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Behavioral and Reproductive Aspects of Captive Maxwell's Duiker (*Cephalophus mawellii*) Husbandry

Janet McNeill MacKinnon

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A Thesis

Presented to

the College of Graduate Studies of

Georgia Southern University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

In the Department of Biology

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by

Janet McNeill Mackinnon

December 2002

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To the Graduate School:

This thesis, entitled "Behavioral and Reproductive Aspects of Captive Maxwell's Duiker (*Cephalophus maxwellii*) Husbandry", and written by Janet McNeill Mackinnon, is presented to the College of Graduate Studies of Georgia Southern University. I recommend that it be accepted in partial fulfillment of the requirements for the Master's Degree in Biology.

C. Ray Chandler, Chairperson

We have reviewed this thesis
and recommend its acceptance:

Stephen P. Vives, Committee Member
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Bruce Schulte, Committee Member

Accepted for the College of Graduate Studies

Charles J. Hardy
Acting Dean, College of Graduate Studies

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ABSTRACT

BEHAVIORAL AND REPRODUCTIVE ASPECTS OF CAPTIVE MAXWELL'S DUIKER (*Cephalophus maxwellii*) HUSBANDRY

December 2002

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Female Maxwell's duikers (*Cephalophus maxwellii*) were studied at the Wildlife Survival Center on St. Catherine's Island, Georgia. The objectives were to quantify the effects of housing on activity budgets and progesterone cycling. Four animals were studied across two housing situations: housed individually versus housed in a grouped setting. Behavioral observations revealed no significant change in access to resources, rumination, or repetitive behaviors, once animals were housed together. Fecal samples were collected in order to determine levels of progesterone through radioimmunoassay (RIA). Fluctuations in progesterone levels revealed no clear estrous cycles. Animals showed less variability in progesterone levels and more concordance among animals once introduced into group housing. Identifying activity budgets and estrus in group- versus single-housed Maxwell's duikers will provide critical information in the captive husbandry techniques used to house this species.

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INTRODUCTION

Ex situ conservation is increasingly important in species preservation. For example, The World Conservation Union, International Union for the Conservation of Nature (IUCN) has recognized the need to promote species preservation through captive management and breeding efforts (IUCN 2002). Thus, modern zoos are on the forefront of the battle to conserve biodiversity. However, zoos are often faced with the challenge of wedding successful conservation with profitable business in order to fund their efforts. They must balance the need to exhibit taxa that are larger and more charismatic (to attract visitors) with the need to maintain rare, less glamorous, or management-intensive species (Balmford 1996). This challenge is well illustrated by the duikers of Africa.

Captive rearing of duiker species has been an ongoing challenge to zoo managers. Initiated by the Pan African Decade of Duiker Research, captive management of duiker species has been infrequent and sometimes difficult. For example, the Los Angeles Zoo's major problems concerning duiker husbandry include diet, stress-related medical conditions, neonatal mortality, and postanesthetic pneumonia (Barnes *et al*. 2002). There have been several reports from captive facilities that duikers also face a fatal medical condition often referred to as rumen hypomotility or "slosh belly" (Willette *et al*. 2002). This syndrome is poorly documented but has been especially problematic in the group of Maxwell's duikers (*Cephalophus maxwelli*) at the Wildlife Conservation Society's

Wildlife Survival Center on St. Catherines Island. Symptoms usually include a sloshing sound when the animal makes sudden movements, possibly clumpy stools, and bloating. If left untreated, this syndrome can lead to death (Norton 2000).

The need to manage duikers successfully in captivity is heightened by the species precarious status in the wild. Deforestation and an increase in the bushmeat trade are thought to be threatening the existence of many wild populations (Dinesen *et. al*. 2001). However, accurate population counts are difficult to conduct given the secretive nature of these forest antelope. Even when captive breeding is successful, problems such as inbreeding, loss of natural behavior patterns, and loss of genetic variability can occur (Ebenhard 1995). Given the difficulty of capturing wild stock and successfully transporting them to captive facilities, there is a pressing need to develop more successful management techniques. It is the need for better duiker management and conservation that led to this study on captive duiker behavior.

By understanding behaviors and reproductive patterns, zoologists will be able to better manage for viable captive stock to aid in the protection of this species. To date, there have been no detailed studies of duiker behavior in captivity and no studies outlining activity budgets and ethograms for Maxwell's duikers in particular. In addition, estrous cycles have not been quantified in Maxwell's duikers to determine length of estrus. Therefore, the goal of this study is to quantify the effects of housing on behavior and estrous cycles in a group of four captive female Maxwell's duikers at the St. Catherines Wildlife Survival Center, Georgia. My approach is to correlate variation in measures of behavior with variation in housing (housed individually versus housed together). In addition, this study quantifies estrous cycles in a group of females by means of fecal steroid analysis through analysis of progesterone (Garrott *et. al.* 1998). I will address three specific questions: 1) does a change from housing duikers as individuals or pairs to group housing alter the behavior of captive Maxwell's Duikers?, 2) what are the estrous patterns of this group of captive duikers?, and 3) does a change in housing alter estrous cycles in captive duikers?

By moving duikers into a more social environment, I predict that there will be changes in feeding behaviors, social interactions, and estrous cycling (Ryan *et. al.* 1995). First, I predict that foraging and ruminating among animals will differ between phases. Once introduced, animals could compete for resources such as food and water. This might result in a decrease in foraging behavior and possibly ruminating behavior as well. Secondly, I predict that scent marking among animals will increase once introduced due to an increased opportunity for social interaction. Lastly, I predict that estrous patterns will vary among phases and that animals will begin to show some synchrony of estrous cycles when housed together (Brown 1985, McClintock 1971, Stern and McClintock 1998, Uttley 1979). In addition to these observations, I predict that same-sex housing will offer a better chance to observe behavioral indicators of estrus (Fitzgerald *et. al.* 1998).

Background

Duikers (Family Bovidae) are commonly known as forest antelope. Totaling 17 species and found only in Africa, these small ungulates range from dense lowland rainforests in West Africa to the dense thickets of the savannas in Central Africa.

Duikers are thought to have evolved around the early Tertiary period. They adapted to forests by consuming fallen fruits and foliage, and these species are some of the only antelopes that can survive solely as frugivores (Dubost 1984). Overall, the duikers are known to be both sedentary and territorial in the wild (Estes 1991).

Comprising two genera (*Cephalophus* spp. and *Sylvicapra* spp.), these species possess pre-orbital scent glands that are unlike other antelope species. Situated in front of the eyes, these glands secrete a clear, sometimes sticky substance. These glands play an important role in social behavior by identifying mates and offspring, establishing territories, and initiating behaviors that often lead to agonistic interactions (Estes 1991).

Duikers have diversified to occupy a variety of niches (Estes 1991). The largest of the duikers, the Yellow-backed (*Cephalophus silvicultor)*, weighs up to 80 kg and is restricted to rainforests and montane forests of western to central Africa. The smallest of the duikers is the Blue duiker (*Cephalophus monticola*), weighing 3-6 kg and inhabiting densely wooded areas of 17 African countries. In addition to these species, the Savanna or Bush duiker (*Sylvicapra grimmia*), as its name implies, depends on the savanna woodland, grasslands, and open bush country for its survival.

All species of duikers are at risk from over-exploitation due to human overpopulation, an increase in the bush-meat trade, and degradation of habitat. The World Conservation Union (IUCN 2000) has published a Red List on which all duiker species are listed. The IUCN's Red List is a compilation of scientific data that serves as a leading source of documentation for wildlife and conservation issues globally. Those data are used for monitoring the trends in species decline. Recently, the Maxwell's duiker was included on the Red List by the International Union for the Conservation of Nature and listed as "lower risk, near threatened" (IUCN 2000). Most threats posed to duikers are human-induced (Wilson 1987). Duikers have been hunted for many years and serve as an important source of protein for many people (Whittle and Whittle 1977). They are also sold in markets along with apes and other species as bushmeat, an illegal trade in African countries. Reports suggest that duikers make up as much as 50-70% of commercial bushmeat in central African countries (American Zoo and Aquarium 2000).

