environmental enrichment, with a focus on felids. The natural history of tigers is briefly summarized in the last section, which presents the social and environmental requirements of the species in the wild.

Goals of Zoological Parks

The changing relationship between humans and animals has influenced the development of modern zoological parks. Private collections of exotic animals were once a status symbol of the wealthy, such as the Versailles menagerie, created by Louis XIV, when he built an enclosure for lions and elephants around his palace (Anderson, 1995). In Europe, these menageries developed into places of public entertainment. The increase in numbers of zoological parks throughout Europe and later in the United States resulted in public concern for the treatment of the animals in captivity (Mench and Kreger, 1996). In 1970, the Animal Welfare Act was established in the United States to implement ethical protocol among the zoological parks, prompting the development of the modern zoo.

Today, zoological parks are dramatically different from the earlier menageries. The parks often boast their “new” goals to change negative public attitudes towards their practices: (1) education, (2) conservation, (3) research, and (4) recreation (Mench and Kreger, 1996; Shettel-Neuber, 1988).

Education

Education is an important mission of most American Zoo and Aquarium (AZA) accredited zoological parks. Wolf and Tymitz (1980) found that many parents use zoos for direct educational purposes. Parents often take children to zoos to learn animal identification, extinction and conservation, and animal habitats. They also found school groups of all ages touring zoos to complete assignments regarding a variety of animal species. Art classes use zoos to practice drawing animals, zoology students carry out research projects, and many visitors who are interested in birding and photography make use of zoological parks (Wolf and Tymitz, 1980).

Research has shown that visitors spend more time at naturalistic exhibits than at artificial exhibits and prefer to view healthy animals that are active and involved with the staff (Shettel-Neuber, 1988). As visitors spend more time at well-managed exhibits, they will obtain a greater appreciation of the educational value of the animals and their natural habitats. For many people, zoos are the only place where they will ever see a majority of the animals presented (Anderson, 1995). They learn about the animals, but also about regions of the world where the animals are found in the wild (Anderson, 1995). There is a growing trend in the zoo community to recreate habitats that resemble the animals' natural habitats, which will have an even greater impact on the educational value of zoological parks.

Doherty and Gibbons (1993) agree that education programs are important components of every zoological park because people develop an appreciation for plants and animals while learning about wildlife conservation and ecosystems. Mench and Kreger (1996) found that when visitors entered an exhibit that immersed them within that habitat, which was free of bars or barriers, they would leave with a greater understanding of the animals and their habitats. This method is conceptualized as "landscape immersion" and will be discussed later in the chapter.

Conservation

During the 1960's and increasingly in the 1980's, the successful breeding of endangered species in captivity for reintroduction into the wild became a major goal of many zoological parks. Specialty scientists, such as population and reproductive biologists, examined gene pools in the zoo stock to determine how they could contribute to the conservation of animals threatened with extinction (Anderson, 1995). Computer databases were created to help zoos manage animal exchanges that would avoid the possibility of inbreeding.

Bradley et al. (1999) present four requirements for the establishment of a captive breeding program. First, biological knowledge of the species is necessary, especially knowledge of species' habits, diet, and life cycle. This may be difficult to obtain for some rare or little-studied species. Second, husbandry protocols for captive breeding of the species are important. Third, information on the species' breeding behavior is necessary including the number of offspring, the seasonality of behavior, and conditions necessary for breeding to take place. Finally, genetic implications of the species are important to understand. Predetermining the level of inbreeding within both the wild and captive population is necessary for captive breeding success.

Successful captive breeding reintroduction programs include the Przewalski's horse (*Equus przewalski*), black-footed ferret (*Mustela nigripes*), Arabian oryx (*Oryx leucoryx*), and the golden lion tamarin (*Leontopithecus rosalia*) (Mench and Kreger, 1996). Captive breeding reintroductions have also been successful for many felid species such as tigers, leopards (*Panthera pardus*), servals (*Leptailurus serval*), Iberian lynx (*Lynx pardinus*), cheetahs (*Acinonyx jubatus*), and European wildcats (*Felis silvestris*) (Law et al., 1997). A large portion of the information on the reproductive biology of felids has come from studies of captive animals (Law et al., 1997). Doherty and Gibbons (1993) point out that many outdated zoo environments do not encourage natural behaviors for those species that are to be reintroduced into the wild. This knowledge has added to the transition from "sterile" exhibitory to the modern "natural" exhibits.

Research

Zoological parks provide research opportunities for animals that are difficult to study in the wild (Doherty and Gibbons, 1993). The parks provide unique sites for research because they house a diverse set of animals in a standardized and controllable area (Kleiman, 1992). Zoos are excellent places for studies regarding environment-behavior relationships and human-animal relationships (Martin and O'Reilly, 1988). Journals such as *Zoo Biology*, *International Zoo Yearbook*, and *Environment and Behavior* are the foremost scientific journals in the field of zoological research. Martin and O'Reilly (1998) have established three types of researchers that use zoological parks. Researchers may be hired by the zoo to solve day-to-day design problems, usually in education, or research and evaluation departments. Others are hired as consultants to conduct research on specific projects, and the third group conducts academic research.

Law et al. (1997) provide interesting examples of how captive felid research is important to the study of wild felids. Researchers studying wild populations can use plaster casts of captive animals' footprints to identify the presence of a particular species in their study area. This technique has been used in the study of wild margay (*Leopardus wiedii*) and jaguars (*Panthera onca*). Similarly, vocalizations of captive felids have been used to determine whether the same species is present in wild areas, for example, clouded leopards (*Neofelis nebulosa*) in Southeast Asia.

Recreation

The American Zoo and Aquarium Association [AZA] (2001) found that almost 135 million people visited zoos and aquariums throughout the United States in 2001. Zoos are a place for human enjoyment of the "natural" environment. People go to zoos for mental and physical relaxation, and to get away from it all (Wolf and Tymitz, 1980). Many people simply enjoy watching animals, especially if the animals are in good condition and they are in a naturalized exhibit (Finlay et al., 1988). Templeton (2002) found that overall visitor satisfaction could have a significant impact on whether visitors will make repeat visits. Templeton (2002) also found that the geography of visitor attendance was directly related to the diversity of species represented in the zoo because visitors want to see a wide variety of animals rather than large numbers of animals.

Current Exhibit Design and Landscape Immersion

Johnson (1994) labeled the decades between 1960 and 1990 as "The Great Zoo Revolution." Zoological parks began to expand their facilities and build more naturalistic exhibits, and public awareness regarding conservation and animal welfare increased. The Endangered Species Act of 1973 was passed and captive breeding programs appeared (Plaatsman, 1996). New trends in zoo exhibit design began with the following types of exhibits: naturalistic exhibits, behavioral exhibits, habitat exhibits, zoogeographic exhibits, and landscape immersion exhibits (Plaatsman, 1996). The most widely discussed and impressive of these exhibit types is “landscape immersion”.

The concept of landscape immersion began in the 1970’s, and its goal is to essentially immerse the zoo visitor in the habitat of the animals (Coe, 1996). Invisible barriers separate humans from the animals, and anything that would detract from the experience (such as buildings, vehicles, and workers) is removed or hidden with vegetation (Coe, 1996). A goal of landscape immersion is to make it appear that the animals dominate the scene and that humans are on a “mini-safari” (Coe, 1996). The visitors are in the animal’s habitat rather than the animals being in a human-dominated park. Landscape immersion has been successful at the Woodland Park Zoo, the Arizona Sonora Desert Museum, the North Carolina Zoological Park, and Zoo Atlanta (Coe, 1996).

“Natural” exhibition was thought of much earlier by Carl Hagnebeck (1910), who opened a new zoological park outside of Hamburg, Germany, that displayed animals as seen in the wild. The Bronx Zoo and Cincinnati Zoo were among the first to incorporate his ideas (Mench and Kreger, 1996). Hediger (1950), the “founding father” of zoo biology, also recognized early on the need for a change in the way captive animals were exhibited (Seidensticker and Forthman, 1998). His idea was that animals did not need a “kennel” but a “territory”—a natural division of space with specific habitat and social organization (Hediger, 1970). His views went largely unnoticed until the 1970’s (Seidensticker and Forthman, 1998).

Two modern approaches to zoo exhibit design were identified by Forthman Quick (1984). In the first approach, technology and knowledge from field studies are combined to make naturalistic environments. There are four goals to this approach (1) to display the “natural” habitat of the species (2) to encourage breeding (3) to offer settings for research that are approximate to the wild, and (4) to provide information from researchers who have the time to systematically observe behavior (Forthman Quick, 1984). The second approach, originally proposed by Markowitz (1982), focuses on the belief that captive animals should have some control over their environment and involves incorporating an apparatus that provides food when a specific behavior is performed.

Seidensticker and Forthman (1998) identify three factors that are responsible for the modern approaches for captive animal housing:

(1) a transformation in American cultural and economic circumstances that has strongly influenced animal welfare issues;

(2) an expanded understanding of the natural history of wild animals, a refined understanding of the ways natural systems and wild animals are affected by human activity, and an enhanced ability to assess the impacts that zoo environments can have on wild animals;

(3) advances in zoo exhibition technologies, especially those employing "natural habitats."

Zoos are influenced by "the socioeconomic and political environment in which they develop and function" (Seidensticker and Forthman, 1998). A shift in the public view of animal welfare has resulted in changes in the management of zoological parks.

Abnormal Behaviors in Captivity

One reason for the shift to "naturalistic" exhibition styles was an increased public concern for animal welfare. Many animals in captivity perform abnormal behaviors known as "stereotypies" (Carlstead, 1996). Stereotypic behavior can be described as a pattern of movement such as pacing and head bobbing that is performed repeatedly, is relatively invariant in form, and has no apparent function or goal (Carlstead, 1996). Such behaviors are rarely seen in wild animals; therefore they are considered an indication of stress. Stereotypies occur in many species and are thought to have a variety of causes. For example, they may arise when animals are consistently unable to reach a goal, such as natural feeding behavior (Carlstead, 1996; Rushen and de Passille, 1992; Sheperdson et al., 1993). Sheperdson et al. (1993) found that captive felids often spent the time prior to feeding performing stereotypic pacing behaviors. Duckler (1998) found that the skulls of captive tigers had distinctively malformed external occipital protuberances that are not found in wild specimens. These were caused by excessive grooming behavior in the captive tigers and a reduction in the jaw muscles due to eating processed food (Duckler, 1998).

Stereotypic behavior may also appear when an animal is physically restrained from moving to a desired place. For example, Meyer-Holzapfel (1968) found that a dingo (*Canis familiaris dingo*) separated from its pack, paced in a figure-eight pattern along the separating barrier. Stereotypies may also develop from other behavioral and physiological stresses, such as boredom, physical restraint, fear, or frustration (Carlstead, 1996).

The limitation of space is thought to be another cause of stereotypic behavior. In most cases, the smaller the enclosure, the more likely the animal will display stereotypies (Carlstead, 1996). However, it would be difficult to determine the exact amount of space that an animal needs to avoid developing stereotypic behaviors. Draper and Bernstein (1963) found that changes in the physical dimensions of the captive environment were often accompanied by a marked change in behavior. Lyons et al. (1997) studied the behavior pattern of 19 captive felid species and found that the cats in relatively larger enclosures had a higher level of exploratory behavior.

Low stimulus diversity is yet another factor influencing stereotypic behavior. In sterile environments, captive animals often appear to be "bored" or lethargic due to a lack of stimulation. Carlstead (1996) reports two ways that captive animals adapt to low stimulus environments: (1) they decrease the stimulus-seeking behavior (lethargy), or (2) they attempt to satisfy the stimulus-seeking behavior through other means (stereotypies). Common stereotypies in felids include pacing, head-twisting, tail and toe sucking, and fur plucking (Wooster, 1997). Mellen et al. (1998) found that the relationship between pacing and several variables that characterize the physical and social environment was a useful measure of well being in small captive felids.

