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GENETICS AND DEMOGRAPHICS

Is reversing the decline of Asian elephants in captivity possible? A modeling approach

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Demographic models are important tools for assessing population status, diagnosing potential causes of population decline, and comparing management strategies that might change population trajectory. Wiese (2000) used a demographic model that predicted a continued decline in the population of Asian elephants (*Elephas maximus)* maintained in North American zoos. We developed a model to quantitatively evaluate the prospects for slowing or reversing this decline given potential management strategies of improving reproduction via artificial insemination, reducing infant mortality, and recruiting additional individuals from outside the population. Our stage-based model integrates the current age and sex structure with the biological limitations on reproduction (interbirth interval and reproductive lifespan) to permit assessment of the biological growth potential of the population. If current demographic trends continue, our simulations predict a continued population decline of 2% per year. Even under the most optimistic (and likely unrealistic) scenario, where all females reproduced at the maximum possible rate, the existing age structure would only allow the population to grow at 0.76% per year. Reductions in infant mortality or immigration of additional individuals are unlikely to be able to reverse the population decline unless undertaken in combination with substantial increases in reproduction. Given the current population structure and the problems with reproductive cycling in the population, it will likely be difficult to either increase the population substantially or sustain it at its current size.

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Genetic paternity analysis of the African elephant (*Loxodonta africana*) population of Amboseli National Park, Kenya

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In an effort to measure patterns of male reproductive success in a wild, undisturbed population of a highly charismatic, threatened species, we carried out a genetic paternity analysis of the African elephant population in Amboseli National Park, Kenya. We genotyped 270 calves born between 1979 and 2002, their mothers, and 117 adult males that were potential fathers, at eight tetra-nucleotide microsatellite loci. We established paternity for 138 calves. Using the long term records of the Amboseli Elephant Research Project we present data on paternity success by male age, musth state at the time of conception, and across family groups. Our data indicate that males sire an increasingly large proportion of calves as they age (well into their 50s and beyond); this represents an unusual reproductive pattern for mammals. Paternity, however, is not monopolized by only a few individuals as over 1/3 of the adult males we sampled sired at least one offspring, including males as young as 28 years of age. We conclude that in typical wild elephant populations the oldest males sire the largest proportion of offspring, but multiple males of varying ages sire calves, and all adult males in the older age classes (over 25) are reproductively active.

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Genetic variation in the North American captive collections of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants

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With the serious depletion of many natural elephant populations, scientific study of captive elephants is paramount to the future management and understanding of elephant populations and social dynamics. In order to maintain genetic diversity and develop a self-sustaining captive collection, genetic data is needed to determine the genetic diversity of managed collections and to identify the pedigree or lineage of the captive elephants. In this study, a continuous 3790 bp fragment of the mitochondrial genome was sequenced for 109 African elephants and 203 Asian elephants. An assessment of 24 nuclear microsatellite loci for all the individuals confirms species-level genetic differentiation. Our captive genetic data compared to public sequences from wild-sampled individuals deposited in GenBank indicate that 1) there are individuals in the North American captive collection derived from African forest and savannah elephant founders or are founders themselves, and 2) among the captive Asian elephants, haplotypes consistently separate into two highly differentiated clades, one clade includes individuals from Sri Lanka, India, Thailand, and Burma, and the second clade includes individuals from Malaysia and Indonesia. Our results infer that representatives from savannah elephants harbor lower genetic diversity than representatives from forest elephants; however, significant differentiation is evident among the pooled sample collections of African savannah, African forest, and the two Asian elephant ancestries. We argue that genetic screening and ancestral assignment may be important tools for future breeding and management of the North American captive elephant collections.

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Genetics of African elephant species

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Recent morphological and genetic studies have indicated that African forest (*Loxodonta cyclotis*) and savanna (*L. africana*) elephants are distinct species. Dart-biopsy samples from wild African elephants at 21 locations were examined for DNA sequence variation in three X-chromosome (biparentally inherited) and one Y-chromosome (male lineage) gene from 21 elephant populations in Africa. For three X-linked genes (n=2124 chromosome segments), savannah elephant-specific alleles were absent among forest elephants, while very few forest elephant alleles (<0.2%) were present among savanna elephants. Y-chromosome sequences from 205 males also demonstrated genetic separation between forest and savanna male lineages. These results affirm and extend the evidence that deep and almost complete genetic separation, estimated at more than 3 million years, exists between forest and savanna African elephants. (Funded in part by DHHS #N01-CO- 12400.)

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Calculation of longevity in captive elephants

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The concepts of longevity (longest lived) and life expectancy (typical age at death) are common demographic parameters that provide insight into a population. Defined as the longest lived individual, longevity is easily calculated but is not representative, as only one individual will live to this extreme. Longevity records for North American Asian elephants (*Elephas maximus*) and African elephants (*Loxodonta africana*) have not been set as the oldest individuals (79 and 54 years, respectively) are still alive. This is comparable to the maximum (though not typical) longevity estimated in wild populations. Many different methods of estimating life expectancy exist. When selecting a method for estimating life expectancy it must be appropriate for the data available, the distribution of the data, and the life history of the species. The popular press often reports life expectancies that are calculated incorrectly giving faulty longevity estimates. Use of life table analysis to estimate median survivorship or survival analysis to estimate average survivorship are more appropriate for the elephant's biology, the data available and thus provide more accurate estimates. Using a life table for median life expectancy for female Asian elephants (Lx=0.50) is 35.9 years in North America and 41.9 years in Europe. Survival analysis estimates of average life expectancy for Asian elephants are 47.6 years in Europe and 44.8 years in North America.