In addition to selective hunting pressures, duikers are also subject to the pressures of non-selective hunting. Snares, hunting at night with shotguns, and netting are the most common forms of hunting in dense forested areas. Snares and netting are, for the most part, considered non-selective and result in the capture of a wide range of species. These techniques, compounded by species-specific hunting methods, result in hunting pressures that are believed to be unsustainable locally and possibly regionally (Lahm 1993).

Restrictions on the overexploitation of bushmeat in most African countries are nonexistent. Virtually no zoning regulations or limitations have been established in order to protect duiker populations that are susceptible to intense hunting pressures. Over the years, attempts have been made to document population numbers in all duiker habitats. Fischer and Linsenmair (2001) performed drive counts in the Comoe National Park, Ivory Coast in search of species numbers for ungulates of all sizes. Compared to work of a similar scope from 1978 and 1984, Maxwell's duiker populations in the park have decreased by 91.7% over this time period.

Unfortunately, data such as these are controversial. Methods such as drive counts, track counts, and fecal pellet pile counts have been viewed as not only time consuming and expensive, but also inaccurate. Each method is subject to sampling bias and statistical interpretation (Newing 2001). Dense habitat cover makes it difficult to assess population viability within forest antelope. As a result, researchers have found it necessary to involve the hunting community in order to compile statistics on hunting pressures. It is often difficult to involve hunters in this process considering the legality of the issue of the bushmeat trade.

Duikers depend on the protection of their habitat for survival. Therefore, deforestation poses a significant threat to these species. Clearing forests for agricultural use and commercial logging creates forest fragmentation. As a result, decreases in under-story habitat are leaving forest-dependant species with no place to live (Newing 2001). Duikers play the role of an indicator species, determining the health of a forest, which has a direct affect on the human population through economics. With this in mind, conservation organizations have realized the need to dedicate more attention to this group. This led to the establishment of the Pan African Decade of Duiker Research – an integrated program of field and captive-based conservation efforts (Pinchin 1992). This program was implemented in 1985 and extended through 1994. Throughout this period, studies were aimed at assessing wild populations of all species, working in local markets to gather data on duikers that were brought in to sale, and establishing captive research studies. Specifically, the Duiker Research and Breeding Center was established near Bulawayo, Zimbabwe through the Chipangali Wildlife Trust. To date, this is the only research center solely dedicated to research on captive management of duiker species despite the need for data on captive duikers.

Hormone Analysis in duikers

Hormone analysis has been used to determine physiological state in many mammalian species over the years. Scientists have experimented with many techniques of collecting blood or urine for the purpose of monitoring the reproductive- and stress-related status and behaviors of mammals. The use of serum chemistry analysis and urinary steroid metabolite analysis has been used for pregnancy detection and overall physiological state (feral horse, Kirkpatrick *et al.* 1990; dik dik, Fitzgerald and Hnida 1994; okapi, Loskutoff *et al.* 1982; giraffe, Loskutoff *et al.* 1986). Serum chemistry analysis, however, often involves the need for immobilization, therefore adding to the stresses that the animals undergo. Urinary analysis is a time-consuming method. Although proven successful in the past, soil extraction for urinary hormone analysis is weather-dependent and hormone metabolites have been found to bind with soil particles (Fitzgerald and Hnida 1994), leaving results difficult to interpret.

Because of these difficulties, the use of fecal steroids to evaluate reproductive state in species has become increasingly valuable. Within recent years, this method has proven itself to be not only an accurate measure of a number of hormonal correlates, but this method also permits frequent and non-invasive sampling (Wasser *et al.* 1995).

Radioimmunoassay (RIA) is a method of hormone extraction used to analyze hormones in large quantities. This method of hormone analysis has been shown to be dependable and time efficient (J. Bauman, pers. comm. St. Louis Zoo). Studies have used RIAs to analyze hormone levels in diverse mammal species such as bison (Kirkpatrick 1992), hartebeest (Spratt 1999), maned wolves (Wasser *et al.* 1995), and pygmy loris (Jurke *et al.* 1997). However, there have been no published studies that use radioimmunoassay as a means of estrus detection in duikers.

Captive Management of Maxwell's Duikers

The Maxwell's duiker (*Cephalophus maxwellii*) is one of the smallest duikers. Weighing approximately 8-9 kg, this small, skittish antelope feeds primarily on fruits and fibrous foliage. In the wild, they have been known to ingest birds and insects, but they remain primarily herbivorous and frugivorous. Population surveys of Maxwell's duikers have revealed a stable population throughout its range (IUCN 2002). Their size, behavior, and habitat have apparently shielded this species from the hunting pressures that larger savanna dwellers have faced. However, with an increase in human population as well as an increase in deforestation, Maxwell's duikers have been more subject to the pressures induced by man. It is expected that their populations will decline in the near future, or they may already be in decline (Fischer and Linsenmair 2001).

The first duikers were imported into U.S. zoological facilities in the late 1800s (International Duiker Workshop, St. Catherines Island, 2000). The Bronx Zoo was one of the first North American institutions to incorporate duikers into their collection (J. Robertia, WSC Zoologist, unpublished). Maxwell's duikers have bred successfully at the Bronx Zoo for nearly 40 years (J. Doherty, pers. comm.). At present, only five facilities worldwide house the Maxwell's duiker. The Wildlife Conservation Society (WCS) –

Bronx Zoo houses 10.10 animals (males to females), WCS - St. Catherines Wildlife Survival Center houses 2.4, San Diego Wild Animal Park houses 1.0, San Diego Zoo houses 1.1, and Duiker and Mini Antelope Breeding and Research Institute (Dambari) in Bulawayo, Zimbabwe houses 1.1 (Bowman and Plowman 2002, ISIS 2000).

Currently, the Maxwell's duiker is one of the most poorly understood of the duiker species. Its low numbers in captivity compounded by the difficulty in managing this species makes research challenging. As a result, zoo managers often look to studies of other small antelope as a guide to captive management of Maxwell's duikers.

This study attempts to fill in some of the gaps in our knowledge about captive duikers. Specifically, I will assess how variation in housing affects the behavior and estrous cycling of a group of captive Maxwell's duikers. The goal is to develop more health and cost effective techniques for housing these increasingly uncommon mammals. Although my study is based only on a sample size of four related animals, these numbers are typical of captive facilities. Furthermore, no previous ethogram or detailed behavioral assessment exists on captive Maxwell's duikers.

Chapter II

METHODS

Study Site

St. Catherines Island is a 4,000-hectare barrier island located in Liberty County, Georgia. The island is managed by the St. Catherines Island Foundation. The Wildlife Conservation Society (formerly the New York Zoological Society) established a breeding facility for rare and endangered species on the island in 1974, and since this initiation the Society has been successful in rearing a variety of species of rare birds, reptiles, hoofstock, and primates. In 1994, the Wildlife Conservation Society transported the first Maxwell's duikers to be housed on the island. Currently, a group of four females and two males are housed on the island.

Study Animals

The study group consisted of four female Maxwell's duikers: a dam, Maxine [DOB:11/26/94], and her three offspring, Dixie [DOB:12/28/00], Frankie [DOB:11/24/99], Bobbi [DOB:07/14/98]). The duiker collection is housed in a series of enclosures ranging in size from 23 - 46 m^2. The enclosures are made up of a perimeter of wire fencing with Bermuda grass as the foundation of each enclosure. Vegetation is scattered throughout enclosures and consists of wax myrtles (*Myrica cerifera*), pampas grass (*Cortaderia selloana*), loquat trees (*Eriobotrya japonica*), and hercules club (*Xanthoxylum clava-herculis*). Vines are also present along fencelines including Virginia creeper (*Parthenocissus quinquefolia*), trumpet vine (*Campsis radicans*), and poison ivy (*Toxicodendron radicans*). Each enclosure provides a 1.2 x 1.8-m wooden box with one entrance/exit door. These boxes are lined with hay and provide shelter from rain, cold, and insects. The duikers are offered a daily supplemental diet of pellet feed (Mazuri Browser Breeder-300g/animal/day) and fruit or vegetable greens. Seasonal browse is offered approximately three times per week. This browse may include sweetgum (*Liquidambar styraciflua)*, hickory (*Carya* spp.), bay (*Persea borbonia)*, and/or hackberry (*Celtis occidentalis).*

In early spring 2000 (approximately one year before the study was initiated), Wildlife Survival Center staff introduced various shelter designs into the duiker yards. New shelters consisted of A-frame houses, wooden flat-topped roofs, and sited mounds of tree limbs and other brush to act as barriers (brush barrier) (Friedner and Morrow 2000). These barriers were introduced as part of a study conducted by zoo staff to provide additional hideouts and shelters for the animals. By the time of this study, there were four different enclosure arrangements for the study group. One enclosure consisted of an A-frame shelter and a wooden flat-topped roof shelter with one brush barrier, one enclosure contained only an A-frame shelter, and two enclosures had only natural vegetation. Each enclosure had different canopy covers.