Preventing Stereotypic Behavior Through Environmental Enrichment

According to Sheperdson et al. (1998) environmental enrichment "is an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological well-being". Environmental enrichment includes a wide variety of techniques. For instance, food can be hidden throughout exhibits to entice animals to perform hunting behaviors; wood blocks or logs can be given to satisfy felid scratching behavior when trees are not available; stimulating scents can be spread throughout enclosures; and sterile concrete enclosures can be replaced with natural substrate and vegetation.

Environmental enrichment programs are important in that they provide for the well being of the animals, allow the animals to display "natural" behaviors to the public, and increase reproductive success (Sheperdson et al., 1998). Adding natural substrate, vegetation, water features, rocks, and other features not only makes the environment more pleasant for the animals, but it also increases the educational value of zoo exhibits for visitors. Poole (1998) explains that

> the captive environment should be sufficiently complex to allow a full range of locomotor activities, including walking, climbing, swimming, or burrowing as appropriate to the species concerned. In the wild, a mammal chooses a living area that offers suitable facilities for its needs, so the zoo manager should do the same for those in his care.

Carlstead (1998) illustrates that making the environment more complex and unpredictable can reduce stereotypic behavior; by providing stimuli, you reduce the tiger's desire to perform a negative behavior (Carlstead, 1998).

In planning for environmental enrichment, scale (Seidensticker and Forthman, 1998), vertical spacing, and horizontal spacing (Mench, 1998) are three important spatial factors that should be considered. In captivity, large animals are placed in scaled-down versions of the natural environment. All aspects of the natural environment should be included in the captive enclosure, and planning by scale is important to ensure that this criterion is met (Seidensticker and Forthman, 1998). Vertical and horizontal spaces, including height, levels, and angles are also important in planning zoo exhibits as they are a part of the "natural" world that are often left out of exhibit design. Deroo (1993) emphasizes the importance of vertical and horizontal spacing, as "space can be used to create a safe, enriching environment that encourages and rewards natural behavior…[A] boulder, an incline, a well-placed tree or stream can give an animal an illusion of space, as well as the distance it needs from other animals." Mammals live in complex three-dimensional habitats, and their captive environments should reflect a similar topography (Poole, 1998).

Enrichment for Felids

A modest amount of literature has been published on specific enrichment techniques for felids. Most enrichment options include the use of the following: strategic exhibit plantings, olfactory stimulation, intact carcasses, alternate feeding methods, suspended log toys, different substrates, and water pools (Grams and Ziegler, 1998; Law, 1991; McPhee, 2002; Ziegler and Roletto, 2000; Barclay and Lewis, 1998; and Knapik, 1995). Law (1993) and Powell (1997) agree that a well designed enrichment program for captive felids should include the stimulation of all five senses. In the wild, felids depend on sensory information, and this should be provided for in the captive environment.

Carlstead (1998) experimented with four leopard cats (*Prioailurus bengalensis*) and found that when the cats were housed in a barren enclosure in a building that also contained lions and tigers, their frequency of stereotypic pacing was chronically elevated. After the barren enclosures had been enriched with logs, boxes, and branches, the leopard cats' frequency of pacing declined. Carlstead (1998) hypothesized that the leopard cats were stressed from living in the same building as larger cats and that the new enriched environment provided hiding places for the leopard cats, which reduced their level of stress. Mellen et al. (1998) found in a study of 68 captive small felids representing 16 taxa, that the cats spent significantly less time pacing in complex exhibits and in exhibits with seven or more visual barriers.

Carnivores, most notably solitary felids, are among the most difficult species for which to develop enrichment plans (Mellen, et al., 1998). Large home ranges in the wild and natural methods of capturing prey are almost never provided for in the captive environment due to a lack of space and negative public reactions to providing live prey. Enrichment for captive felids is also difficult because cats habituate quickly to novel conditions (Mellen et al., 1998). According to Mellen et al. (1998), "enrichment must be dynamic and constantly modified to effectively induce the behaviors in captives that are more characteristic of their wild counterparts".

Enrichment for tigers based on their natural history

Implications for the proper management of captive tigers can be gleaned from an examination of their natural history. Tigers are solitary animals and have home ranges that vary from 50–1,000 km^2 for the Bengal subspecies and 500–4,000 km^2 for the Siberian subspecies (Tilson et al., 2002). This difference in home range size between subspecies is due to the higher density of prey in India and Nepal compared to the low density of prey in Siberia. Individual hunting tactics rely on "concealment, a stalk, and sudden rush and dispatch of the prey" (Sunquist et al., 1999). A tigress requires 5-6 kg of meat a day to maintain proper health (Sunquist et al., 1999), and tigers' main prey are medium-sized deer and wild boar (Tilson et al., 2002).

Tigers are very adaptable species and can tolerate a wide range of temperature and rainfall regimes (Sunquist et al., 1999). They live in a diverse range of habitat types, and generally live where their prey can be found. This is typically a tall-grass or forest-edge habitat near water. An understanding of these social and environmental habits provides a basis for what tigers might require in a captive environment. However, some of these habits such as the huge home range size and the ability to stalk and chase live prey are difficult to provide for in captivity. Providing the captive tigers with sufficient environmental enrichment, might help to attend to these "wild" behaviors (Law, 1993).

Relation of this Study to Broader Literature

Menageries that were once solely focused on entertainment have changed into modern zoological parks that pride themselves on their goals of education, conservation, research, and recreation. Growing concern for animal-welfare has led to more naturalistic exhibit design; sterile exhibits are being refurbished with "natural" environments to reduce abnormal behaviors in captive animals and to appease unhappy visitors. Environmental enrichment is the process that takes into account the captive animals' spatial environment by providing features that induce natural behaviors and reduce stereotypies.

As previously mentioned, felids are especially difficult to enrich in captivity due to their naturally complex behaviors in the wild and their need for dynamic environments (Mellen et al., 1998). This study is focused on a single felid species, *Panthera tigris,* because few felid environment-behavior studies have been species-specific (Carlstead et al., 1993; Powell, 1997) and almost none have focused on tigers. Most studies that examine the relationship between environment and behavior have focused on multiple species (Baldwin, 1991; Lyons et al., 1997; Mellen and Sheperdson, 1997; Sheperdson et al., 1993; Wooster, 1997). This may be because multiple species are easier to sample from a single zoological park, whereas single species sampling may require travel to a few parks to obtain a sufficient sample size. This study is focused on a single species and therefore helps to fill the gap in the literature.

This study examines the relationship between captive tigers' spatial environments and their behaviors. It will add to the felid environment-behavior literature and focus on an endangered species that has received relatively little attention regarding stereotypic behavior and environmental enrichment. I will also provide recommendations for future captive tiger management based on these results.

CHAPTER 3

METHODS

Study Sites and Animals

I visited the following zoological parks and wildlife refuges as data collection sites for my study: T&D's Cats of the World; Philadelphia Zoo; Natural Bridge Zoo; and Mill Mountain Zoo (Figures 3.1 and 3.2, Table 3.1). I conducted fieldwork during summer between June and August of 2002. The summer season presents two extra stressors on captive animals—high temperatures and high visitation rates—that makes it an ideal time to conduct this study. Stereotypic behaviors in captive animals have been shown to increase due to such stresses (Baldwin, 1991).

T&D's Cats of the World is a family owned, non-profit refuge for abused or unwanted exotic animals. It is located in Penn's Creek, a rural town in central Pennsylvania. The refuge receives animals from private individuals, government agencies, zoos, and other refuge organizations. They currently house over 40 individual exotic felines and many other animals. T&D's Cats of the World is only open to visitors on weekends from May through September. The Philadelphia Zoo, America's first zoo, is located in southeastern Pennsylvania within a major metropolitan area and is home to over 1,600 animals. The Natural Bridge Zoo, in rural Virginia near Roanoke, is named after the geological arch that draws many visitors to the area. It boasts the largest and most complete collection in the state of Virginia, including 400 individual animals. The Mill Mountain Zoo is unique in that it is located atop Mill Mountain, which rises about 1,000 ft above the city of Roanoke. It houses 171 animals comprising 46 species.

Eighteen individual tigers were the subjects of my study. Of these, eight belong to the Siberian subspecies (*Panthera tigris altaica*), and ten belong to the Bengal subspecies (*Panthera tigris tigris*). The animals vary in age from one to sixteen years. All of the tigers were born in captivity and have unique histories (Table 3.2).

The results of this study (presented in Chapter 4) do not necessarily reflect the quality of the zoological parks, for example, the Philadelphia Zoo has a large outdoor enclosure, but my study examines animals only when they are in the indoor enclosures. Also, the Mill Mountain Zoo, Natural Bridge Zoo, and T&D's Cats of the World have "night dens" for their animals, which were not included in the study as the animals are not housed there during visitor hours. Certain indoor or outdoor enclosures were not included as observation sites because some study animals were rotated from one section of their exhibit to another at night, and I was interested in viewing the animals during the day when visitors were present.

Enclosure Variables

The following environmental variables of the enclosures were evaluated: enclosure size, substrate, vegetation, pool availability, and enrichment items. These factors are considered important in animal husbandry (Carlstead,1996; Bush et al., 2002; Hediger, 1969; Law et al., 1997). Each variable was recorded and compared with the behavioral data in order to identify those that affect stereotypic behavior in captive tigers.

I sketched the enclosures (Appendix B), and divided them into regions to facilitate the data collection and analysis process. This method of dividing the enclosure space of captive animals was also used by Mahler (1984), Bettinger et al. (1994), and Blasetti et al. (1988).

Enclosure Size

Lyons et al. (1997) found a significant correlation between relative enclosure size and average apparent movement in captive felids. A "large" space provides the animals with the opportunity to run, stalk, chase, and play. These behaviors allow the animals to fully exercise their muscles and expend energy, which they would normally spend on hunting in the wild (Lyons et al., 1997). I classified the sizes of the enclosures as large or small based on whether the tigers have room to run within them (see Appendix B for approximate measurements). In this study, large spaces were >45.7 m x 36.5 m and small spaces were < 8.5 m x 6.7 m.

Substrate

Unnatural substrates (e.g., concrete) can result in stereotypic behaviors in captive animals (Hediger, 1969) and can cause captive cats to get sore footpads and leg injuries (Law et al., 1997). In the past, concrete floors were thought to be more hygienic than soft, natural substrates, but recent research has proved otherwise (Law et al., 1997). I classified substrate as unnatural, natural, or mixed. Concrete floors, often used in older zoos, were classified as "unnatural," while grass, wood chips, dirt, or a combination of these were considered "natural". A combination of natural and unnatural substrate was assigned to the "mixed category".

Vegetation

The presence of vegetation creates a more natural environment for captive animals by providing hiding areas away from the public and creating areas of shade (Law et al., 1997). Plantings also attracts insects and birds into the exhibits, which provide more complex environments for the animals (Law et al., 1997). I classified vegetation as being "present" or "absent".

Pool Availability

Pool availability is considered important because tigers are avid swimmers. Tigers appear to enjoy the water, and swimming provides an alternate form of exercise and enrichment (Bush et al., 2002). I classified pool availability as small, large, or absent. A "small" sized pool is one in which the animals can sit or lie but not swim. In this study, small pools were store-bought plastic tubs in which the tigers barely fit or shallow ponds in which the animals could wade or lie. A "large" pool is one in which the tigers could completely submerge themselves and swim.