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VETERINARY MEDICINE

Initial thoughts and results on the use of multi-antigen print immunoassay in the diagnosis and monitoring of therapy of *Mycobacterium tuberculosis* in captive elephants

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The National Tuberculosis Working Group for Zoo and Wildlife Species has been monitoring TB in elephants since 1996. The current standard for diagnosis of tuberculosis in elephants is culture from a trunk wash or other suspected source of infection. Ancillary diagnostics are in development stages. Enzyme linked immunoassays (ELISA) have shown to have some promise but have limitations in sensitivity and specificity. Recently, a multi-antigen print immunoassay (MAPIA) has been utilized in a couple of cases of *Mycobacterium tuberculosis* (Mtb) in Asian elephants (*Elephas maximus*). Two female Asian elephants with culture confirmed Mtb had the infection detected years prior to culture results when examined retrospectively. The MAPIA exam detected seropositivity about one year prior to the existing ELISA test. A change in the antigen profile was also seen in both elephants than corresponded to a response to anti-tuberculocidal therapy. This change in antigen profile had parallels ELISA designed for detection of TB in elephants and may have some use in monitoring therapy.

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Quantifying the degree of seasonal acclimatization in African elephants

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Acclimatization occurs in several different systems in the mammalian body. The best known and tested cold and hot acclimatization mechanism involves the seasonal shift in the thermal neutral zone due to changes in insulation. As the seasonal ambient temperature changes there is a change in the insulation provided by hair coats. Cold conditions stimulate the growth of the hair coat in many species to retard heat loss. The loss of the hair insulation during the hot season increases heat loss from the animals surface. Heat loss from the surface of an animal can now be measured accurately from 25 m or more. The long wave radiative heat loss from an animal can be calculated from surface temperature measurements. The questions purposed in this study were: 1. Are African elephants capable of shifting their thermal neutral zones seasonally without a hair coat and 2. If these naked skin species can acclimatize, can the degree of acclimatization be measured and quantified. It was hypothesized that African elephants would not exhibit seasonal shifts in their thermal neutral zone. Siberian tigers were used as a control in this study since they were kept in outside enclosures and exhibited changes in the thickness and insulation of their coat seasonally. Surface temperature, insulation and thermal conductance were measured on Siberian tigers and African elephants during the winter and summer of 2002, 2003 and 2004. The tigers and elephants were being held at the Cheyenne Mountain Zoo in Colorado Springs, Colorado. Both species were exposed to ambient conditions daily. Over an ambient temperature range from –6 °C to 36 °C the measured insulation values for Siberian Tigers ranged from 0.19 – 0.69 m_2 $°C_{-1}W_{-1}$. The insulation values measured for African elephants over the same range of ambient temperatures was 0.18 – 0.19 m_2 $°C_{-1}W_{-1}$. The elephants exhibited the same insulation factors throughout the year. African elephants don't acclimatize using internal or external insulation changes. African elephants have the same heat loss from the skin surface in the hot and the cold season and show no seasonal thermal neutral zone shifts.

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Endosurgical reduction of a vaginal cyst in an Asian elephant

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A 37-year-old female Asian elephant was evaluated for breeding soundness. The elephant had raised 4 live calves born between 1983 and 1994. After her last calf had been weaned, she was exposed to several male elephants. Based on weekly hormonal assays, it was determined that she was cycling regularly. Rectal ultrasounds were performed staring in 1998 and showed evidence of a 1 cm vaginal cyst on October 1999. In May of 2004, vaginoscopy was performed. A thin-walled cyst was visualized and dissected using endo-scissors. Although pregnancy status is undetermined, the cyst had not reformed 4 months later. Video recordings of the examinations and dissection will be included in this presentation.

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Elephant foot pathology: New perspectives

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Foot lesions and degenerative joint disease are the most common medical problems observed in captive elephants. Potential causes of ineffective treatment of chronic foot ailments include a lack of anatomical knowledge regarding the relationships of structures within the elephant foot, as well as an incomplete understanding of the causative factors of these lesions. Internal bony remodeling and degeneration of the digits in older elephants or those with conformational abnormalities and altered weight bearing seem to play a significant role in the development of external lesions in the pad and nails. Soft tissue dissections, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI) have proved very useful in the identification of degenerative processes within the bones of the feet and their relationship to the development of chronic, persistent foot lesions.

INTRODUCTION

Foot lesions are the most common source of medical ailments observed in captive elephants (Mikota et al. 1994). Cracks, abscesses, ulcerations, and other lesions in the sole, nail, and cuticle, as well as degenerative joint disease, are frustrating and potentially debilitating problems. Etiologies are traditionally thought to include foreign bodies, trauma, wet or contaminated surfaces, concurrent health issues, poor nutrition, lack of exercise, and inadequate foot care (Gage 2001).

Serious infections of the nail or pad may progress into surrounding tissues. The distal phalanges are closely associated with the toenail, and the development of osteomyelitis is a potentially life threatening condition. Infected phalanges have been treated by surgical removal; however the prognosis for resolution of infection after treatment is guarded (Boardman et. al 2001, Cooper et. al 2001, Finnegan and Monti 2001, Gage et. al 1997). Serious and chronic infections which do not involve bone tissue may become chronically debilitating and life threatening as well.

Potential causes difficulties in treatment of chronic foot lesions include a lack of detailed anatomical knowledge of the elephant foot, and an incomplete understanding of the reasons for the development and persistence of chronic foot pathology. In addition, degenerative processes occurring in older elephants or in animals with abnormal conformation and altered weight bearing may occasionally contribute to the development of these conditions.