Behavioral Observations

Preliminary data were gathered beginning in January of 2001. During this period, activity of the duikers was quantified during morning (600-1000), midday (1200-1400), and afternoon (1600-1900) hours as well as during varying precipitation, wind, temperature, and intensity of biting insects (e.g. mosquitoes, sand gnats, deer flies). A low-light surveillance camera (Radio Shack® 2.4 GHz wireless security monitor and cameras) was installed in shelter sites (i.e. boxes) in order to record behaviors when animals were out of observer view. Camera placement and observer location were varied during this period to maximize the viewing of animals while minimizing apparent disturbance.

Behavioral observations were initiated in June of 2001 and took place over a 24-week period. This time frame was chosen in order to sample several possible estrous cycles (estimated to be every 17-18 days in Gunther's dik dik; Fitzgerald and Hnida 1994) . The study was divided into two 12-week phases. During Phase I (reference), Bobbi and Frankie were housed as singles. Bobbi's enclosure was approximately 46 m^2 and Frankie's enclosure was approximately 23 m^2. Maxine and Dixie were housed together in two 23-m^2 enclosures with an open, adjoining gate. Zoo managers felt that Dixie was too young to be weaned from her mother and therefore required they be housed together during the study. During Phase II, animals were introduced into a group enclosure (experimental). The group enclosure consisted of four, 23-m^2 enclosures with the connecting gates opened constantly. The group had access to four wooden boxes, two A-frame structures, three brush barriers, and a box with a wooden flat-topped roof.

During Phase I, animals were observed 2 days per week for a 12-week period. Behavioral observations were made using 90-minute continuous focal animal sampling (Altmann 1974). Preliminary data suggested that duikers were more active during early morning and evening hours or when temperatures were cooler (Bowland and Perrin

1995). Therefore, observations were made between the hours of 0700-1100 and in the evening between 1400-2000. I also operated the camera during daytime hours to record any behaviors within the shelter sites. Nocturnal observations were made using the camera only. These observations totaled 8 hours per week.

During Phase II study animals were housed adjacent to one another for two consecutive weeks, separated only by a fence line. Maxine and Dixie remained housed together during this time. At the conclusion of the two-week period, all four females were introduced into the same enclosure. Behavioral observations were made using 90-minute continuous focal animal sampling (Altmann 1974) and continued for 10 more consecutive weeks.

Ethogram

It is essential to any study of animal behavior to create a consistent method to define behaviors. In order to do so, I constructed an ethogram during the preliminary period of the study, and I supplemented the ethogram to include interactive behaviors as the animals were housed together. Behaviors were classified as states or events (Altmann 1974) and recorded correspondingly. States were behaviors that occurred over appreciable durations, and events consisted of those behaviors that were relatively instantaneous. States were recorded in duration (minute) and expressed as a percent of total observed time. Events were recorded as frequencies (number of events/hour).

Attempts to document the nocturnal behaviors of this group of captive duikers have been unsuccessful in the past due to enclosure setup and unreliable equipment such as spotting scopes (Friedner and Morrow 2000). For these reasons, additional monitoring was performed in order to determine if these animals were active during nighttime hours. Nocturnal behaviors were monitored one night per week via the infrared surveillance camera, capturing activity within shelters only. The camera was rotated among wooden boxes each week so that each animal would have equal coverage.

Hormone Analysis

I collected fresh fecal samples five times per week (for each animal) throughout the study. Once collected, fecal samples were scored for consistency on a scale of 1 to 5 (Roeder 2000, Willette 2002). A score of 1 was defined as a "normal" pelleted feces; 5 described "doglike stools". These scores may be valuable in detecting health problems in duikers. Samples were frozen at 20^{o} F until shipment on dry ice to Dr. Joan Bauman at the St. Louis Zoo for hormone analysis by radioimmunoassay.

Progesterone levels were analyzed as an indicator of reproductive state (Hafez 1987). Specifically, progesterone is a hormone produced by the corpus luteum at the onset of ovulation. Its function is to prepare the lining of the uterus for implantation and to maintain the uterine lining during pregnancy. If pregnancy does not occur, progesterone levels will lower several days after ovulation. Thus, I defined estrus as the period just prior to progesterone spike and extending until progesterone readings leveled out again. Progesterone (P_4) can be used along with estrogen (E_2), follicle stimulating hormone (FSH), and luteinizing hormone (LH) to interpret estrous cycles in mammals.

Chapter III

RESULTS

Ethogram

I recorded 17 different behaviors during 424 hours of total observations (Table 1). Of these 17 behaviors, I recorded 11 states (Table 2, Figures 1 and 2) and 6 events (Table 3, Figure 3).

Foraging was the most frequent behavior, occurring approximately 22% of the total observation time (Figure 1). Walking occupied approximately 16% of the activity budget and standing was observed frequently, also comprising 16% of the total study time (Figure 1). Overall, out of sight accounted for 14% of the total diurnal observation time (Figure 1). Of the remaining 13 behaviors, none accounted for more than 13% of the activity budget.

Behavior

I predicted that moving duikers into a more social housing arrangement might affect feeding behavior, social interactions, or repetitive behaviors.

<u>Feeding behavior</u> – One possible outcome of group housing would be an increase in dominance or agonistic interactions, which might result in less time devoted to foraging (at least in some animals) or ruminating. However, I observed no significant decrease in time spent foraging between Phase I and Phase II (Table 2). In fact, Bobbi showed a pronounced increase in time spent foraging (0 to 11.7%). Although the animals

Table 1. Ethogram for female Maxwell's duikers at the Wildlife Survival Center, Georgia

Behavior	**Description**
Allogrooming	Allogrooming was recorded when one animal licked another with the apparent purpose of cleaning the fur or skin. The groomer usually approached the recipient. Most often grooming another animal consisted of licking/cleaning its face and/or head area.
Autogrooming	Autogrooming was recorded when an animal licked itself with the apparent purpose of cleaning the fur or skin. This grooming usually consisted of licking/cleaning the upper legs and/or neck.
Drinking	Drinking was recorded each time an animal was observed standing over the provided water dish, with muzzle in contact with water.
Foraging	Foraging occurred when animals were observed eating food. This included feeding or grazing on natural vegetation including grass, tree leaves, and vines or feeding on supplemental diet provided by WCS staff.
Laying	Laying was defined as a resting position characterized by the animal positioned horizontally on the ground. During this behavior, no rumination was observed. Animals would usually lay under the shade of trees or within the wooden box shelters.
Lay, Head Down	Lay, head down was defined as a resting position characterized by the animal positioned horizontally on the ground, but with the head placed chin down on the ground.
Lordosis	Lordosis was defined as an obvious decurved flexing of the spine. This behavior was pronounced and the stretch itself may last up to several seconds. Lordosis was not always directed toward an animal or object.
Out of Sight	Out of sight describes an animal that was not viewable due to barriers such as pampas grass or other tree or shrub. In addition, when animals were in their wooden box shelters during the day, they were recorded as out of sight.
Pacing	Pacing was defined as a back-and-forth movement in a small area, usually performed in a figure-eight fashion. This behavior appeared to be caused by something unfamiliar to the animal (i.e. presence of a group of people, lawnmower, etc.). The repetitive nature of this behavior (figure-eight movement) distinguished it from walking and/or running.
Ruminate Lay	Ruminating animals regurgitate partially digested food and chew it again. This behavior was defined by the characteristic circular movement of the jaw, but only when the animal was lying on the ground,

Table 1 (continued).