Environmental Enrichment

The concept of "environmental enrichment" involves providing the captive animals with items that stimulate exploratory behaviors (Lyons et al., 1997). These items may be fixed in the enclosure, such as ledges and waterfalls, or they may be manipulable objects such as sticks, balls, and ice blocks. Enrichment furnishings are thought to improve the quality of life in captive animals (Maple and Perkins, 1996). For example, Carlstead et al. (1993) found that stereotypic pacing in captive leopard cats (*Felis bengalensis*) significantly decreased after the environment was made more complex.

I classified environmental enrichment by tallying the total number of enrichment items in each enclosure and then I ranked each enclosure as being low (0–4.5), medium (5–7.5), or high (8–10) based on the mean of all samples ± the standard deviation. Enrichment items include: objects that can be torn/chewed, solid toys, water (pool, waterfall, stream, tub), logs, plants, enclosure outside, shelves/ledges, hiding spots, room to run, ability to view other animals, and feeding of whole animal parts, which are considered important in felid enrichment (Shepherdson et al., 1993; Kleiman et al., 1996; Law et al., 1997; Mellen and Sheperdson, 1997; and Wooster, 1997). I scored one point for each item present in the enclosures.

Behavioral Survey

The main body of data in this study comes from an observational survey of tiger behavior. I observed tiger behaviors using the "focal-animal" sampling method, which is often used when behaviors of an individual animal or a group of animals are recorded during a sampling period (Altmann, 1973). My presence did not appear to influence any specific behaviors in the study animals, probably because the animals were accustomed to visitors. They appeared to ignore visitors and me. I recorded behaviors of individual animals every 10 minutes from 1230-1630 hours each day for a period of five days, a technique consistent with other published methodologies (Lyons et al., 1997; Mahler, 1984; Bettinger et al., 1994; Blasetti et al., 1988; Freeman, 1983; and Shepherdson et al., 1993). I chose to observe the tigers during the afternoon hours, even though tigers are naturally nocturnal, in order to study the influence of visitors on tiger behavior. Also, most of the zoological parks in this study had guidelines that prohibited research after park hours, and most of the tigers go into "night dens" after hours which make them difficult to observe.

At 10-minute intervals, scan samples of five variables were recorded for each animal. These variables were 1) animal behavior, 2) animal location on a grid, 3) keeper presence, 4) in shade or not, and 5) number of visitors. In addition, I recorded temperature, precipitation, and other events occurring in or near the exhibit. During some sampling days, animals were moved into a section of the exhibit that was not included in the data collection. For example, the Philadelphia Zoo rotates animals from the indoor and outdoor enclosures. I only collected data when the animals were located in the indoor enclosures at this zoo to standardize this aspect of enclosure types from my four study sites.

Animal Behavior

I classified behavior based on an ethogram of common tiger behaviors (Table 3.3), which I created during preliminary observations in June 2002 at the Philadelphia Zoo. Several studies identify common felid behaviors (Baldwin, 1991; Lyons et al., 1997; Lindburg, 1988; Seidensticker and McDougal, 1993; and Wasser, 1978) and were useful in the creation of the ethogram. I observed and recorded behaviors for approximately 10 seconds at each 10-minute interval. I later consolidated related behaviors on the ethogram into three groups to facilitate statistical analysis. These groups are: 1) rest, 2) explore, and 3) stereotypies. The only stereotypic behavior on the ethogram is pacing, as this was the only one I observed. Other stereotypic behaviors performed by captive felids include excessive grooming, tail sucking and paw chewing, which were not seen in this study.

Animal Location

I observed animal location for approximately 10 seconds at each interval and recorded one or more location for each individual. Each enclosure was roughly measured and sketched (Appendix B). Exact dimensions were not available; therefore the sketches are not to scale. The enclosures were divided into grids based on similar environmental variables and visual landmarks to facilitate analysis.

Keeper Presence

The presence of an animal keeper can influence the behavior and location of a captive animal (Baldwin, 1991, and Del Thompson, 1989). Animal keepers feed, clean, train, and observe the animals on a daily basis. In many cases, the animals become accustomed to a daily routine and learn to expect the keeper's actions. At each 10-minute interval, I noted the presence or absence of keepers.

Shade

The presence of shade may influence the location and preferences of captive animals (Baldwin,1991). For example, animals often remain in shaded spots on hot days (personal observation). I noted whether tigers were in shaded locations within their enclosures.

Visitors

The presence or absence of visitors can also influence the behavior and location of the animals; for example, large, crowds may cause animals to become nervous or agitated (Del Thompson, 1989). Animals not accustomed to many visitors may drastically change their behaviors when unknown people are around (Del Thompson, 1989). At each 10-minute interval, I recorded the number of visitors that were present in the immediate area of the tigers' enclosures.

Data Analysis

The daily frequencies of individual tiger activities, behaviors, and locations were averaged to obtain the overall percentage of each activity, behavior, and location. For categorical variables (enrichment, age, visitors), I used the total mean ± one standard deviation to establish category levels. For example, enrichment and visitors were ranked as low, medium and high, and age was categorized as juvenile, adult, and senior. The number of visitors was totaled by day for each animal at each site and then ranked into "low" or "high" categories accordingly.

I used Chi-Square Analysis (Ebdon, 1988) to determine the association between multiple dependent variables (behaviors) and single independent variables (environmental and animal components, such as enclosure size, vegetation, and subspecies type). I used ANOVA (Ebdon, 1988) to determine whether single independent variables (enrichment, visitors, age, and substrate) had significant influence on tiger behaviors. Overall percentages were arcsine transformed before the analysis. This transformation is often used to normalize data that are presented in percentages or proportions.

Table 3.1. Location and other information on study sites. Temperature data are from the National Climatic Data Center.

Study Site	Latitude/Longitude	Observation Date Range (2002)	Ave. Max. Temp. Observation Period	Individuals Observed
T&D's Cats of the World	40.78°N, 76.87°W	June 23—Aug. 11	88° F	10
Philadelphia Zoo	39.87°N, 75.25°W	June 10—25	87° F	5
Natural Bridge Zoo	37.58°N, 79.50°W	July 16—Aug. 2	89° F	2
Mill Mountain Zoo	37.32°N, 79.97°W	July 31—Aug. 7	90° F	1

Table 3.2. Background information on study animals (NA = not available, TDC = T&D's Cats of the World, PZ = Philadelphia Zoo, NBZ = Natural Bridge Zoo, MMZ = Mill Mountain Zoo).

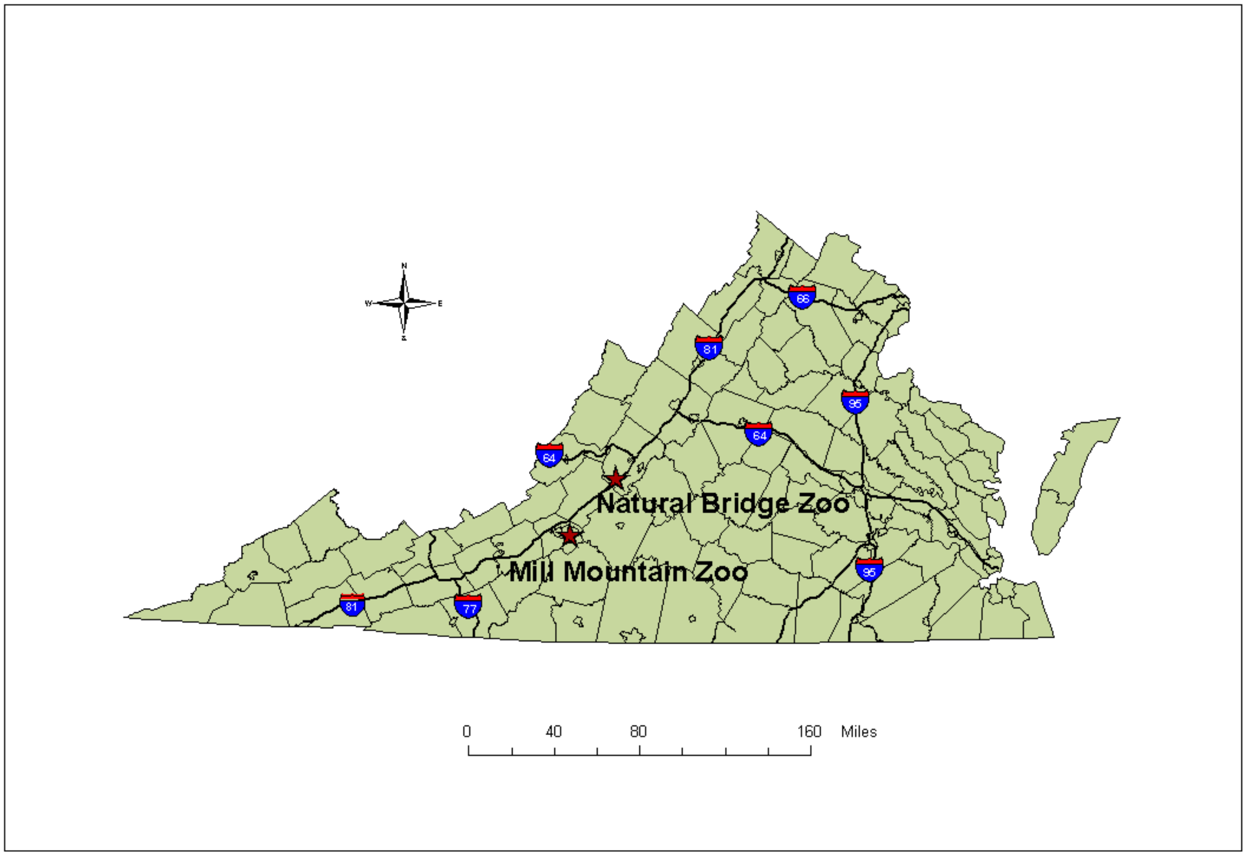
Tiger	Species	Age	Sex	Study Location	Origin
CJ	Siberian	16	M	TDC 1	Other Zoo
Spaz	Bengal	6	F	TDC 2	Private Owner
Tyrone	Bengal	11	M	TDC 3	Roadside Zoo
Taz	Bengal	7	M	TDC 4	Private Owner
Tom	Bengal	6	M	TDC 5	Private Owner
Max	Bengal	6	M	TDC 5	Private Owner
Sheena	Siberian	12	M	TDC 6	Circus
BooBoo	Bengal	4	M	TDC 7	TDC
Ally	Bengal	6	F	TDC 8	Private Owner
Aggie	Bengal	6	F	TDC 8	Private Owner
Kalista	Siberian	1	F	PZ 1	PZ
Baikal	Siberian	1	M	PZ 1	PZ
Kira	Siberian	4	F	PZ 2	Leipzig Zoo
Yorgi	Siberian	5	M	PZ 3	Moscow Zoo
Lantar	Siberian	15	M	PZ 4	PZ
NBW	Bengal	NA	M	NBZ 1	NA
NBO	Bengal	NA	F	NBZ 1	NA
Ruby	Siberian	15	F	MMZ 1	Private Owner

Table 3.3. Ethogram of captive tiger behaviors.

Explore	Rest	Stereotypies	Other
AG – aggravated	LB - laying on back	PC - pacing	OE – off exhibit
AL - alert/alarmed	RA - resting awake		CS – can not see
CL - chewing/clawing item	SI - sitting		
DG – digging	SL - sleeping		
DR – drinking			
EG - eating grass			
ET - eating given food			
GR – grooming			
LI - licking ice			
LP - laying in pool			
PL – playing			
RO - roll over/stretch			
RU – running			
SC - scratch body against object			
SCM - scent marking			
SM – smelling			
SMO – sitting in moat			
ST – stalking			
SW – swimming			
VO – vocalization			
WK - walking			

Figure 3.1. Map showing site locations in Pennsylvania: T&D's Cats of the World and the Philadelphia Zoo.