Our objective was to review the normal anatomy of the elephant foot and to investigate abnormalities using a variety of techniques on post-mortem specimens, including soft tissue dissections, arterial cast preparations, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI). Particular focus has been placed on the development and persistence of chronic foot lesions in elephants with conformational abnormalities.

METHODS

Soft Tissue Dissections

The left forelimb of an elephant with a history of abnormal conformation and a chronic foot ulceration was obtained after necropsy. The leg was fixed in formaldehyde and the vessels were injected with colored latex, allowing for slow and detailed dissection.

Arterial Cast Preparation

The forelimbs of an elephant were obtained at necropsy, and the arteries were flushed with saline. A red methylmethacrylate plastic was injected into the arteries, forming a hard cast. This allowed for visualization of arterial vascularization throughout the limb. The foot was frozen and sectioned into 5mm transverse sections using a band saw, approximating the slices obtained via transverse imaging using CT or MRI.

Computed Tomography (CT)

Elephant forelimbs were scanned using transverse and saggital imaging. High detail, high contrast, cross sectional images were obtained which allowed for visualization of bony anatomy without superimposition of adjacent structures. Bony abnormalities were compared to external lesions of the pad and toenails.

Magnetic Resonance Imaging (MRI)

One fore limb and one hind limb were scanned using MRI, allowing for excellent cross sectional detail of both bony and soft tissue structures, again allowing for comparison to external pathology of the pad and nails.

RESULTS

CT scans have proved very useful in the identification of bony abnormalities, while soft tissue dissections and MRI have allowed for detailed investigation of bony, cartilaginous, and soft tissue structures. Arterial cast preparations and dissections provided information as to the extent of vascularization within the leg and foot. In several elephants studied thus far, internal bony remodeling and degeneration of individual digits was found to be anatomically related to the site of external foot pathology. Animals with a history of conformational abnormalities and abnormal weight bearing exhibited obvious degenerative changes in digits directly above chronic, non-healing solar ulcerations.

DISCUSSION

It has been recognized that elephants with abnormal limb conformation tend to develop chronic and often serious foot problems as they age (Gage 2001). These animals tend to be especially sedentary, and often have unequal weight distribution between the feet. Several elephants in this study exhibited abnormal limb conformation that preceded the development of persistent foot lesions. These conformational abnormalities resulted in abnormal and excessive weight bearing on specific portions of the limbs. Bony remodeling of individual digits likely occurred in an effort to compensate for unusual pressures and increased weight load. This remodeling and malalignment of digits may have caused excessive pressure beneath the digits themselves, possibly leading to pressure necrosis, decreased blood supply, and ischemia. Pressure and lack of blood supply may have led to chronic, persistent, ulcerative lesions. This underlying pathology of bony remodeling and degeneration may contribute to the lack of response to therapy commonly encountered when treating such conditions.

The development of certain cases of chronic foot lesions in elephants may therefore be the result of degenerative processes occurring within the digits rather than from external etiologies. Abnormal weight bearing and lack of activity may significantly increase the risk of lesion development. More serious complications such as osteomyelitis may occur after these degenerative processes create chronic lesions.

CONCLUSIONS

1. A thorough and detailed anatomical knowledge of the elephant foot is critical in understanding the development, persistence, and treatment of foot lesions in captive elephants.

2. Abnormal limb conformation may result in unequal weight distribution in the feet.
3. Altered weight distribution may induce bony remodeling and degeneration of individual digits in an effort to compensate for the increased weight load.
4. Degenerative changes within the digits may alter pressure distribution on the pads and nails, causing localized ischemia and ulcer formation.
5. Elephants with conformational abnormalities and alterations in weight bearing may have increased susceptibility to chronic foot ulcerations.
6. CT and MRI, although not currently practical in a clinical situation, provide high detail images allowing for visualization of individual structures without superimposition. These studies have proved extremely useful in furthering our understanding of elephant foot anatomy as well as the pathologic processes which contribute to chronic foot lesions.

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Medical management of dystocia and vestibulotomy for removal of a retained fetus in an African elephant (*Loxodonta africana*)

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In April 2003, dystocia occurred at full-term pregnancy in a 34-year-old nulliparous African elephant cow that conceived by artificial insemination. Progression of labor was monitored by frequent transrectal and transabdominal ultrasound examinations and staff observations. Induction was attempted over the course of two days before further attempts were abandoned based on the concerns for the cows' condition. Medical management of the cow afterwards consisted of regular monitoring of blood parameters and clinical signs, ultrasound exams, and long-term administration of antibiotics, anti-inflammatories, and topical therapy for vulvar edema. The elephant was relatively stable although her white blood cell count remained elevated compared to her previous values.

In May 2003, clinical signs, rectal palpation and ultrasonography confirmed that the cow was experiencing uterine contractions and had pushed the fetus up to the pelvic brim. Estradiol cypionate was administered to aid in cervical softening the cervix and mucus production. Contractions were unsuccessful in expelling the fetus overnight and the calf dropped back into the abdominal uterus. A similar set of events occurred in November 2003, except that the contractions resulted in the fetal feet protruding through the cervix and under the cow's tail, with the appearance of a "bulge." A vestibulotomy was performed under standing sedation to surgically remove the dead fetus. Post-surgical management of the incision has included a short course of antibiotics and anti-inflammatories, and a series of surgical debridements and attempts at closure. A small vestibular fistula remains one year post-operatively, although the elephant is clinically normal in all other aspects. This case report will review the overall medical and surgical management of the case.