	not standing.
Ruminate Stand	This behavior was characterized by a circular movement of the jaw, but only when the animal was in an upright or standing position.
Run	Running was defined as a rapid movement through an enclosure. This behavior differs from walking because it involves more than one step per second. Running usually resulted from an animal being startled by either another animal or noise.
Scent Mark Duiker	Scent mark duiker was observed when an animal pressed pre-orbital scent glands against another animal. This behavior often consisted of a consecutive press on each side of the other animal's pre-orbital scent glands. Scent marking was seen when animals approached one another, usually approaching with a head down posture. Each animal was observed scent marking, and no particular individuals appeared to solicit this behavior.
Scent Mark Object	Scent mark object was recorded when an animal pressed pre-orbital scent glands against an object. This object could consist of, but was not limited to, trees, fence posts and fence wire.
Stand	Stand was recorded when an animal was stationary, upright on all four legs, but not moving. Standing did not involve ruminating.
Stare at Observer	Stare at observer was defined as looking directly at the observer for longer than one minute, without moving the eyes away. During this behavior, the animal stands in one spot, with a clear focus on the observer. It is unknown whether this behavior was a result of curiosity, surprise, fear, etc.
Walk	Walking was defined as the movement or traveling on foot, by alternating one foot in front of the other and proceeding at a slow to moderate pace (approximately one step per second). During this behavior, there was always one foot on the ground.

did not significantly alter their foraging behavior, they did appear to spend more time in rumination while lying down (Table 2). Given the low power of the statistical tests, the paired t-test was strongly suggestive of an increase ($P = 0.13$). Rumination while standing was not affected by phase (Table 2).

Social interactions – Housing in a more social setting should increase the opportunity for social interactions such as scent marking, allogrooming, or agonistic interactions. I observed no agonistic interactions, but there was an increase in scent marking of other animals during Phase II, as might be expected (Table 3). Allogrooming was unaffected by the change in housing, but autogrooming actually decreased (Table 3).

Repetitive behaviors – Captivity can result in certain repetitive behaviors indicative of "boredom" or lack of social stimulation. I defined pacing and stare at observer as this type of behavior, and I expected that these might decrease between Phase I and Phase II. This was not the case for pacing (although the pattern varied among animals; Table 2), but the one animal that was prone to staring (Bobbi) did so only during Phase I (Table 2).

Nocturnal Behavior

Twenty nights (176 hours) of nocturnal data were recorded. Duikers spent most of the observed hours within the wooden box shelters (mean = .029). Averaged across animals, 60% of the nocturnal hours were spent laying, 28% foraging on supplemental diet, 10% ruminate laying, and 2% standing (Figure 4). Bobbi was not observed inside her wooden box during Phase I. However, she was observed in a wooden box along with the other duikers during Phase II. Maxine and Dixie frequented the shelters at night more often than the other duikers.

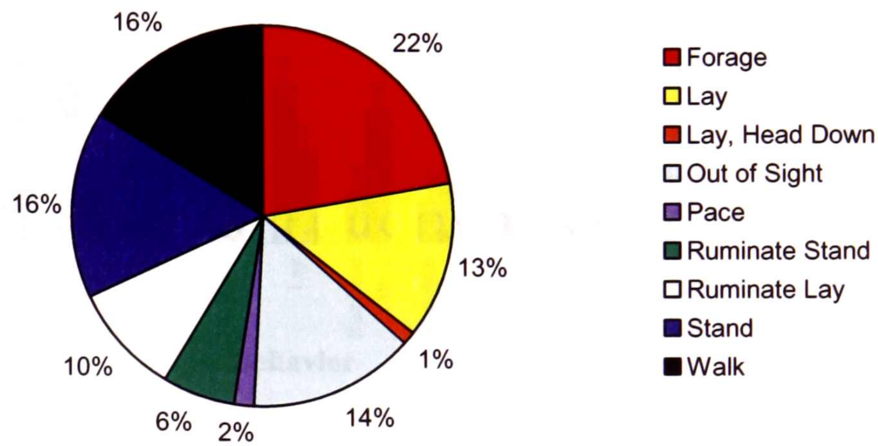

Figure 1. Percent frequency of state behaviors for Maxwell's Duikers at the Wildlife Survival Center averaged across phases and animals.

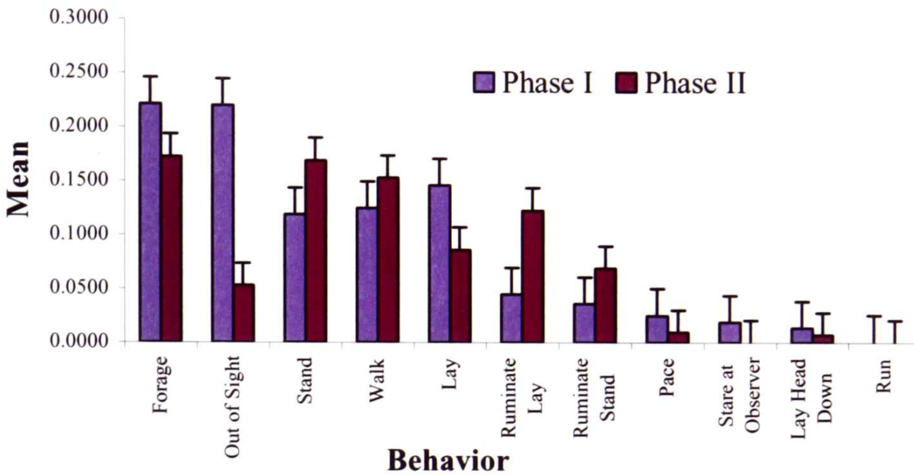

Figure 2. Mean (± 1 SE) proportion of time spent in various state behaviors for Maxwell's Duikers at the Wildlife Survival Center, Phase I and II (132 hours of observation per phase).

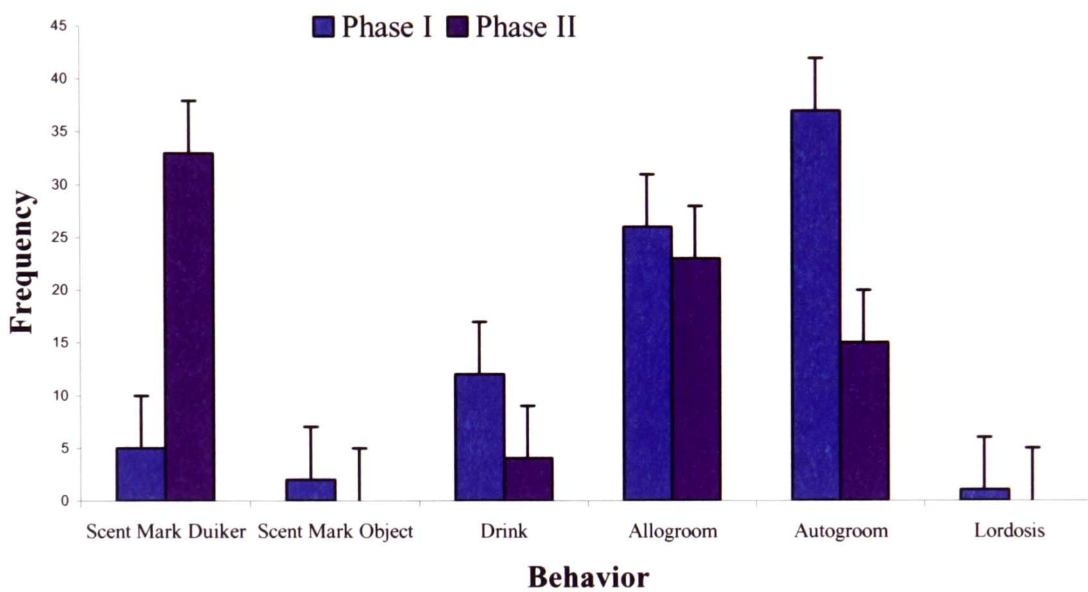

Figure 3. Mean (± 1 SE) frequency of event behaviors for Maxwell's Duikers at the Wildlife Survival Center Phase I and II (132 hours of observation per phase).

Table 2. Mean state behaviors for four female Maxwell's duikers at the Wildlife Survival Center, Georgia.