Figure 3.2. Map showing site locations in Virginia: Natural Bridge Zoo and the Mill Mountain Zoo.



CHAPTER 4

RESULTS AND DISCUSSION

This study clearly showed that tigers in more "natural" and "complex" enclosures performed less stereotypic pacing and more exploratory behaviors than those in "unnatural" enclosures. Environmental enrichment was an important factor in reducing inactivity and aberrant behavior in the study animals. These results suggest that captive tigers should be housed in large enclosures containing natural substrate and vegetation, water pools, ample shade, a variety of resting locations, and a variety of enrichment items.

Effects of the Captive Environment on Behavior

Tables 4.1 and 4.2 present the enclosure evaluation variables and enclosure characteristics. The enclosures represented a wide range of different sizes, substrates, vegetation, and enrichment. In this study, enclosure size significantly influenced exploring and pacing behaviors of the captive tigers (Table 4.3, Figure 4.1). Animals in larger enclosures explored more and paced less often. This result was consistent with Baldwin (1991), who found a correlation between relative cage size and diversity of behavior when studying several species of felids at the National Zoo in Washington D.C. Lyons et al. (1997) also found that cats in larger enclosures had higher levels of movement at the Scottish National Zoological Park in Edinburgh, United Kingdom. A larger enclosure not only provides appropriate space for exercise, but it also allows animal keepers and zoo designers to implement a wider variety of enrichment items such as vegetation, scents, ledges, and substrates. Smaller enclosures are restricted in the amount of useable space, which makes it difficult to provide captive animals with a variety of enrichment. The larger enclosures in this study generally had higher levels of enrichment.

The use of natural substrate and vegetation in enclosures also reduced stereotypic pacing and increased exploratory behaviors (Tables 4.3 and 4.4, Figure 4.2) at these sites. This result supports the findings of several other studies addressing the issue (Barclay and Lewis, 1998; Law, 1991; and Wooster, 1997). Wooster (1997) suggested that natural substrates such as grass/hay beds, piles of leaves, large clumps of grass, and wood chips, could stimulate natural behaviors in captive animals. These substrates stimulate olfactory senses when soaked in different scents such as catnip or urine from other animals, and crickets or other insects added to the substrates can stimulate play or hunting behaviors (Wooster, 1997). Vegetation and natural substrates also attract birds and insects into the enclosures, which provides a greater diversity of stimulation. Some plants recommended for cats by Wooster (1997) include seaweed, sagebrush, Christmas trees, rose petals, and pinecones.

Concrete was the only type of substrate used in early zoo animal enclosures, as it was considered more hygienic and easier to clean than natural substrates. Law et al. (1997) found that concrete floors are actually less hygienic and more odoriferous than floors covered with wood chips. Law et al. (1997) showed that cats had a lower incidence of parasites and sore footpads when they were housed with a wood chip substrate. Some tigers in this study that were housed with unnatural or mixed substrate had obvious skin abrasions (mostly on elbow joints) that appeared to be caused by lying on concrete.

Baldwin (1991) found that enclosures containing natural substrates and vegetation increased the diversity of behavior of the cats at the National Zoo. He concluded that natural substrates and vegetation contain chemicals used by the animals in olfactory communication which increased natural behaviors (Baldwin, 1991). Vegetation can also be used as cover from adverse weather and for hiding from stresses such as noisy visitors or other exhibit animals that may appear threatening. Law et al. (1997) stated that "plants and substrates that help provide shade and hiding places are extremely important to the psychological and physical welfare of cats…planting in the enclosures provides a more complex and sympathetic environment for the animals." My results agree with this statement, as the animals housed with natural substrate and vegetation paced less and did not have abrasions.

Environmental enrichment has been widely recommended for maintenance of the physical and psychological well being of captive animals (Wooster, 1997; Carlstead, 1998; Forthman Quick, 1984; Law, 1991; Maple and Perkins, 1996; Mellen and Sheperdson, 1997; and Mench, 1998). While many studies have shown that environmental enrichment improves the lives of small felids, this study shows that large felids, in this case tigers, also benefit from environmental enrichment. A high level of enrichment significantly reduced stereotypic pacing of the captive felids in this study, and was marginally significant in increasing time spent exploring (Table 4.4 and Figure 4.3). These results were not surprising given the large body of literature regarding environmental enrichment and stereotypic behaviors. Baldwin (1991), Powell (1997), Lyons et al. (1997), Wooster (1997), and Mellen and Sheperdson (1997) have all found that cats living in enriched enclosures appeared to be healthier and more content than those living in sterile enclosures. This study agrees with the others in that animals in enriched environments seem to maintain a healthy weight, groom themselves properly, and lack stereotypic behaviors. Three of the animals in this study that were living in sterile enclosures did not appear to be physically or psychologically healthy.

Some enrichment items that have been successfully used for cats include intact carcasses of rabbits, rats, mice, and chickens; scents such as catnip and blood; toys such as ice blocks, balls, pine cones, and hanging logs; speakers playing “natural” sounds; feeding plans that allow smaller amounts of food to be given more than once per day; and the provision of water and vegetation. The most common enrichment items that I observed at these sites were logs, boxes, phone books, balls, water, vegetation, and ice blocks. Boxes and phone books appeared to be the most desirable items, as the tigers would give them immediate attention when they were placed in the enclosure. In contrast, balls were often ignored perhaps because they were present for a long period of time and had lost their novelty. Law et al. (1997) discusses an enrichment item specifically designed for tigers that I did not see used at these sites. The “feeding pole” is a 6-m wooden pole that the tiger must climb to reach food. The goal of using this device is to have the tigers expend a lot of energy and muscle power to obtain their “prey”, rather than simply being given food (Law et al., 1997). Tigers use a complex routine when reaching food from the feeding pole by stalking from the ground and then running straight up (Law et al., 1997). According to Law et al. (1997), no injuries have occurred from use of the feeding pole and tigers have been seen running up the pole multiple times even after the food is gone.

The presence of a pool, stream, tub, pond, or other water body increased exploratory behaviors and strongly reduced stereotypic pacing (Table 4.3 and Figure 4.4). Surprisingly, there is little published information on the importance of water features for tigers. This may be due in part to the rarity of studies of captive tigers. And, most other cats do not enjoy swimming, thus reducing the chance that pool availability would be considered important. However, tigers are avid swimmers in the wild and this study provides strong evidence that captive tigers need the opportunity to swim or to simply sit in a body of water. Swimming also provides a form of exercise and enrichment for the tigers (Bush et al., 2002). At T&D's Cats of the World, a tub of water was provided to two of the tigers that previously did not have one and the tub was used frequently. The animals appeared to look forward to the keeper filling the tub with fresh water every day and would play in the stream of water. This behavior suggests that any form of water (tub, pond, or waterfall) would dramatically improve an enclosure without this feature.

The study animals spent a majority (76%) of their time resting (Table 4.5), which is not surprising given that captive felids are often inactive. The tigers predominantly rested in a single location of their enclosures, possibly indicating a lack of desirable resting sites in most enclosures. These findings are consistent with Baldwin (1991) who found that cats in the National Zoo rested 75% of the time and used only $^{1}/_{3}$ of their available space. Lyons et al. (1997) also found that nine species of captive felids used little of their enclosure spaces at the Scottish National Zoological Park.

Providing tigers with "favorite" spots in several locations throughout the enclosure might encourage them to use more of the available space. For example, if the individual animal spends most of its time on a raised platform, additional platforms could be constructed in the enclosure to encourage the animal to vary its resting location. This strategy may also work to bring a timid animal closer to visitor viewing locations. A few common characteristics of the preferred resting locations in this study included shade availability, a sheltered space, an elevated platform, a compact dirt substrate (grass appeared to be worn away by overuse), and locations within viewing proximity of other animals. However, shade availability and a compact dirt substrate may not be the most desirable spots for the animals during winter months. Similar research conducted in areas with cold winters might reveal any seasonal differences in location preference.

The animals in this study spent an overwhelming 90% of their time in shaded areas (Table 4.5) illustrating the importance of providing captive animals with ample areas of shade, especially during summer months. Providing more shaded areas would allow animals to occupy larger proportions of their enclosure spaces. Forthman et al. (1995) found that shade alone may be insufficient in reducing thermal load in large mammals. If the shaded area has a heat index higher than in direct sunlight, due to poor air circulation or the thermal performance of certain building materials, the animals may not properly thermoregulate (Forthman et al., 1995). Gunite, a commonly used material in zoos, significantly contributes to thermal distress in large mammals because of its absorptive and reflective properties.

Mellen and Sheperdson (1997) suggested that solitary felids should be housed singly and that the opposite sex should be introduced only for breeding or enrichment purposes. They also suggest that animals that are housed in pairs should be separated and given alternate access to certain exhibit areas. Forthman et al. (1995), on the other hand, suggested that instead of managing solitary species as always in pairs or alone, a subordinate animal should have "controlled access to a conspecific through the use of interconnecting doors operable only from the subordinate's side of the exhibit." In my study, the animals that were housed in pairs were siblings rather than breeding pairs (except for one pair), and they appeared to enjoy one another's presence. My study animals explored more and paced less when they were housed in sibling pairs rather than housed alone. One likely explanation is the increased opportunity for play and stalking behavior amongst the paired tigers. It is less clear why pacing behavior was reduced, but the animals were possibly more content with another tiger in their enclosure. This result was surprising as tigers are solitary animals in the wild. My results (Table 4.3 and Figure 4.5) indicate that housing sibling tigers in pairs is preferable to housing them alone and suggests that further study of unrelated pairs is needed.

Keeper presence did not significantly affect tiger behavior (Table 4.3), but many of the animals did become vigilant when a keeper was nearby. This vigilance occurred less at T&D's Cats of the World, where keepers were present more often than at the other facilities. Keepers at T&D's consist of a family that lives and works on the premises. They were consistently present during visitor hours to moderate visitor activity and answer questions. Keeper presence was low (7-10%) at all other sites, where keepers were present only during cleaning and feeding times.

Effects of Animal Variables on Behavior

Of the two subspecies included in this study, Siberian tigers (*Panthera tigris altaica*) rested less, explored less, and performed more stereotypic behaviors than the Bengal tigers (Table 4.3 and Figure 4.6). Literature regarding variation in behavior of captive tiger subspecies appears to be lacking. A majority of the Siberian tigers in this study were housed in small enclosures; the two Siberian tigers that were housed in larger enclosures did not display any pacing behavior throughout the entire study. For this reason, I cannot rule out the possibility that the behavioral differences were related to subspecies type.

The concept of geographic variation in behavior has been studied in primates, fish and birds (Foster and Endler, 1999). Many studies address geographic variation in tiger subspecies, but few if any focus on behavior (Kitchener, 1999; Wentzel et al., 1999; Hendrickson et al., 2000; Kitchener and Dugmore, 2000). Rather than looking at behavioral differences within the subspecies, most researchers are trying to determine whether the tiger subspecies actually deserve that distinction, or whether morphological differences simply arise from geographic location. Kitchener and Dugmore (2000) found that "most of the geographical variation seen in tigers today is largely clinal in response to environmental and ecological gradients throughout their mainland distribution." Tiger keepers at these sites had varying opinions on the existence of behavioral differences between the two subspecies. Some did not notice any difference in behavior, while others thought that one species was calmer in captivity than another. My results indicate that there may be behavioral differences between the Bengal and Siberian subspecies; however this question should be re-examined on study animals with more comparable enclosure types and with a larger sample size.