INTRODUCTION

Reproductive management of captive elephants is often complicated by lack of access to bulls, ability to adequately time breeding in estrous cows, and reproductive problems such as urogenital pathology or endocrine anomalies (Agnew et al., 2004; Brown et al, 2004; Olson 2004). The advent of assisted reproductive techniques and improved understanding of reproductive physiology has lead to increased numbers of successful pregnancies. Since many captive elephants are older or may have other health issues by the time they are bred, the risk of gestational, parturient and post-partum problems may be increased (Hermes et al, 2004).

Methods traditionally used to manage complications of pregnancy and deliveries in other species are usually not feasible in elephants due to their large size and unique reproductive anatomy. Few reports have been published on successful techniques for addressing dystocia in elephants (Foerner 1999). Cesarean sections have been attempted but have uniformly resulted in the death of both dam and calf. Although some elephants have been able to retain fetuses for long periods, dystocia has also had fatal consequences in elephants (Schmitt, pers. comm.). This case describes one technique that can be considered when presented with a dystocia in an elephant.

CASE REPORT

A 34-year-old nulliparous African elephant cow was impregnated by artificial insemination. She had no significant medical history except the presence of vestibular polyps. Prior to and during her pregnancy, she was conditioned for routine blood collection, rectal and transabdominal ultrasound exams, mammary, vulvar and vestibular palpation, and handling/restraint in the elephant restraint device and on chains.

Pregnancy was monitored by serum hormones (progestogens, prolactin), ultrasonography, and behavioral observations, with increasing frequency during the last two months of gestation. Signs of early pre-parturition were first notice in March 2003; these included an increase in vulvar swelling, ventral edema, and intermittent discomfort. On April 2, 2003, she passed a mucus plug, and over the next three days showed intermittent discomfort. Ultrasound exams confirmed early signs of cervical dilation. Active signs of labor started early on April 6. A "bulge" appeared under her tail. Ultrasonography confirmed fetal feet at the pelvic brim. Although periodic contractions were observed, a lack of progression of the calf in the birth canal was seen on ultrasound exam. A decision was made to induce the cow with a combination of rectal massage and administration of oxytocin. Four doses were administered (30 IU IM, 30 IU IV, 50 IU IV, 60 IU IV) at 40-60 minute intervals. Brief periods of contractions were observed after each dose except the last one. Therefore, the decision was made to allow the cow to rest overnight.

The next morning the cow appeared alert and rested. She did not have any obvious contractions or signs of hard labor during the night. Ultrasonography showed the fetal feet in the cervix with a suspected posterior presentation. Estradiol cypionate (ECP), 30 mg IM, was given to promote cervical softening and up regulate the oxytocin receptors. The amniotic sac ruptured approximately four hours later and the "bulge" disappeared at this time. Oxytocin, 80 mg IV, administered five hours after ECP, resulted in strong contractions with some progress of the calf. A second dose of oxytocin (100 mg IV) was given an hour later when contractions had stopped. A follow-up ultrasound exam showed no further progress. The decision was made to allow the cow to retain the fetus since the dystocia appeared to be due to a large calf that was unable to pass through the dam's pelvis and the location of the fetus would make a fetotomy difficult.

Initial medical management of the elephant cow consisted of flunixin meglumine (Banamine) IM then orally, amikacin and ampicillin IV for the first week, then ceftiofur (Naxcel) IM for six weeks. Topical therapy for the vulvar swelling included hydrotherapy and application of Silvadene cream. Oral probiotics were prescribed to counteract the potential effects of the antibiotics on GI flora. Blood was taken daily to monitor the complete blood count as well as periodically assessing chemistry panel, fibrinogen, and protein electrophoresis. Urinalysis and cultures of vulvar discharge were also performed intermittently. Ultrasound exams were used to assess any changes in fetal position.

Uterine contractions were observed on May 12, 2003, approximate five weeks after dystocia. Ultrasonography showed the fetus pushed up to the pelvic brim. ECP (30 mg IM) was administered to soften the cervix to facilitate passage. Contractions stopped without fetal expulsion. No further significant developments occurred although an increase in the amount of fluid and tissue expelled started in August.

During the following months, the cow developed a leukocytosis (white blood cell count up to 32,000/ul) and hyperproteinemia with increased globulins (total protein as high as 8.4 g/dl with a globulin of 6.2 g/dl). Severe vulvar edema eventually ruptured and developed into an abscess that was treated topically.

On November 21, 2003, the elephant care staff reported observing a "bulge" under the cow's tail along with contractions. Ultrasonography confirmed the presence of fetal feet through the cervix.

Attempts to promote contractions included administration of 30 mg ECP IM, rectal massage and enema. No progress of the fetus was seen over the next four days, although a second dose of ECP was given. Due to concerns that the weight of the fetus could compromise vital structures in the pelvic canal, vestibulotomy with extraction was elected as the most viable treatment.

The cow was sedated with 60 mg butorphanol and 60 mg detomidine administered IM in a single syringe. Restraint with leg and abdominal straps in the elephant restraint device resulted in minimal movement during the procedure. Due to the length of the entire procedure, supplemental doses of butorphanol and detomidine were given at 1.5 hours (15 mg of each drug IM) and 2 hours (20 mg of each drug IM). Sedation was reversed with yohimbine (150 mg IV, 150 mg IM) and naltrexone (300 mg IV, 300 mg IM). Additional local analgesia was provided by a line block using 2% lidocaine injected ventral to the anus and along the incision line.