	Phase I	Phase II	Paired t-test
Behavior	Mean Maxine Dixie Frankie Bobbi	Mean Maxine Dixie Frankie Bobbi	t= P=
States Forage	0.049 0.103 0.069 0	0.028 0.058 0.069 0.019	0.85 0.46
Ruminate Lay	0.019 0.011 0.015 0	0.061 0.028 0.011 0.024	2.08 0.13
Ruminate Stand	0.015 0.013 0.006 0.002	0.003 0.012 0.030 0.026	0.59 0.59
Lay	0.050 0.027 0.053 0.016	0.035 0.031 0.009 0.012	1.49 0.23
Lay, head down	0.012 0 0.002 0	0.007 0 0 0	1.48 0.24
Out of sight	0.014 0.017 0.0003 0.189	0.021 0.007 0.0003 0.025	1.02 0.38
Pace	0.008 0 0.017 0.0005	0 0 0.003 0.006	0.96 0.41
Run	0 0.0001 0.003 0	0 0.0001 0 0	1.00 0.39
Stand	0.017 0.026 0.042 0.034	0.019 0.034 0.055 0.061	2.35 0.10

Table 2 (continued).

Walk	0.040 0.041 0.041 0.003	0.025 0.038 0.040 0.050	0.51 0.64
Stare at Observer	0 0 0 0.019	0 0 0 0	1.00 0.391

Table 3. Mean event behaviors for four female Maxwell's duikers at the Wildlife Survival Center, Georgia.

	Phase I	**Phase II**	**Paired t-test**
Behavior	Rate/10 hours Maxine Dixie Frankie Bobbi	Rate/10 hours Maxine Dixie Frankie Bobbi	t P
Events			
Allogroom	0.91 0.99 0 0	0.15 0.30 0.46 0.83	0.1463 0.8930
Autogroom	0.76 0.68 0.91 0.46	0.08 0.08 0.76 0.23	3.1323 0.0520
Scent Mark Duiker	0.08 0.30 0 0	0.23 0.91 0.53 0.83	3.7381 0.0334
Scent Mark Object	0 0.15 0 0	0 0 0 0	1.0000 0.3910
Drink	0.46 0.30 0.15 0	0.08 0 0.46 0	0.6081 0.5861
Lordosis	0 0 0 0.08	0 0 0 0	1.0000 0.3910

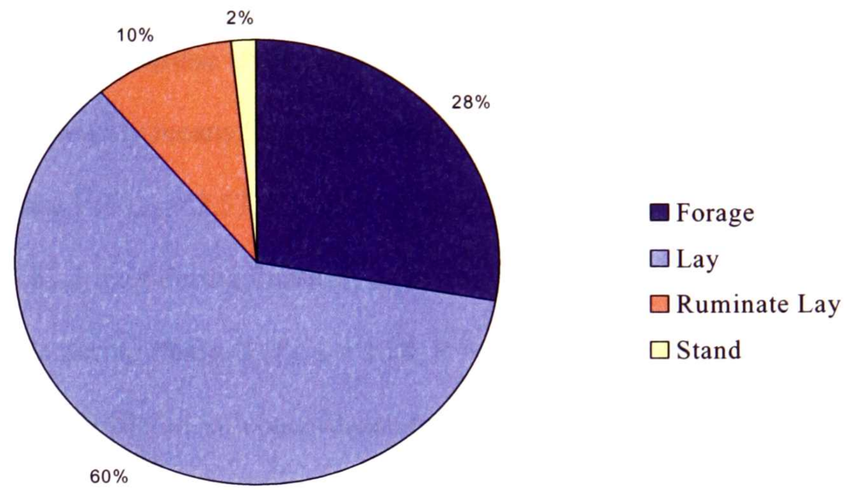

Figure 4. Nocturnal Behaviors for Maxwell's Duikers at the Wildlife Survival Center, Phases I and II (176 hours).

Hormone Analysis

Over the 24-week study, progesterone levels ranged from 393.8 ng/g to 9528.6 ng/g (Figure 5). The mean progesterone level was 1973.98 ng/g throughout the entire study period.

During Phase I, progesterone levels among animals ranged from 393.8 ng/g to 9528.6 ng/g. Based on weekly means for each animal, progesterone levels varied among individuals during Phase I ($F_{3,40} = 3.57$, $P = 0.02$) (Figure 6). Progesterone levels ranged from 460.7 ng/g to 7183.3 ng/g during Phase II. However, progesterone levels did not vary among individuals during Phase II ($F_{3,48} = 1.28$, $P = 0.29$) (Figure 6).

I used Kendall's coefficient of concordance to determine whether there was concordance in weekly progesterone levels among animals during each phase of the study. There was no significant concordance during Phase I (P= 0.2, W=0.31, df=30) (Figure 7) but during Phase II progesterone levels were concordant among individuals (P=0.01, W=0.35, df=28) (Figure 8). Progesterone levels were significantly more variable during Phase I than Phase II for Maxine, Dixie and Frankie (F=4.16, 8.90, and 5.43, respectively; $P_s < 0.025$). Bobbi, however, showed no difference in variation of progesterone levels between phases (F=0.92, P>0.50) (Figure 9).

It was difficult to identify exact estrous periods given the fluctuations in progesterone readings throughout the study. However, judging by progesterone pattern over the entire study period, peaks in progesterone levels may have occurred every 12-24 days.

Fecal Scores

Fecal scores ranged from category 1 to category 4 in both phases. Fecal score varied among animals ($G=30.9$ $P=0.0003$ $df=9$), but did not vary with phase of the study ($G=3.3$ $P=0.345$ $df=3$).