Not surprisingly, the senior animals in this study rested significantly more than the adult and juvenile animals (Table 4.4). This result suggests that age should be considered when planning an exhibit. While providing more resting areas might enhance enclosures for older animals, enrichment items are probably still important. During my observations, I noted the oldest animals tearing up boxes and phone books and sitting in pools; older animals may not be as active but still enjoy novelty and enrichment.

Table 4.1. Enclosure evaluation variables. TDC = T&D's Cats of the World, PZ = Philadelphia Zoo, NBZ = Natural Bridge Zoo, MMZ = Mill Mountain Zoo.

Tiger	**Site/ Enclosure**	**Size**	**Substrate**	**Vegetation**	**Pool**	**Enrichment**
CJ	TDC 1	large	natural	present	small	High (8)
Spaz	TDC 2	small	natural	absent	small	Medium (5)
Tyrone	TDC 3	small	natural	absent	none	Low (4)
Taz	TDC 4	small	natural	absent	none	Low (4)
Tom	TDC 5	large	natural	present	small	High (8)
Max	TDC 5	large	natural	present	small	High (8)
Sheena	TDC 6	small	natural	absent	small	Medium (5)
BooBoo	TDC 7	large	natural	present	large	High (8)
Ally	TDC 8	large	natural	present	small	High (8)
Aggie	TDC 8	large	natural	present	small	High (8)
Kalista	PZ 1	small	unnatural	absent	none	Low (4)
Baikal	PZ 1	small	unnatural	absent	none	Low (4)
Kira	PZ 2	small	unnatural	absent	none	Low (4)
Yorgi	PZ 3	small	unnatural	absent	none	Low (4)
Lantar	PZ 4	small	unnatural	absent	none	Medium (5)
NBW	NBZ 1	small	mixed	present	none	Medium (6)
NBO	NBZ 1	small	mixed	present	none	Medium (6)
Ruby	MMZ 1	small	natural	present	none	High (9)

Table 4.2. Summary of enclosure characteristics (n=14).

Variable	**Result**
Size	Large 36% Small 64%
Substrate	Natural 29% Mixed 7% Unnatural 64%
Vegetation	Present 43% Absent 57%
Pool	Large 7% Small 43% Absent 50%
Enrichment	High 36% Medium 28% Low 36%

Table 4.3. Influence of enclosure variables and animal variables on tiger behavior. Results of Chi-Squared test; an ** indicates significant values. $\alpha = 0.05$, critical value = 5.99.

Variable	**Test Statistic**	**P-Val**
Cage Size**	18.48**	0.0000**
Vegetation**	16.46**	0.0002**
Pool**	26.09**	0.0000**
Alone/Paired**	14.18**	0.0008**
Keeper Presence	1.08	0.5812
Subspecies**	8.57**	0.0137**
Sex	1.00	0.6038

Table 4.4. Influence of enclosure variables and animal variables on tiger behavior. Results of ANOVA test = 0.05, critical value = 3.68. Variables are in bold font. Statistics indicating the strength of the influence of variables on behaviors are shown below the variable. An ** indicates significant values. An * indicates values significant at α = 0.1.

Variable	F	P-Val
Substrate		
Stereotypies*	3.36*	0.0621*
Rest	1.71	0.2142
Explore*	3.19*	0.0699*
Enrichment		
Stereotypies**	4.49**	0.0295**
Rest	2.66	0.1024
Explore*	3.52*	0.0555*
Age		
Stereotypies	0.60	0.5617
Rest*	4.06*	0.0510*
Explore	2.38	0.1311
# of Visitors		
Stereotypies	0.03	0.9685

Table 4.5. Summary of animal behavior, animal location on a grid, presence of a keeper, and time spent in shade (n=18). TDC = T&D's Cats of the World, PZ = Philadelphia Zoo, NBZ = Natural Bridge Zoo, MMZ = Mill Mountain Zoo.

Variable	**% Total Time**
Resting	76%
Exploring	16%
Stereotypies	8%
<35% time in 1 grid location	28%
36-55% time in 1 grid location	44%
>60% time in 1 grid location	28%
Keeper present - TDC	49%
Keeper present - PZ	10%
Keeper present - NBZ	9%
Keeper present - MMZ	7%
Time in shade	90%

Figures 4.1–4.6. Percent time spent exploring or pacing related to selected variables.

Fig. 4.1. Effect of Enclosure Size on Exploratory and Pacing Behaviors

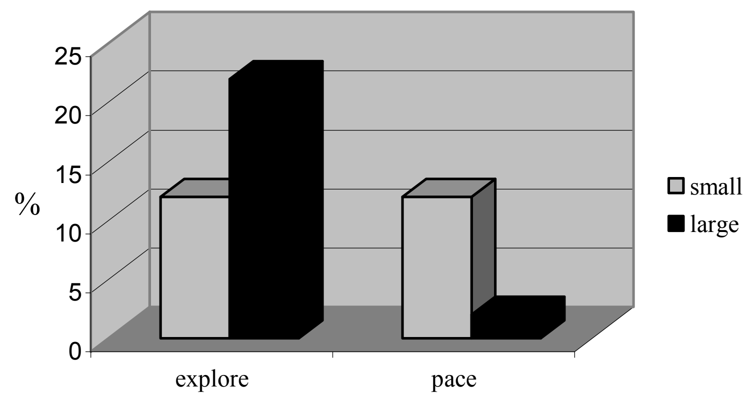


Fig. 4.2. Effect of Vegetation on Exploratory and Pacing Behaviors

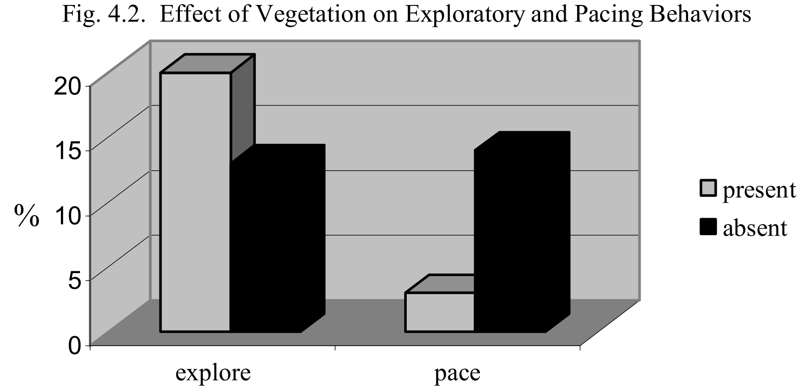


Fig. 4.3. Effect of Enrichment Level on Pacing Behaviors

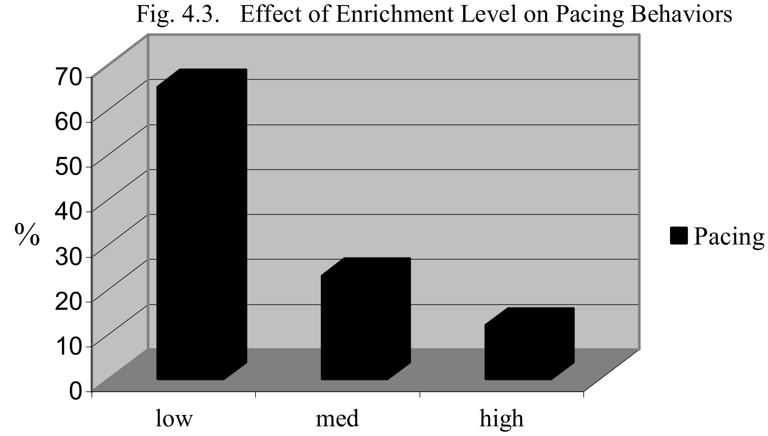


Fig. 4.4. Effect of Pool Availability on Exploratory and Pacing Behaviors

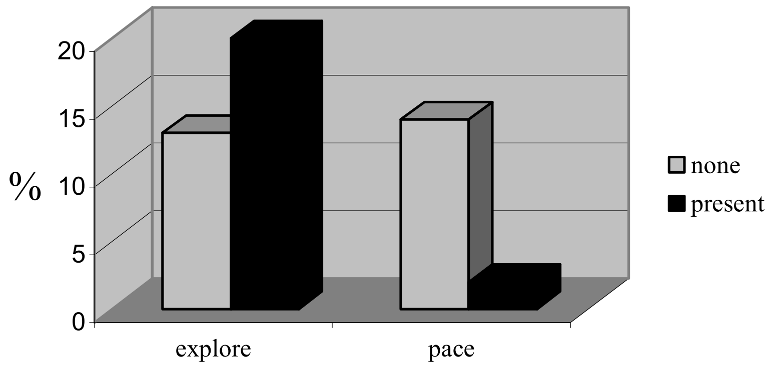


Fig.4.5. Effect of Conspecific on Exploratory and Pacing Behaviors

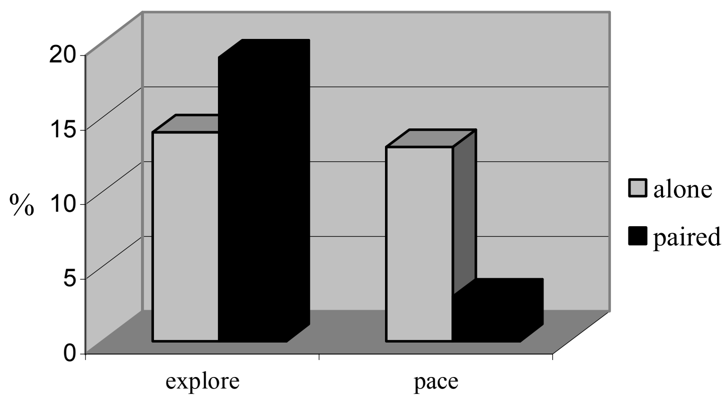
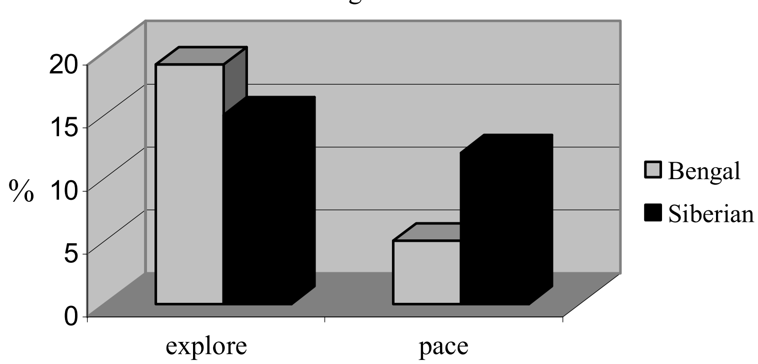


Fig. 4.6. Effect of Subspecies Type on Exploratory and Pacing Behaviors



CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Animals living in zoological parks depend entirely on humans to provide their daily needs. The captive environment is dramatically different from the wild, so it is difficult for wild animals to reproduce in captivity: space is limited, hunting and mating opportunities are dramatically reduced, and other environmental components are dependent on the humans that manage the institution. Improving the lives of captive tigers by providing appropriate environmental stimulants will likely increase the success of captive breeding for this endangered species. This is currently a major goal of conservation biologists, who are trying to increase the numbers of wild tigers, which are estimated to be in the range of 5,000-7,000 worldwide (Seidensticker et al., 1999).

This study focused on evaluating the effects of several environmental and animal variables on the behaviors of 18 captive Bengal and Siberian tigers (*Panthera tigris*). Stereotypic pacing was an important behavior to evaluate, as captive carnivores often display this behavior when stressed. Documenting the tigers' use of space was also a focus, as large felids are notoriously inactive in captivity. The results from this study add much needed information to the small body of literature available on captive tiger management.