A vertical incision was made just below to the anus, over the fetal feet and extended ventrally for approximately 60 cm. Once the fetal feet were exposed, nylon webbing straps were placed around the fetal limbs. The surface was lubricated using petroleum gel and general liquid lube pumped by a stomach pump and tubing placed around the fetus. A block-and-tackle was attached to the nylon webbing straps so that the limbs could be independently manipulated in a downward direction. The fetus was extracted intact and weighed 135.5 kg.

Immediate post-operative care included flushing of the uterus with warm tap water and thorough palpation to assess trauma to soft tissue structures, administration of oxytocin, antibiotics, non-steroidal anti-inflammatories, hydrotherapy and topical treatment with silver sulfadiazine cream for the incision. Antibiotics and anti-inflammatories were continued for eight days. Complete blood counts, chemistry panels and fibrinogen were monitored on a regular basis until values returned to normal (approximately three weeks post-op).

Five attempts were made to surgically close the vestibulotomy incision. The first attempt was December 1, 2003 (six days post-vestibulotomy). The cow was sedated using the butorphanol-detomidine combination described above. After debriding the wound margins, the dorsal third of the incision was closed. Mucosa and submucosa was sutured using 0 PDS in inverting horizontal mattress patterns, and the skin was closed using umbilical tape and plastic stents in a simple interrupted pattern. Due to movement and tension on the suture line, the closure started to breakdown after 2-3 weeks. A second closure was attempted on January 8, 2004. This closure included only the mucosa. Unfortunately, the cow rubbed out the sutures three days after surgery. Additional surgeries were performed in February, May, and June 2004, using different surgical techniques and materials to close only the mucosal layer. Eventually, all wound closure techniques resulted in dehiscence. However, during this time, the wound continued to contract. At one-year post-vestibulotomy, there is an 8 cm long elliptical opening to the vestibule. The wound continues to contract and re-epithelialize. No complications or medical problems persist.

DISCUSSION

Management of dystocia in elephants is difficult due to their size and the limited success of techniques that can be used in other species. Recognition and treatment of dystocia may be complicated if the temperament of the elephant or facilities limit veterinary evaluation and intervention (Foerner 1999). Most elephants will deliver a calf within 3-4 hours after active contractions are seen, but labor may stop, especially if the cow is disturbed (Schmidt 1999).

The trend of aging in the captive elephant population may increase the likelihood of dystocia in those cows that are bred, especially for the first-time, as older animals (Lung et al, 2002). Lack of fitness, uterine and abdominal tone, the presence of intra-abdominal fat, fusing of pelvic symphysis, increased fetal size and number, and metabolic conditions (ex. hypocalcemia) are general risk factors for dystocia (Roberts, 1986). The incidence of dystocia increased in farmed red deer that had higher body condition scores (Audige et al., 2001). The large size of the fetus was believed to result in a mechanical obstruction in the elephant described in this case. Both age and over-nutrition were speculated to be possible contributing factors. Currently all pregnant elephant cows are managed to minimize weight gain during pregnancy.

The elephant in this report was conditioned for monitoring and examination by multiple methods that facilitated early recognition of dystocia and treatment. Ultrasonography was critical to assessing the position and progression of the fetus. In addition, medical and surgical intervention would not have been possible without prior training. Peri-parturient and post-partum medical problems are not uncommon in elephants; therefore, training and planning by elephant and veterinary staff is critical prior to the requirement for these procedures (Foerner, 1999; Lung et al, 2002; Murray 1996; Schaftenaar, 1996).

Vestibulotomy was used to extract the fetus once it was in the pelvic canal and could be reached. This surgical approach has been previously described for use in assisted reproduction techniques for insemination (Schmitt, pers. comm.), evaluation of the reproductive tract by endoscopy (Lung et al, 2002), and treatment of dystocia through attempted fetal reduction (Foerner, 1999) or removal of a dead fetus (Schaftenaar, 1996). Although applied both under general and standing anesthesia for dystocia, the only other successful cases (2 Asian cows) have been in Europe with standing sedation, similar to this report. In both of those, the calf was dead at the time of delivery. Similar to our elephant cow, attempts at surgical closure of the incision in one of the cows resulted in dehiscence and a small fistula (Schaftenaar, 1996).

CONCLUSIONS

1. Weight control in pregnant cows is important part of their management.
2. Conditioning for ultrasound and other medical procedures is critical prior to the potential need for these procedures.
3. ECP should be used in combination with oxytocin when induction is necessary.
4. Vestibulotomy should only be considered a viable procedure if the fetus can be easily reached.
5. Managing the surgical incision should include considering allowing healing by second intention; surgical closure is often hindered by movement and tension on the suture line.

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Abdominal surgery and enterotomy in a juvenile African elephant (*Loxodonta africana*)

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A 3-year-old, captive born, 932 kg, female African elephant (*Loxodonta africana*) was examined for weight loss, partial anorexia, and depression. The condition of the patient deteriorated rapidly and the regurgitation of stomach contents, accompanied by the absence of gut sounds in all quadrants and the detection of gas distended bowels during rectal palpation, elevated concerns of a gastrointestinal impaction. The elephant was immobilized with etorphine hydrochloride and maintained with isoflurane in oxygen. A sand impaction was discovered in the area of the pelvic flexure of the large colon (ascending colon) and the pelvic flexure was displaced cranially. An enterotomy was performed to relieve the impaction. The abdominal and enterotomy incisions healed without complication but the elephant died 14 days after the surgery of a multi-organ inflammatory disease process suggestive of an *E. coli* septicemia. The relationship between the septicemia and intestinal impaction are not known.