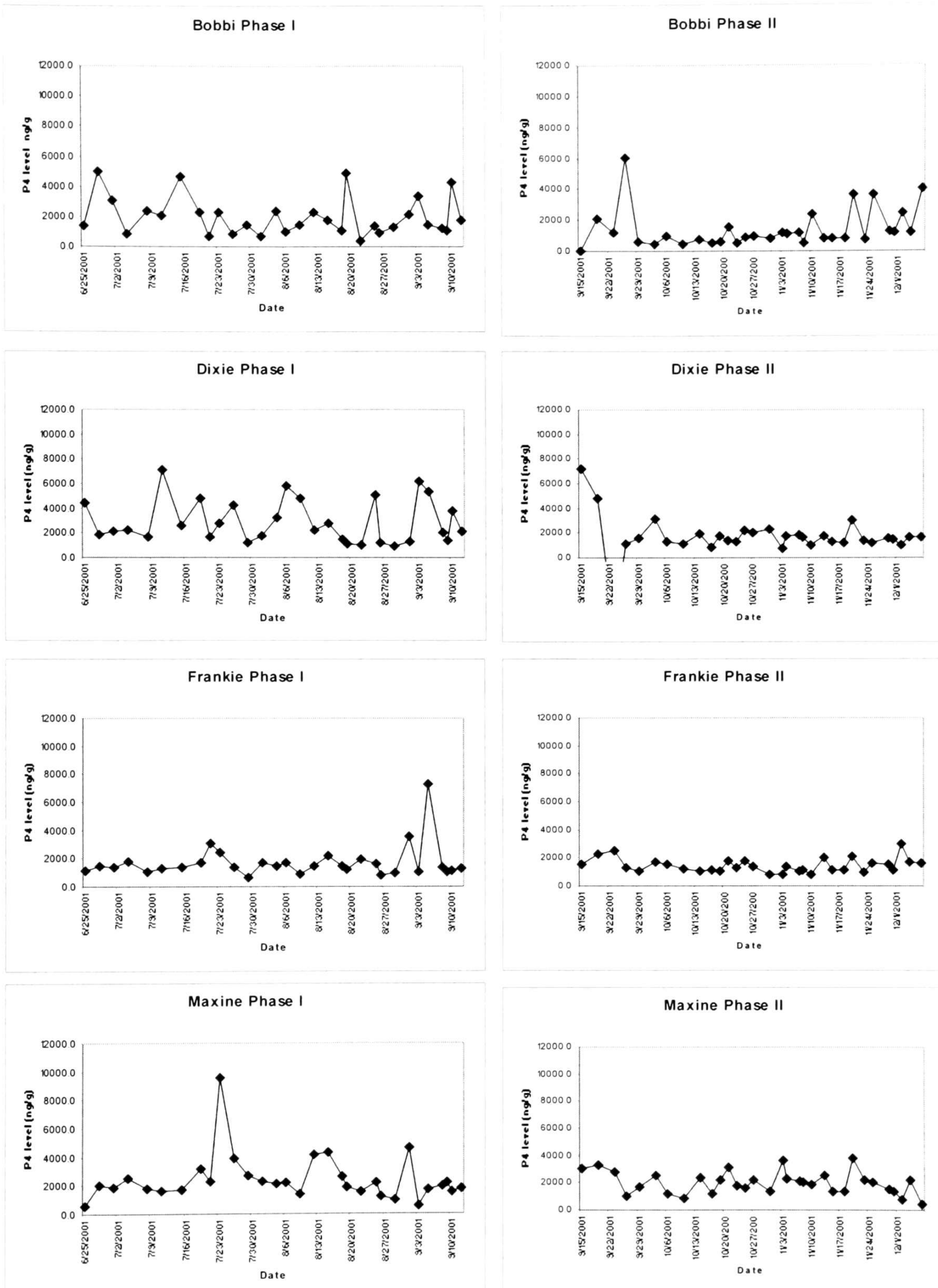

Figure 5. Progesterone readings (ng/g) for four female Maxwell's duikers at the Wildlife Survival Center, Georgia between June and December 2001.

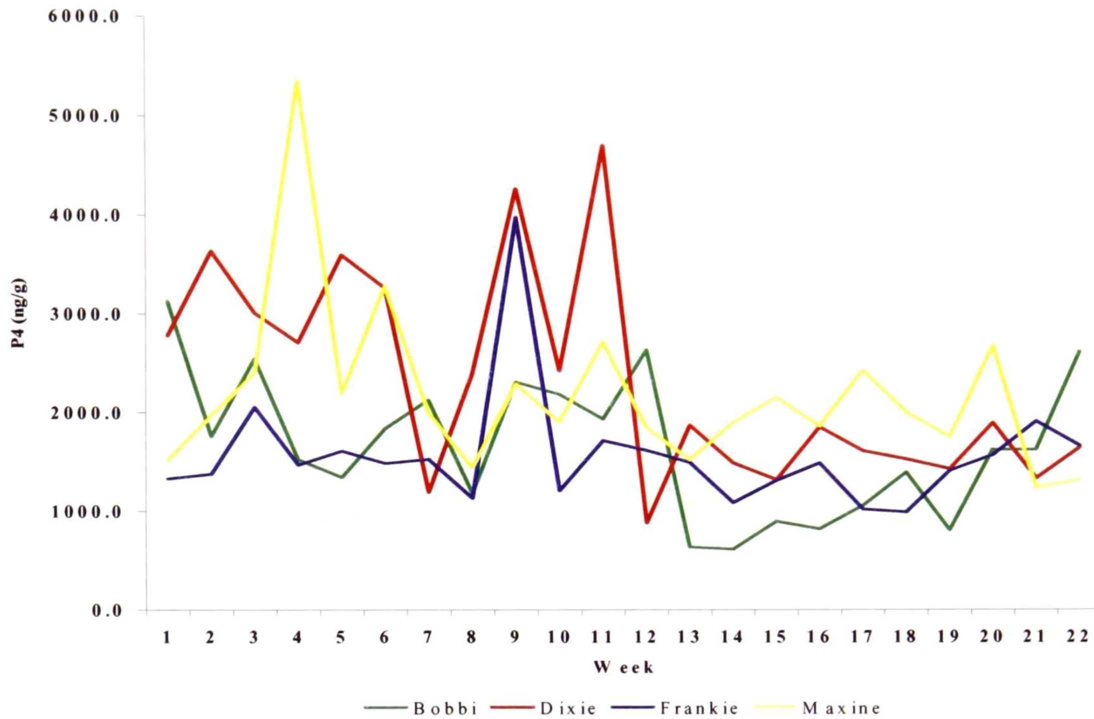

Figure 6. Average progesterone levels for each animal per week Phases I and II.

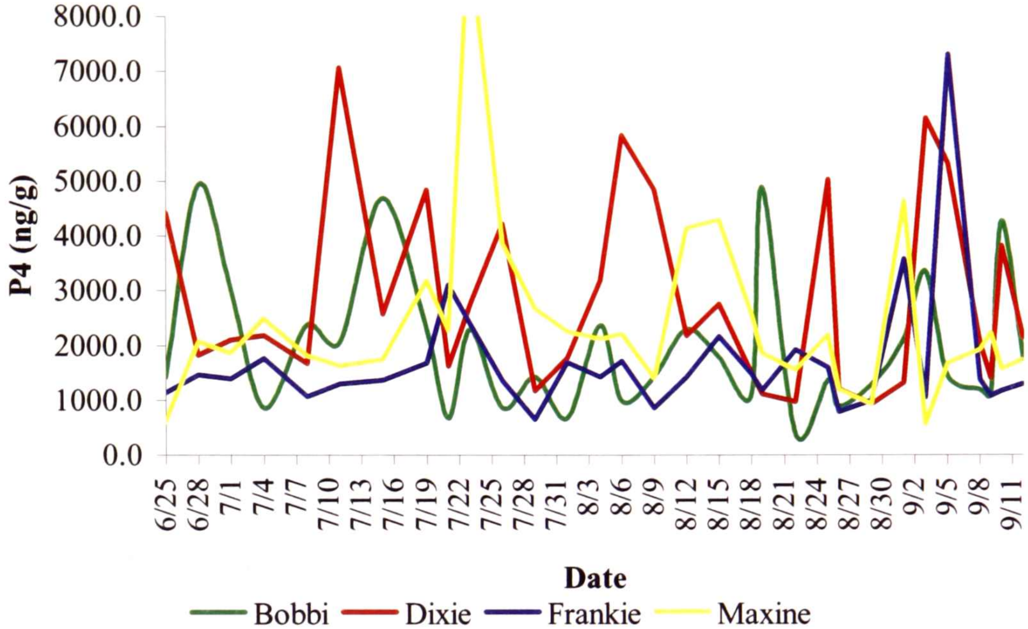

Figure 7. Progesterone Levels for Maxwell's Duikers at the Wildlife Survival Center, Phase I.

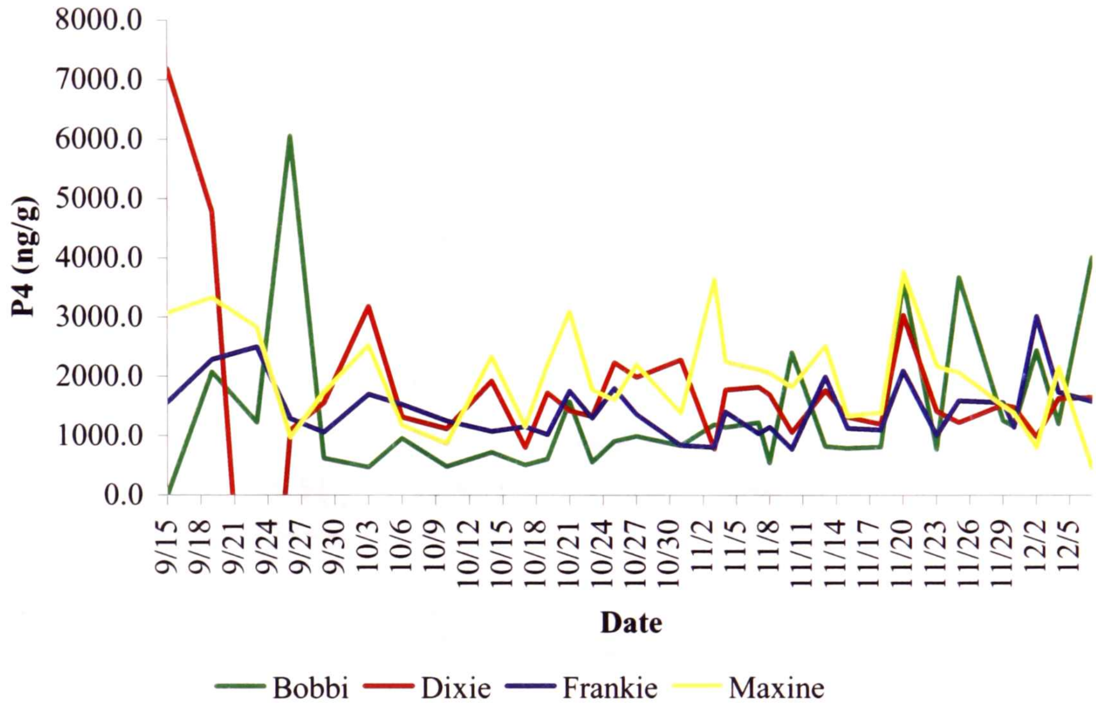

Figure 8. Progesterone Levels for Maxwell's Duikers at the Wildlife Survival Center, Phase II.