The major findings and recommendations are as follows:

- The study animals spent the majority of time (average 76%) resting. Captive tigers should be provided with multiple resting sites throughout the enclosure to maximize the total use of available space and to entice timid animals closer to public view. This may be especially important for older animals, which spend even more time at rest.

- These tigers spent 90% of their time in shaded areas. Animals will use more of their available space in the summer months if it is shaded. During the summer months, exhibits should provide multiple areas of shade to ensure animal safety.

- Enclosures that provided enough space for the animals to run resulted in an increase of exploratory behaviors and a decrease in stereotypic pacing. Captive tigers should always be housed in large areas or have daily access to such an area.

- The use of natural substrates and vegetation in the enclosures resulted in reduced stereotypic pacing and an increase in exploratory behaviors. Substrates such as grass and wood chips are preferred by tigers over concrete or gunite and should be used instead.

- The presence of a water body resulted in a dramatic decrease in stereotypic pacing and an increase in exploratory behaviors. Pools, lakes, streams, or waterfalls are all acceptable and enhance tiger well being.

- Enclosures with a high level of environmental enrichment resulted in significantly lower levels of stereotypic pacing and more exploratory behaviors. A variety of enrichment items should be provided for the animals.

- Study animals housed in sibling pairs displayed fewer stereotypies and more exploratory behaviors. Although tigers are solitary animals, these results suggest that the presence of a conspecific may be preferable. The pairs in this study were siblings with one exception where it was not known whether or not the pair were siblings; further study may verify whether the same is true for non-related animals.

Additional Suggestions

This and other work suggests that captive cats would benefit from the feeding of whole animal parts (one aspect of "enrichment"; p.21). This practice can reduce stereotypic pacing and enhance other aspects of animal health (such as teeth and jaw muscles). Most facilities do not practice this type of feeding, possibly because of negative public sentiment. However, the animals could be fed at night, away from public view. And explanations to the public on the importance of feeding whole animal parts may generate a more positive view.

I did not make quantitative comparisons of types of enrichment items, but my observations suggest that variations in enrichment may be important as higher numbers of enrichment items imply more variation. New items easily lose novelty for captive cats. There are a wide variety of enrichment materials and techniques that can be easily obtained or developed. Streams of water, cardboard boxes, and old phone books are a few examples of inexpensive enrichment items that were effective in these study animals.

Finally, it is important to recognize the individuality of captive tigers in terms of their temperaments and needs. The suggestions above represent an ideal start for planning a tiger exhibit based on my sample group. Changes will most likely be required based on individual animal behavior. For example, T&D's Cats of the World received a tiger that was previously housed in a small concrete enclosure. The animal was introduced to its new large, grassy space, but was reluctant to walk on the grass. Eventually, the animal became content in its new home. This illustrates the importance of considering each animal's individual history and needs when implementing new items or re-designing an enclosure, especially if the animal's previous situation was less than ideal.

Areas of Further Study

- This study could be repeated at other zoological parks to increase the sample size and the robustness of the results.
- A similar study could expand on these results by comparing diurnal (nighttime vs. daytime)/or seasonal (summer vs. winter) behaviors.
- A similar study of other species of large cats would determine whether any similarities or differences exist between them and tigers.
- A study of zoological park visitors could determine public attitudes and preferences on animal enclosures (such as sterile vs. natural).
- More refined measures of water and vegetation sampling could provide more in-depth understanding of tiger behavior.

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Appendices

Appendix A

Sample Data Sheet

Sample Data Sheet

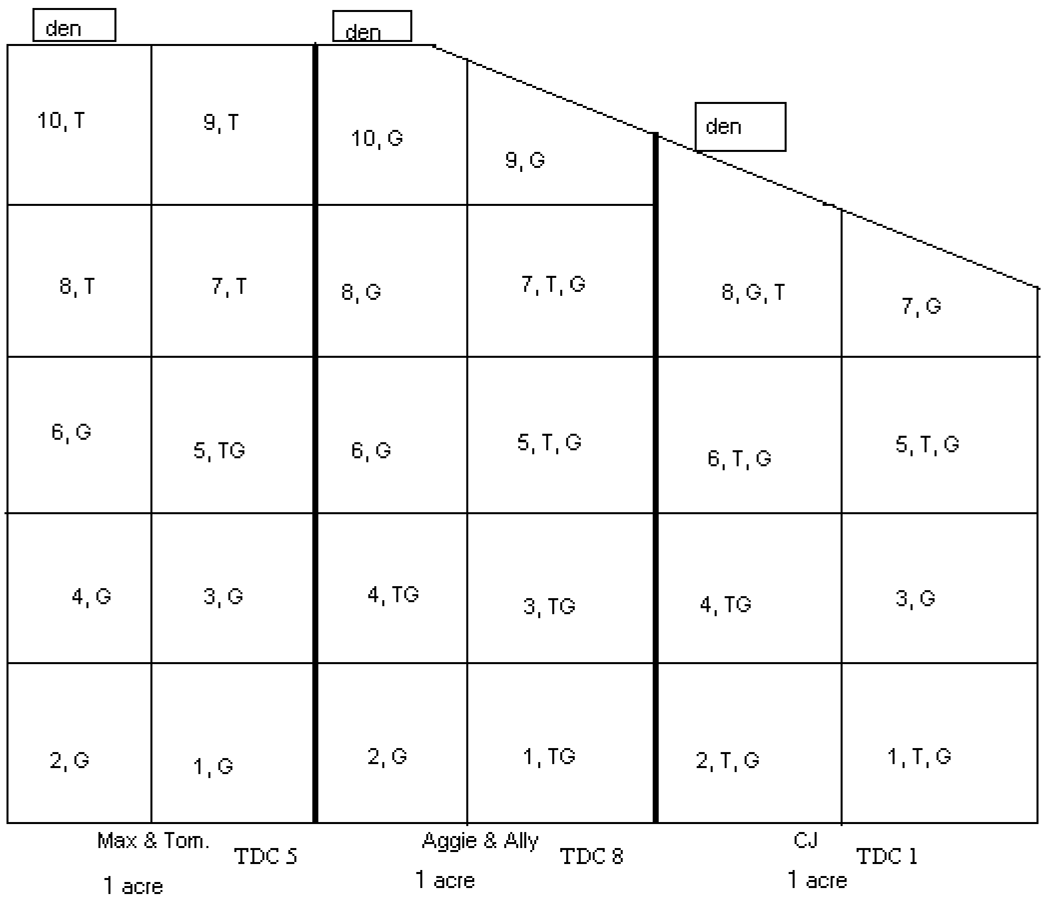
Zoo:
Animal:
Date:
Temperature:

Time	Behavior	Area	Keeper	Shade	Visitors	Other
12:30						
12:40						
12:50						
1:00						
1:10						
1:20						
1:30						
1:40						
1:50						
2:00						
2:10						
2:20						
2:30						
2:40						
2:50						
3:00						
3:10						
3:20						
3:40						
3:50						
4:00						
4:10						
4:20						
4:30						

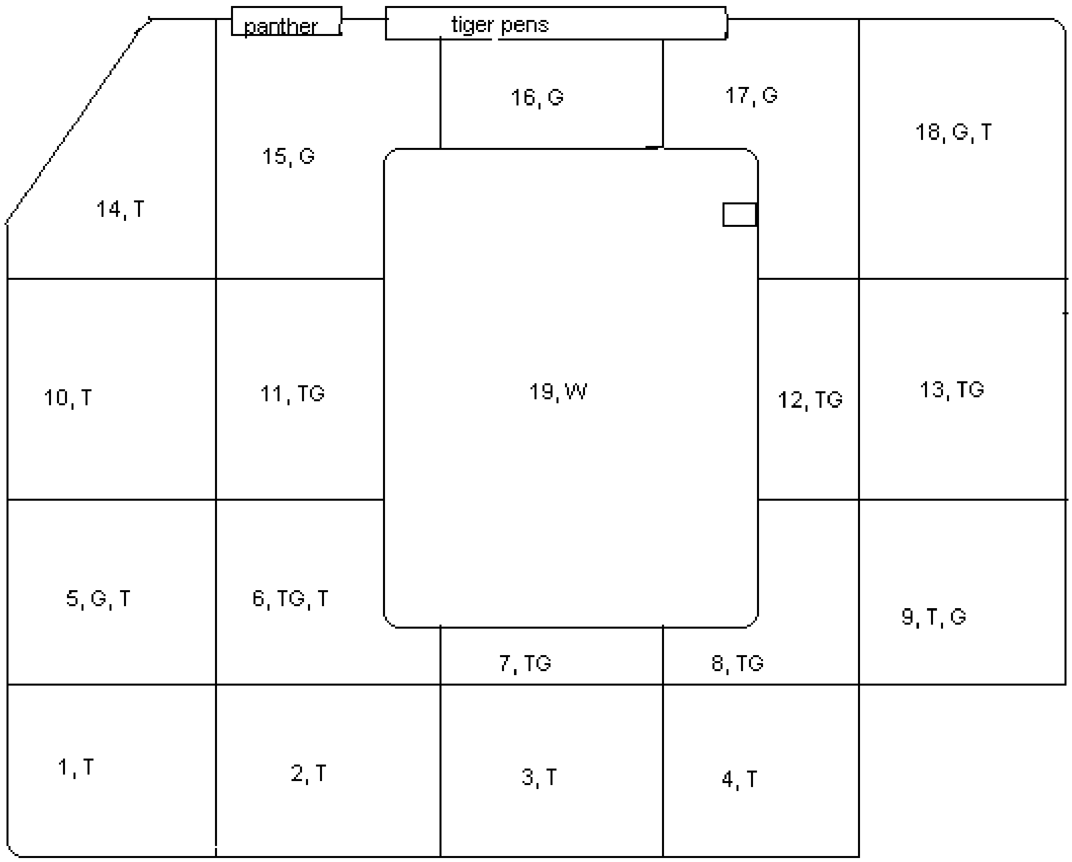
Appendix B

Sketches of Animal Enclosures

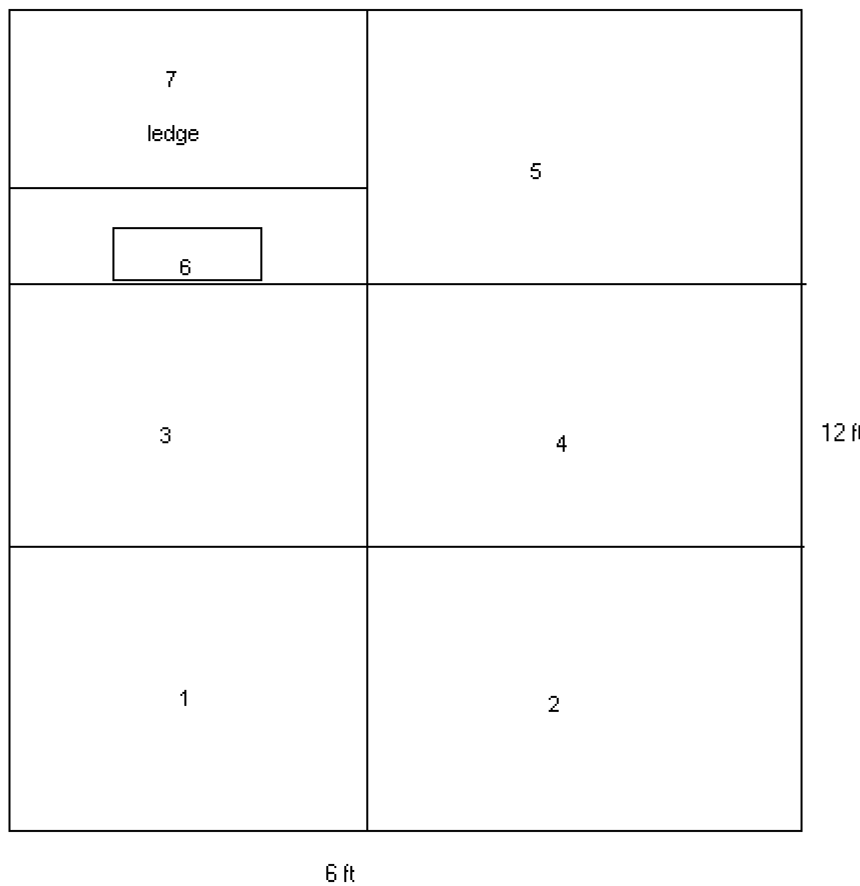
Three adjacent enclosures for five of the tigers at T&D's Cats of the World (TDC 1, TDC 5, TDC 8). Each is approximately one acre in size. Each enclosure is outside, with a small inside den area. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Letter symbols indicate the presence of vegetation that section: T = Trees, TG = Tall Grass, G = Grass. Outer perimeter is fenced and inner bold separations are also fenced. Not to scale.