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Atipamezole as a reversal agent to medetomidine-ketamine anesthesia in Asian elephants (*Elephas maximus*)

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Ten elephants were anaesthetized by injecting medetomidine @ 5µm/kg and ketamine 150 mg/elephant. Both the drugs were drawn into a syringe mixed and injected intramuscularly. The elephants started snoring at 15.6±0.5 minutes of injection and depth of sedation was attained at 28.2±0.35 minutes, which was ascertained by protusion of penis, widening of legs, cessation of movements of ear and tail, slight dropping of head with ataxia. During sedation operation ferragall, tail amputation, removal of bullets etc. were performed. The elephant exhibited complete analgesia. After completion of operations atipamezole were injected intravenously into the ear vein. Five elephants group I received atipamezole @5µ/kg and the remaining five elephants received atipamezole @10µm/kg. in group I, the elephant reversed within 4.2±0.15 minutes and started walking and taking food. However, a second phase of drwsiness was exhibited by the elephants at 43.4±0.68 minutes of reversal. The elephants tried to stand by keeping their weight on nearby trees and again showed reluctancy in feeding as well as in movement. In the second group, the sedation reversed at 3.7±0.13 minutes like the first group, but drowsiness were not at all recorded. The elephants of these group started feeding after 5.0±0.11 and continuing this effect. All the operations were performed successfully. From this clinical trial it may be suggested that atipamezole at the double dose of medetomidine could reverse the elephants completely.

INTRODUCTION

Sedation and good analgesia is very much essential in veterinary practices with special reference to wild animal treatment. Following completion of the clinical procedure, a quick recovery of the wild animals are essential from the point of safety. Otherwise the wild animal may die because of the anaesthesia or they may be killed other wildlife or by poachers.

Medetomidine, a α_2- adrenoceptor against has been evaluated alone as a sedative in elephants (Sarma *et al.,* 2002) and produce its combination with ketamine to produce balance anaesthesia. It reduces dose dependant depression of CNS, so that during maximal effect the animal is relaxed and do not react the external stimuli (Stenberg and others, 1987). Medetomidine has been proved as a very much potent sedative in elephant and its dose has been standardized as 5µg/kg body weight in Asian elephant. Such a potent sedative is essential to carry out surgical operation in elephant viz. amputation of tail, removal of bullets following injury, excision of ferragall, suturing of ruptured cornea and also for antidepredation activities by the officials.

Atipamezole is a potent, selective and specific α_2 – adrenoceptor antagonist. It was synthesized to find a potential medetomidine antagonist for use in veterinary practice. Recently it has found to produce an efficacious and quick reversal of medetomidine induced sedation, analgesia and bradycardia in laboratory animals (Vaha-Vahe, 1990) and in wild or zoo animal (Jalanka, 1989 a). But perusal of the available literature revealed not a single record of its use as reversal in elephants throughout the globe. Therefore, this study was conducted to find out the ability of atipamezole as a reversal of medetomidine in the clinical cases of Asian elephants.

MATERIALS AND METHODS

This study was conducted in different National Park in Assam as well as in some domesticated elephants of private owners. Ten elephants of either sex, weighing 3000-4000 kg were taken to carry out the research work. All of the elephant received injection of medetomidine and ketamine. Medetomidine @ 5µg /kg and ketamine 150 mg per elephant were drawn into a syringe, mixed and injected intramuscularly into the gluteal muscle. Following injection, induction time and depth of sedation were observed , depth of sedation was first ascertained by starting of snoring sound at 15.0±0.3 min. of anaesthetic injection and maximum depth of sedation was recorded as 28.2±0.35. The most prominent signs of sedation exhibited by protusion of penis, widening of legs, cessation of ear and tail movements, slight drooping of head with occasional ataxia.

At this stage of sedation first five elephants were reversed by intravenous injection of atipamezole @5µg/kg body weight. They were considered as groupI, the remaining five elephants were considered as group II and received i/v injection of atipamezole @10 µg/kg body weight. Pulse and respiration were recorded before (0 min.) anaesthesia, at maximum depth of sedation (28.2±0.35) min.) and after atipamezole injection. Pulse was recorded as beat/min. by palpation of ear artery, respiration/min. was recorded by putting hand in the opening of trunk. Data were analysed statistically by using the ANOVA method (Snedecor and Cochram, 1967).

RESULTS

The elephants were induced with medetomidine at 4.5±0.5 min. of injection. Muscular relaxation was evidenced by loud snoring sound audible from distance at 15.6±0.3 min. and maximum sedation was attained at 28.2±0.35 min. At this stage protusion of penis, drooping of ear with ataxia were evident. Bradycardia was recorded by reduction of pulse, from 38.00±0.00 to 19.2±0.16 beat/min. Respiratory depression was evident by reduction of respiration from 15.8±0.16 to 7.4±0.17. Following atipamezole injection 5µg /kg body weight, the elephants of first group exhibited disappearance of signs of sedation i.e. profuse urination, withdrawal of penis into the sheath, disappearance of snoring sound, resumption of normal movements. All these activities were started at 4.2±0.15 min. of atipamezole injection. The elephants started walking and even taking food. However, a second phase of drowsiness was exhibited by the elephants of group I at 43.8±0.68 min. of reversal injection. At this stage the elephants were reluctant to move. Some of them were dispersing their body weight by resting their bodies against nearly trees. Pulse rate increased to 31.6±0.22 beat/min., disappearing bradycardia, respiration returned to 13.2±0.16 per minute.