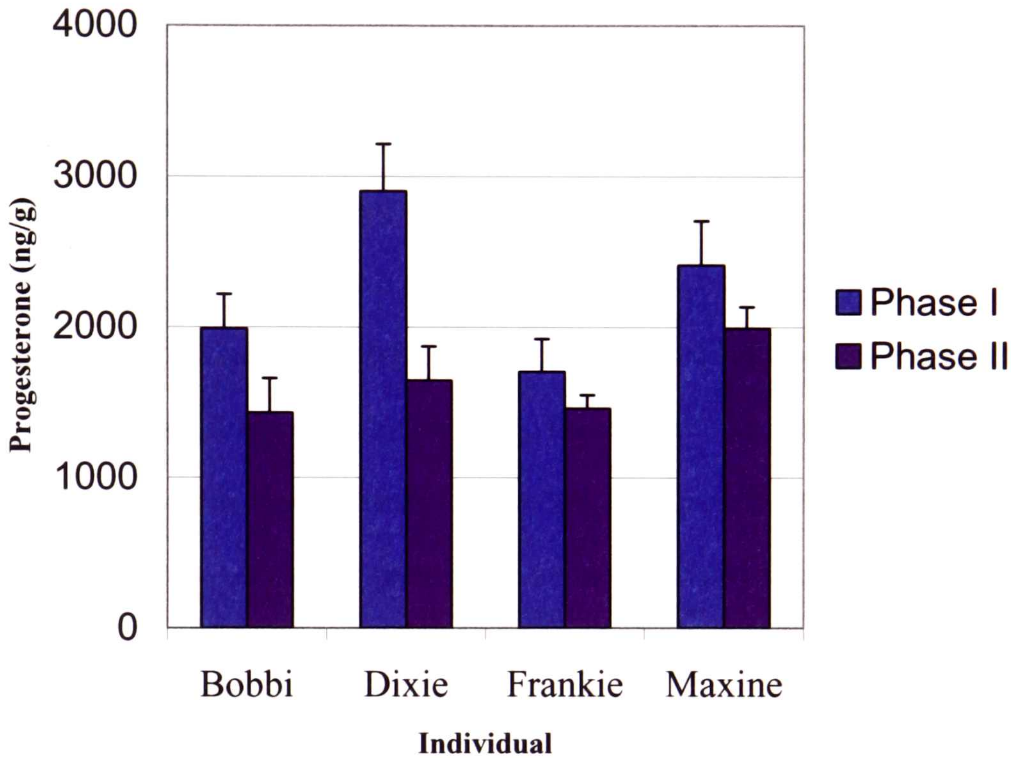

Figure 9. Variation in progesterone levels for four Maxwell's duikers at the Wildlife Survival Center.

Chapter IV

DISCUSSION

Space, money, and staff time are scarce resources at zoological facilities. When feasible, housing animals in groups can yield important benefits. For example, consolidating animals can reduce staff time by reducing daily feeding rounds and enclosure maintenance. In addition, consolidating animals vacates enclosures for other animals and/or species. Same-sex housing also has reproductive and behavioral repercussions (e.g., cheetah, Ruiz-Miranda *et al.* 1998). Housing certain females together can expedite the breeding process by increasing the chances of pregnancy once a male is introduced and resulting in more births within a species. Group housing can facilitate natural social interactions and has been shown to increase social companionship and thus overall health in some species (e.g., lion-tailed macaques, Stahl *et al.* 2000).

There are, however, potential costs associated with group housing. Housing animals in groups can lead to harmful, even deadly, dominance interactions (hartebeest, Spratt 1999; sable antelope, Thompson 1993). Dominant animals might also deny access to important resources by subordinate animals, or suppress reproductive activity by subordinates (Clutton-Brock 1989, Nunn 1999). Disease might spread more quickly in group-housed animals.

Based on my short-term results, housing groups of same-sex Maxwell's duikers is a viable option at the Wildlife Survival Center on St. Catherines Island. Because there has been little research on group housing in antelope species, there were several important results from my study.

First, I observed no change in foraging behavior between phases of my study. This suggests that there was no reduction in access to food among animals. It was possible that an older or more dominant duiker (Maxine) might limit access to food by other duikers (Dunbar 1977), but this was not the case. It is important to note that all animals in this study were related, and that this kinship may have minimized possible dominance interactions. However, kinship does not preclude sometimes aggressive dominance interactions in ungulates (Spratt 1999). My results on foraging suggest that nutrition will not be compromised by a move to same-sex housing in female duikers.

Second, no overt agonistic interactions between animals were observed during the study. Despite animals entering a novel social situation, I observed no fights or aggressive chases. This might again be influenced by the close kinship among animals. Agonistic behavior might also be more likely in male groups as found by Stahl (2000) in working with lion-tailed macaques. Although there were no overt agonistic behaviors, there could have been more subtle indicators of stress in duikers. However, I did not measure cortisol concentrations throughout the study, making it impossible to quantify fluctuations in stress-related hormones. This could be an important question for future research.

Third, although rumination did not differ significantly between phases, both standing and laying rumination increased during Phase II. Given the low power of the statistical tests, these results are probably meaningful. These data could have significant implications when housing small antelope susceptible to rumen hypomotility syndrome. It is believed that adequate rumination could play a key role in maintaining the health of small antelopes such as duikers (Roeder 2000). Diets high in fiber could possibly require longer rumination periods, and this may result in a healthier animal. A comparison of rumination between duikers of varying diets would contribute to this theory. Although dietary studies are ongoing at the Bronx Zoo (Spratt, pers.comm.), detailed observations of rumination in relation to diet have not been conducted.

Fourth, reproductive correlates revealed important information. First, no clear estrous patterns were determined. Judging by pattern alone, progesterone fluctuations could be interpreted as reflecting an estrous cycle of 12-24 days. However, fluctuations in progesterone levels were highly variable among animals, and there was less fluctuation in progesterone levels once animals were introduced into a group-housing setting. Because dominant animals can suppress cycling of various reproductive hormones in subordinates (e.g., marmosets, Saltzman *et al.* 1998; Johnson *et al.* 1996; Abbott *et al.* 1997), this decrease could represent social or stress-induced suppression. It is also possible that the lower variation and higher among-animal concordance indicates synchrony of estrus. More studies are needed in order for the concordance among animals to be determined as synchrony or social suppression. In particular, finer-scale sampling (at least daily) over a longer time period may be necessary.

Generally speaking, all of these study animals appear to have elevated baseline progesterone levels. This is unique in antelope species (J. Bauman, pers. comm.). Typically antelopes exhibit follicular phase readings in the hundreds (J. Bauman, pers.

comm. and Spratt 1999), however, not all antelope species have the same baseline readings. It is interesting to note that Bobbi displayed lordosis on 19 August and may have entered estrus on 18 August (because of a pronounced progesterone peak on 19 August). Unfortunately, I was unable to identify any behaviors indicative of estrus during this study. It is important to note that behaviors that are thought to be indicative of estrus are subtle and usually only identifiable by animal managers that are exposed to these animals daily (Barnes *et. al.* 2002).

Management Implications

Until this research on captive duikers at the Wildlife Survival Center, there were no vacant enclosures available to house additional duikers with viable genetic stock. This research has shown that same-sex housing at the Wildlife Survival Center is an option for managing Maxwell's duikers. Group housing among related females has proven to be successful. However, unrelated animals or animals of a different sex may react to this social situation differently. In addition, estrous cycling does appear to be affected by group housing, but to what extent is undetermined. Because these questions remain open, I suggest that four management-related issues still need to be addressed.