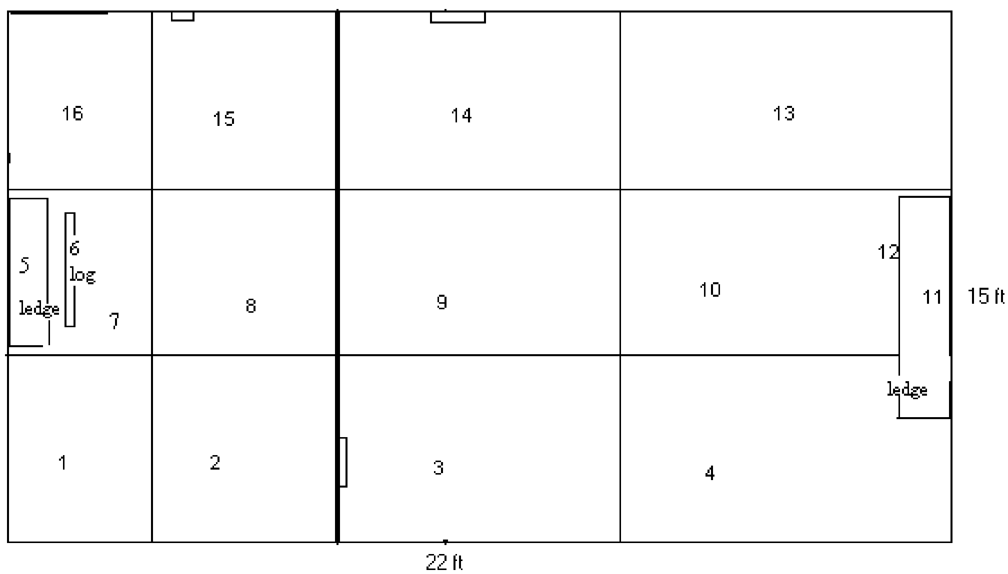
Approximately 2-acre, outdoor enclosure at T&D's Cats of the World (TDC 7). Bubu was observed in this area. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Letter symbols indicate the presence of vegetation that section: T = Trees, TG = Tall Grass, G = Grass, W = Water. Outer perimeter is fenced. Most of the trees were pines. Not to scale.

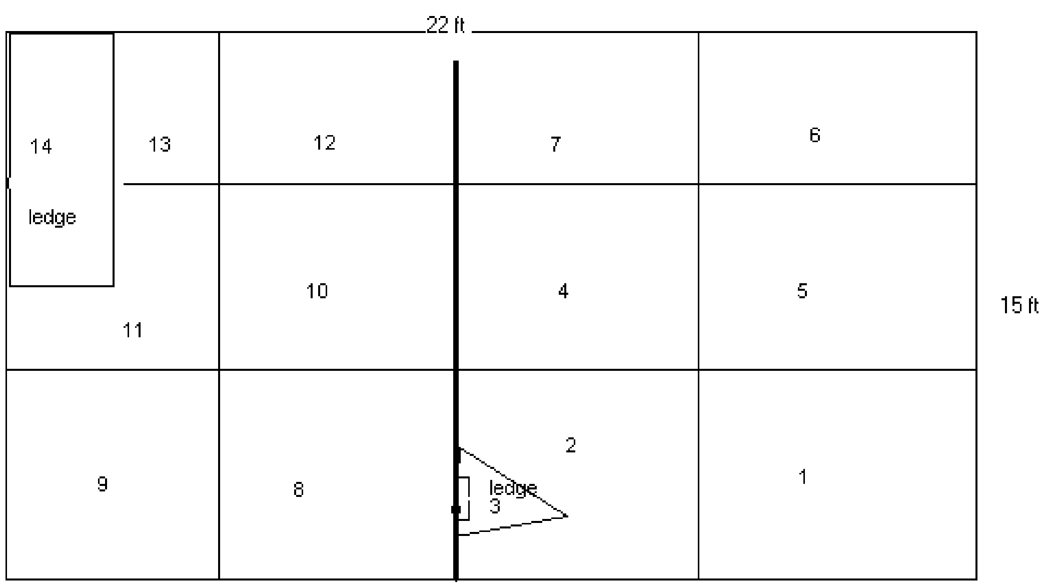


Enclosures for Taz and Tyrone at T&D's Cats of the World (TDC 4, TDC 5). They are kept in identical separate enclosures (one shown here). The enclosure is outdoors with a roof and a compact dirt substrate. No vegetation is present. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Outer perimeter is fenced. Number 6 indicates a small den. Not to scale.

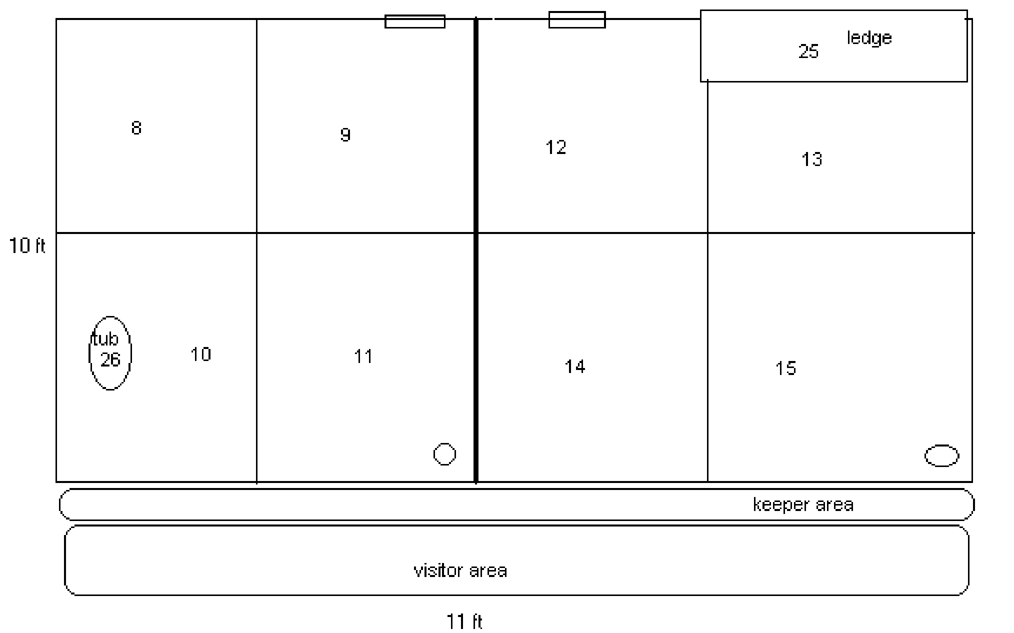


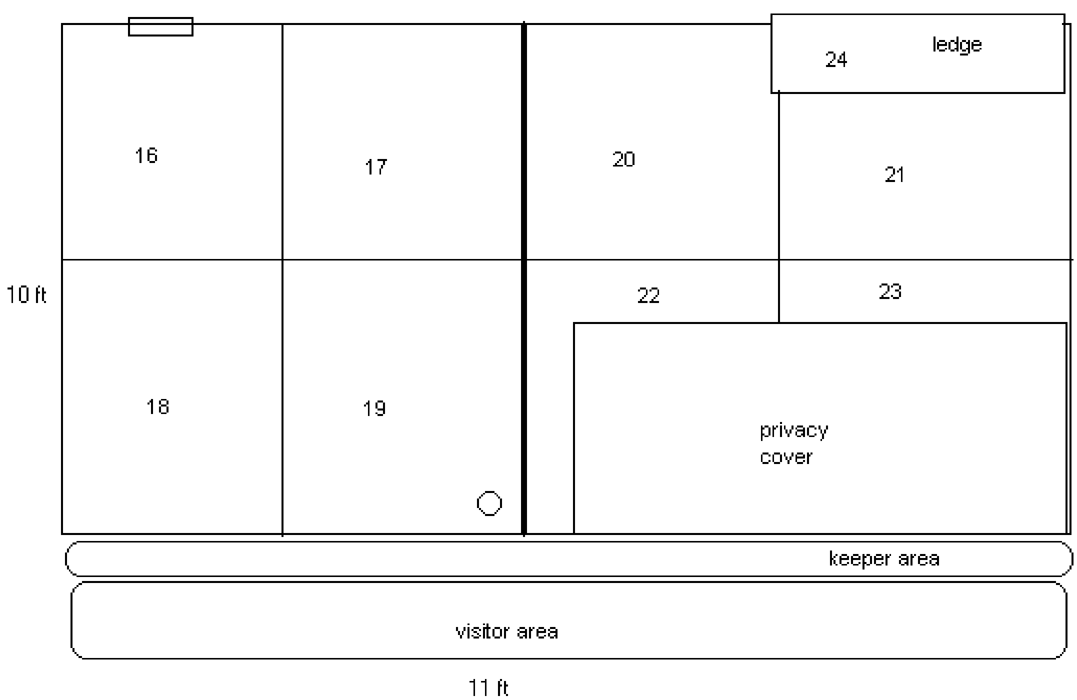
Enclosures for Sheena (top) and Spaz (bottom) at T&D's Cats of the World (TDC 6, TDC 2). The enclosures are outside with a compact dirt substrate and a covered roof. No vegetation is present. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Outer perimeter is fenced. Inner bold line represents a wall, which separates the enclosures into 2 areas. Not to scale.