In the second group, following injection of atipamezole 10µg/ kg body weight, all signs of sedation were disappeared at 3.7±0.73 minutes. Pulse returned from 18.2±0.26 to 34.2±0.21 and respiration from 7.0±10.14 to 14.6±0.22. The elephants started walking and taking food after 5.0±0.11 minute of reversal injection. Drowsiness was not recorded in any elephants of this group.

DISCUSSION

Atipamezole, a novel α_{2-} antagonist has been successfully used in Asian elephants to reverse the sedative action of a very potent α_{2-} agonist medetomidine. All the signs of sedation disappeared quickly after atipamezole injection and exhibited calm recovery of all elephants. Increase in heart rate within two minutes of intramuscular injection of atipamezole recorded in this study well corroborated with the findings Jalanka (1991), when he used the same drug in blue foxes and snow leopards. In wild carnivores and small ruminants atipamezole has been shown to reverse medetomidine-ketamine immobilazation effectively (Jalanka, 1989a). However, in domesticated animal some dogs exhibited relapse into sedation. Vahe-Vahe (1990) had reported about the development of drowsiness in beagles after 0.5-1 hour of atipamezole reversal. Similar findings also recorded in this study of reversal with atipamezole reversal with atipamezole in medetomidine-ketamine sedated elephants, where atipamezole was used in the same dose of medetomidine. Medetomidine released from the trapped organs of tissues might be the reason of second phase of drowsiness in elephants reversed with equal dose of atipamezole. Similar observations were made by Jalanka (1991) in reindeer. Profuse urination just after injection of reversal indicated neutralization of anaesthetic effect.

However in the second group of elephants, where atipamezole was used double the dose of medetomidine, was able to reversed the elephanst quickly and no relapse or drowsiness was recorded. The elephants started walking and feeding following reversal. Jalanka (1989) had reported that sedation, analgesic and cardiovascular effect of medetomidine were reversed by atipamezole in snow leopards. This confirms the findings of present study where bradycardia and decreased respiration was returned to normal after atipamezole.

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Laparoscopic surgery in elephants

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Large animals, such as elephants, pose a significant diagnostic challenge to wildlife health professionals involved with their care and management. Their immense size and anatomy make routine medical testing difficult or impossible. Diagnostic imaging techniques such as radiography, ultrasonography, computerized axial tomography (CT scan) and magnetic resonance imaging (MRI) have very limited use in this species. A large number of infectious and non-infectious medical conditions (e.g., herpes virus, tuberculosis, salmonella, uterine cancer, dystocia, peritonitis, renal disease, etc.) have been reported in free ranging and captive elephants. A testing procedure allowing organs to be visualized and sampled would be a tremendous benefit for diagnosis and treatment of these conditions. Recent advances in medical technology make laparoscopic surgery a viable option for improved disease diagnosis and treatment of elephants. Specific equipment for elephants has been developed, such as a durable, 90 cm long fiber optic laparoscope with an operating channel in which a variety of surgical instruments can be placed. With this laparoscope, a single hole can be placed through the abdominal wall, allowing visualization and sampling of the liver, spleen, kidney, ovary uterus, testes, and intestines. Laparoscopic surgery has been successfully performed in captive elephants and used to diagnose a case of uterine rupture and peritonitis. Efforts are currently underway to utilize laparoscopy in the reproductive sterilization of free ranging African elephants in South Africa. With the advent of this new technology, it is anticipated that a variety of novel medical and surgical uses in elephants will be forthcoming.

INTRODUCTION

Laparoscopic surgery allows medical professionals the ability to directly see, manipulate and sample various internal organs. Due to their size and unique anatomy, abdominal surgery in elephants had previously been considered very risky and rarely undertaken. New medical technology in laparoscopic instruments has made this type of surgery realistic, even in elephants. There are a wide variety of potential applications of laparoscopy for both captive and free ranging elephants. Laparoscopy can be used to aid in the diagnosis and treatment of many different medical conditions. It is also very useful in reproductive procedures and research studies. With the development of large animal laparoscopic equipment, it is anticipated that a wide variety of new uses for laparoscopic surgery will be forthcoming.

In human medicine it has been demonstrated that when comparing traditional surgery to laparoscopic, the benefits of laparoscopy include: less post-operative pain, faster recovery times and often an improved prognosis. Unlike other medical imaging technologies (radiographs, CT scan, MRI, etc.), laparoscopy allows direct visualization of the organs, tissue sample collection and organ manipulation.

Over the last three years an international group of collaborators has been working to develop elephant laparoscopic equipment and surgical techniques. Through partnerships with North American elephant facilities, this group has been involved with post-mortem elephant examinations on ten animals. Laparoscopic instruments have been evaluated and modified for elephants. In addition, anatomical landmarks have been identified to assist in laparoscopic surgery associated with certain organs. For example, it was determined that a high flank incision, just behind the last rib, is the ideal location for surgeries associated with the reproductive tract. In addition to identifying surgical landmarks for various organ systems, measurements and equipment design drawings were conducted to create an elephant laparoscope and associated instruments. Because of the elephant's immense size, instruments were created which are much longer than what had previously been available. The equipment also needed to be thicker and sturdier than what is commonly used with humans or domestic animals. Currently, there are three different laparoscopic telescopes that have been used with elephants. The first is a commercially available equine laparoscope (57 cm length), which has been successfully used in several reproductive surgeries in female elephants. Its relatively short length limits its use to immature animals or organ systems close to the skin surface. There is a similar, but much longer laparoscope (110 cm) that has been used in elephants. This laparoscope provides the length to reach many abdominal organs, but is relatively fragile and can be easily damaged. The most recently developed laparoscope is a 90 cm operating laparoscope, with enhanced fiber optic light abilities and a reinforced frame. This laparoscope allows improved light transmission, sturdy handling, and an instrument operating channel for easy tissue manipulation and sample collection (Karl Storz Veterinary Endoscopy).