First, a more precise determination of the estrous cycle is needed. This might be obtained by more intensive sampling or by measuring other reproductive hormones. I recommend analysis of estrogen, luteinizing hormone (LH), and follicle stimulating hormone (FSH) on a more frequent sampling regime (perhaps daily). Second, mixed-sex housing of unrelated animals may have important effects on behavior or estrus. Thus, I recommend observing behaviors and documenting progesterone levels in a group of unrelated females housed with a male. Third, my study only observed overt behaviors that might hide subtle signs of stress. Future research should measure cortisol levels as an indicator of stress. Fourth, there is a strong need for studies that can link information on behaviors and reproductive cycles in captivity to that observed in wild duikers.

In the field, sustainable programs need to be established to win the support of local hunters and politicians (Noss 1998). Instead of heavy regulation and enforcement from conservation agencies alone, there is a need for education and awareness in local villages and communities throughout the continent. Programs focusing on forest regeneration are recommended to assist in counteracting those deforestation pressures that have and will continue to exist. Without the support at the local level, all initiatives to save this and other species will fail.

Lastly, and perhaps most importantly, captive managers must collaborate with field conservationists in an effort to reach the common goal of species preservation through self-sustaining wild populations. The Wildlife Conservation Society is committed to sustaining viable populations of species worldwide. Through this and subsequent studies involving the behavior and reproductive ecology of forest antelope, we will be better equipped to manage captive and wild populations globally. It is critical to the success of these captive breeding programs to understand estrous patterns and the behaviors associated with these patterns. In assessing reproductive state, zoo managers will be able to promote genetic variability in their selection of mates for particular females (Ralls *et al.* 1979).

LITERATURE CITED

Abbott, D.H., W. Saltzman, N.J. Schultz-Darken, and T.E. Smith. 1997. Specific neuroendocrine mechanisms not involving generalized stress mediate social regulation of female reproduction in cooperatively breeding marmoset monkeys. The Annals of the New York Academy of Sciences, Vol. 807, New York Academy of Sciences, New York.

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour 49: 227-267.

American Zoo and Aquarium Association. 2000. http://www.aza.org Bushmeat Crisis Task Force.

Balmford, A., G.M. Mace and N. Leader-Williams. 1996. Designing the ark: setting priorities for captive breeding. Conservation Biology 10:719-727.

Barnes, R., K. Greene, J. Holland. and M. Lamm. 2002. Management and husbandry of duikers at the Los Angeles Zoo. Zoo Biology 21:107-121.

Bowland, A.E., and M.R. Perrin. 1995. Temporal and spatial patterns in blue duikers *Philatomba monticola* and red duikers *Cephalophus natalensis*. Journal of Zoology, London, 237:487-498.

Bowman, V., and A. Plowman. 2002. Captive duiker management at the Duiker and Mini-Antelope Breeding and Research Institute (Dambari), Bulawayo, Zimbabwe. Zoo Biology 21:161-170.

Brown, R. 1985. Social odours in mammals. Oxford University Press, London.

Clutton-Brock, T. 1989. Female transfer and inbreeding avoidance in social animals. Nature 337:70-71.

Dinesen, L., T. Lehmber, M.C. Rahner, and J. Fjeldsa. 2001. Conservation priorities for the forests of the Udzungwa Mountains, Tanzania, based on primates, duikers and birds. Biological Conservation 99:223-236.

Dubost, Gerald. 1984. Comparison of the diets of frugivorous forest ruminants of Gabon. Journal of Mammalogy 65:298-316.

Dunbar, R.M. and E.P. Dunbar. 1977. Dominance and reproductive success among female gelda baboons. Nature 266:351-352.

Ebenhard, Torbjorn. 1995. Conservation breeding as a tool for saving animal species from extinction. Trends in Ecology and Evolution 10:438-443.

Estes, R.D. 1991. The behavior guide to African mammals. The University of California Press, Berkeley, California.

Fischer, Frauke, and K. Eduard Linsenmair. 2001. Decreases in ungulate population densities: Examples from the Comoe National Park, Ivory Coast. Biological Conservation 101:131-135.

Fitzgerald, Lisa, and John Hnida. 1994. Blood from a stone, or retrieval of urine from Dik Dik for hormonal analysis. Animal Keepers Forum 21:161-163.

Fitzgerald, Lisa, and John Hnida. 1994. Detection of estrus in Gunther's Dik Dik through urinary hormone analysis and behavioral observation. Animal Keepers Forum 21:201-207.

Fitzgerald, L.J., J.A. Hnida, and C. Bennett. 1998. Lordosis in two small antelope species. Mammalia 62:118-122.

Friedner, T. and C. Morrow. 2000. Husbandry study of six captive Maxwell's duikers. Animal Keepers' Forum 27:520-536.

Garrott, R.A., S.L. Monfort, P.J. White, K.L. Mashburn, and J.G. Cook. 1998. One sample pregnancy diagnosis in elk using fecal steroid metabolites. Journal of Wildlife Diseases 34:121-131.

Hafez, E.S.E. 1987. Reproduction in farm animals, fifth ed. Lea and Febiger Press, Philadelphia, Pennsylvania.

International Species Identification System. 2000. http://www.isis.org/abstract/Abs80448.htm#3.0

International Union for the Conservation of Nature (IUCN). 2000. Red List of Threatened Species. The World Conservation Union. http://www.iucn.org

International Union for the Conservation of Nature (IUCN). 2002. The World Conservation Union. http://www.iucn.org

Johnson, E.O., T.C. Kamilaris, C.S. Carter, A.E. Calogero, P.W. Gold, and G.P. Chrousos. 1996. The biobehavioral consequences of psychogenic stress in a small, social primate (*Callithrix jacchus jacchus*). Biological Psychiatry 40:317-337.

Jurke, M.H., N.M. Czekala, and H. Fitch-Snyder. 1997. Non-invasive detection and monitoring of estrus, pregnancy and the postpartum period in pygmy loris

(*Nycticebus pygmaeus*) using fecal estrogen metabolites. American Journal of Primatology 41:103-115.

Kirkpatrick, Jay, K. Bancroft, and V. Kincy. 1992. Pregnancy and ovulation detection in bison (*Bison bison*) assessed by means of urinary and fecal steroids. Journal of Wildlife Diseases 28:590-597.

Kirkpatrick, J.F., B.L. Lasley, and S.E. Shideler. 1990. Urinary steroid evaluations to monitor ovarian function in exotic ungulates: VII. Urinary progesterone metabolites in the Equidae assessed by immunoassay. Zoo Biology 9:341-348.

Lahm, Sally. 1993. Ecology and economics of human/wildlife interaction in northeastern Gabon. PhD dissertation, New York University, New York.

Loskutoff, N., J. Ott, and B. Lasley. 1982. Urinary steroid evaluation to monitor ovarian function in exotic ungulates, I: Pregnanediol-3-glucoronide immunoreactivity in the okapi (*Okapi johnstoni*). Zoo Biology 1:45-53.

Loskutoff, N., L. Walker, J. Ott-Joslin, B. Raphael, and B. Lasley. 1986. Urinary steroid evaluations to monitor ovarian function in exotic ungulates, II: A comparison between the giraffe (*Giraffe camelopardalis*) and the okapi (*Okapi johnstoni*). Zoo Biology 5:331-338.

McClintock, M.K. 1971. Menstrual synchrony and suppression. Nature 291:244-245.

Newing, Helen. 2001. Bushmeat hunting and management: implications of duiker ecology and interspecific competition. Biodiversity and Conservation 10:99-118.

Norton, Terry. 2000. Rumen hypomotility ("Sloshing Syndrome") in small duikers. Animal Keepers' Forum 27 (11), 491-492.

Willette, M.M., T.L. Norton, C.L. Miller, and M.G. Lamm. 2002. Veterinary concerns of captive duikers. Zoo Biology 21:197-207.

Wilson, Vivian J. 1987. Action Plan for Duiker Conservation. IUCN.SSC Antelope Specialist Group and Chipangali Wildlife Trust.