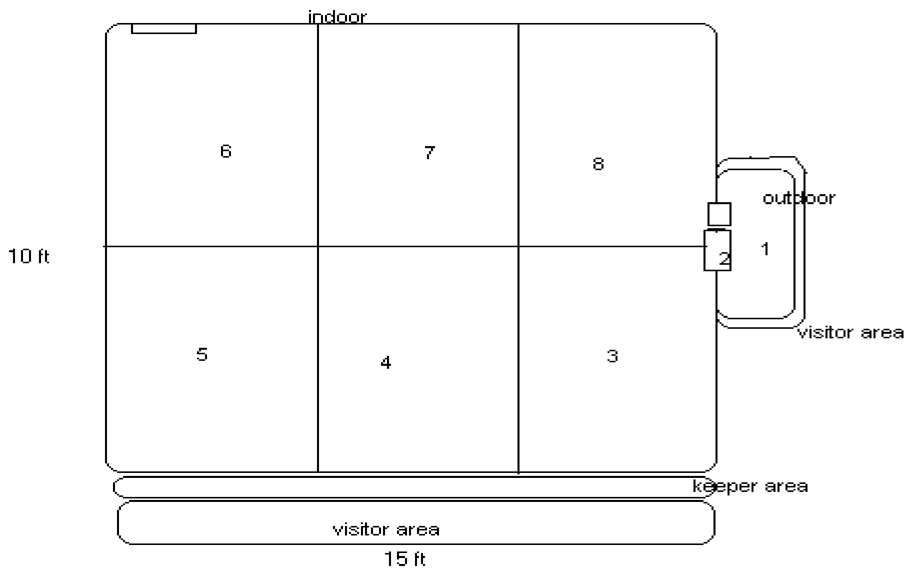


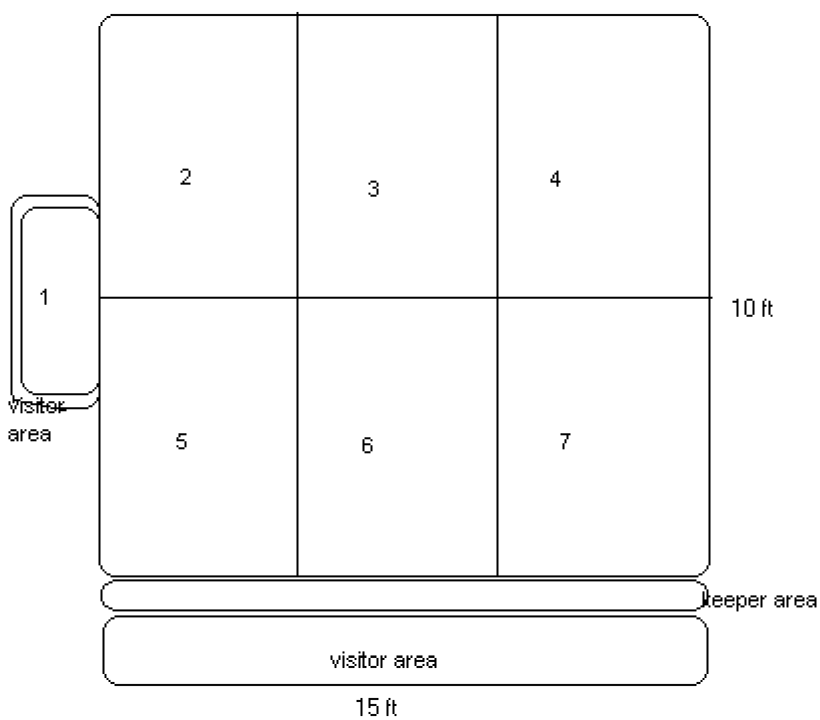
Enclosure for Kalista and Baikal (top) and Kira (bottom) at the Philadelphia Zoo (PZ 1, PZ 2). Substrate is entirely unnatural and both are indoors with no vegetation. Kira's enclosure has a privacy cover to allow her space away from visitors. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Outer perimeter is solid concrete and wall closest to "visitor area" is barred. Inner bold line represents a wall, which separates the enclosures into 2 areas. Not to scale.



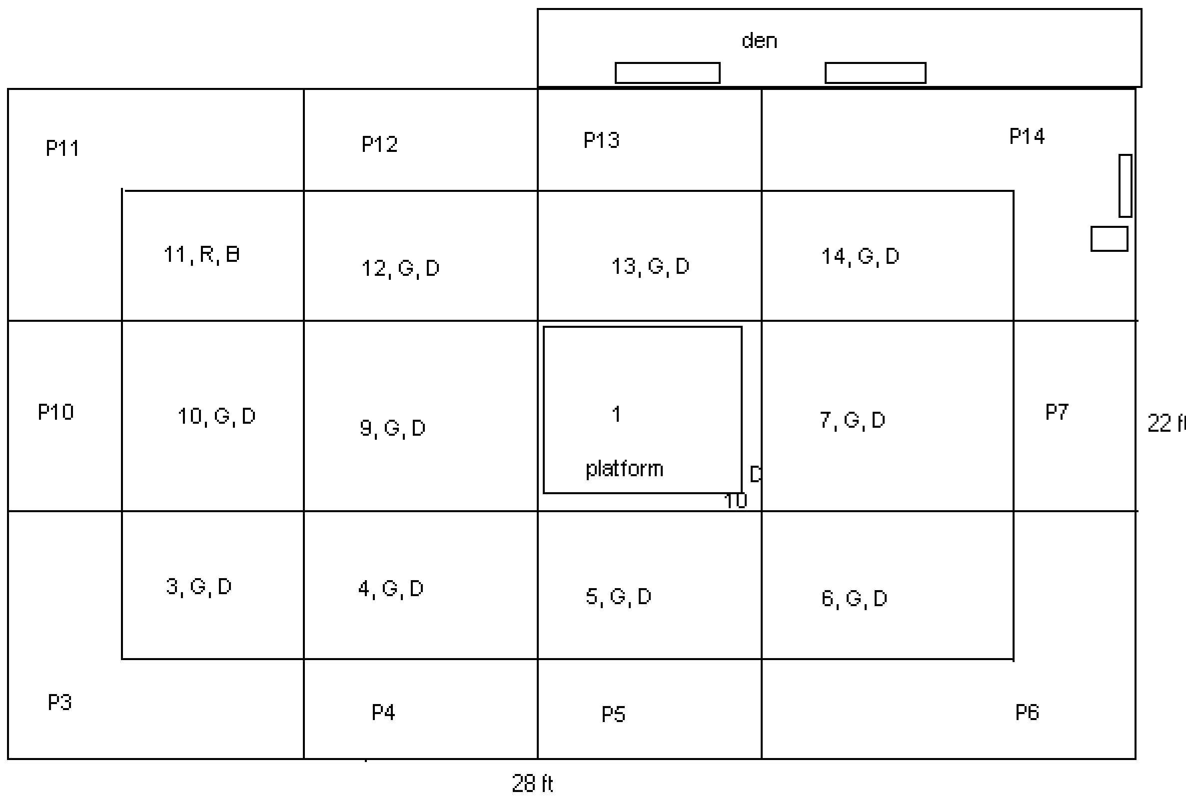


Enclosure for Lantar (top) and Yorgi (bottom) at the Philadelphia Zoo (PZ 4, PZ 3). Sections labeled "1" in both enclosures are covered, outdoor portions, while the rest of the enclosures are indoors. Substrate is entirely unnatural and both are indoors with no vegetation. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Outer perimeter is solid concrete and wall closest to "visitor area" is barred. Not to scale.

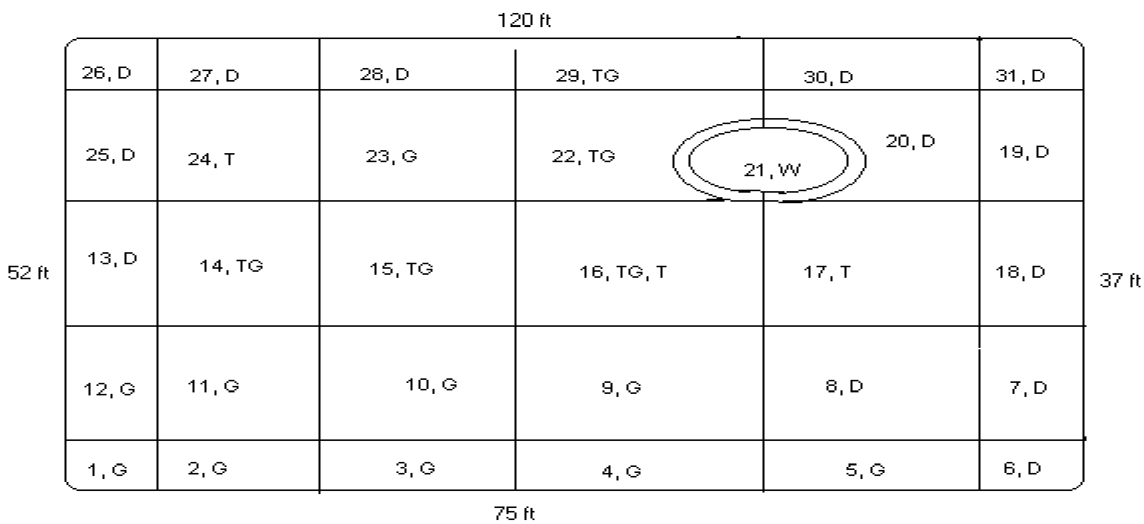


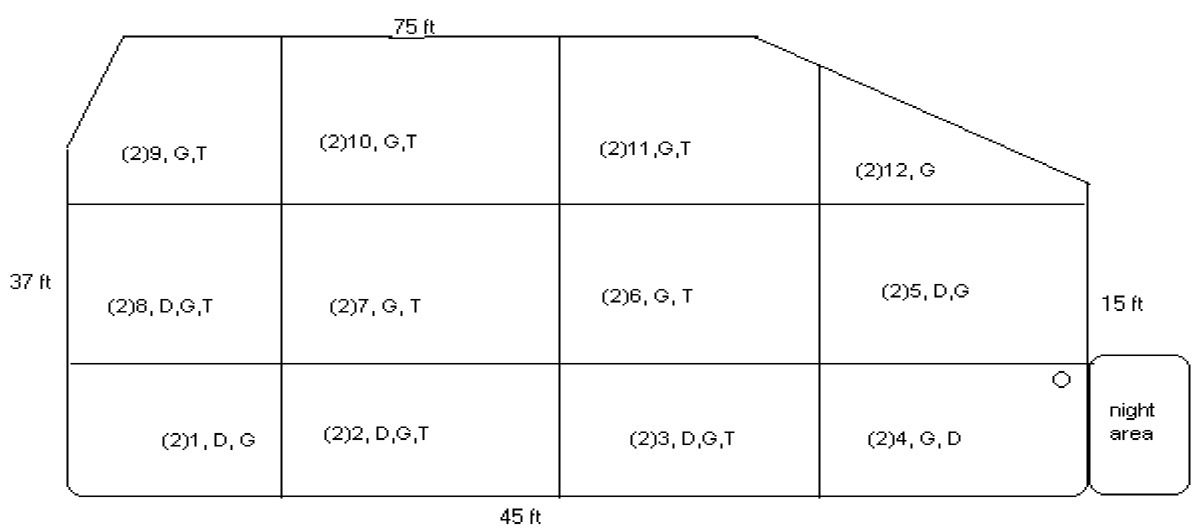


Enclosure for NBO and NBW at the Natural Bridge Zoo (NBZ 1). The substrate is natural with a concrete perimeter. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Letter symbols indicate the presence of vegetation that section: P = Perimeter, G = Grass, R = Rock, D = Dirt, B = Bush. Outer perimeter is fenced. Not to scale.



Enclosure for Ruby at the Mill Mountian Zoo (MMZ 1). It is located entirely outdoors and has natural substrate. The inner numbered sections represent an imaginary grid, arbitrarily defined and used in the spatial analysis. Letter symbols indicate the presence of vegetation that section: D = Dirt, TG = Tall Grass, G = Grass, T = Trees, W = Water. The outer perimeter is fenced and the enclosure is split into two areas by a fence. The second area is identified by a (2) before the grid number. Not to scale.





VITA

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Leigh Pitsko was born in Nazareth, Pennsylvania, in 1979. She attended Nazareth Area High School and grew up with strong interests in wildlife and conservation, which led her to Virginia Tech's Wildlife Science program in the College of Natural Resources. She received her Bachelor of Science in Wildlife Science, with a minor in Biology, from Virginia Tech in 2001. At the end of her undergraduate career, she studied abroad in Kenya for a semester. She was enrolled at Moi University, Eldoret, in the wildlife management program and had the opportunity to study East African wildlife and culture while travelling throughout the country. Gaining an interest in international development, she enrolled in the Geography Master's program at Virginia Tech in 2001, in order to expand upon her undergraduate studies. This summer she will begin a position at the Brevard Zoo in Melbourne, Florida, which will allow her to utilize all of her previous coursework, travels, and interests.