In addition to the development of the laparoscope, advances in technology now provide a small battery powered operating system with a monitor, light source, recording device and camera, all in one unit (Figure 1).

Over the last two years, laparoscopy has just started to be used in captive and free ranging elephants. Laparoscopic surgery was performed on a captive female elephant to diagnose a ruptured uterus and severe peritonitis. Dystocia and post parturient medical disorders are fairly common in captive elephants and laparoscopy can be an important tool in the diagnosis and treatment of reproductive disorders.

In free ranging animals, laparoscopy has been used and is currently being evaluated as a tool to sterilize free ranging female African elephants. In July 2004, hand-assisted laparoscopic ovarian ligation procedures were performed in a South African game reserve. The laparoscope was used to assist in the placement of stainless steel surgical wire ligatures around the ovarian pedicles. These ligatures were used to completely ligate the ovarian vasculature and render the ovary inactive. Studies are continuing with these animals to monitor their post-operative healing and any potential behavioral or social changes. To date, these elephants have completely healed from their surgical procedure and observationally appear to demonstrate no abnormal social, or behavioral ill effects from the procedure.

Our goals have been to improve elephant health by capabilities expanding the diagnostic and treatment options that are available to these animals. We are also interested in assisting international conservation efforts by providing wildlife health professionals with additional tools they might find useful in managing elephant populations and conserving precious ecosystems.

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Figure 1. Portable elephant laparoscopic equipment consisting of (A) battery powered unit (light source, monitor, recording device), (B) camera and (C) elephant laparoscope.

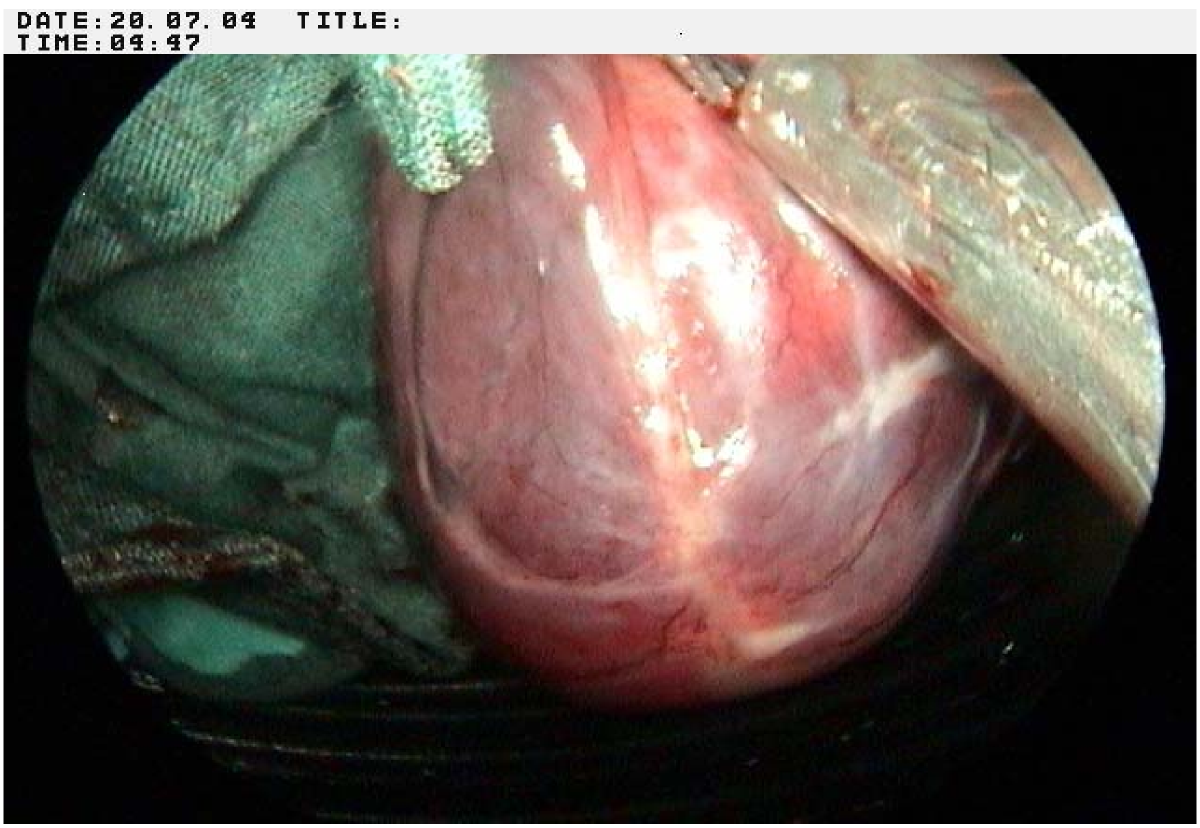

Figure 2. Laparoscopic image of an African elephant's ovary.

Figure 3. Female elephant undergoing a hand-assisted laparoscopic reproductive sterilization in South Africa.

Treatment of a premature Asian elephant calf

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Intensive treatment of a 16-month gestation female Asian elephant (*Elephas maximus*) was attempted following premature delivery most likely secondary to placentitis. Prior to the premature delivery of the calf the progesterone concentrations had decreased but had returned to normal values. The birth was unexpected but observed and the calf was delivered enclosed within the fetal membranes approximately 20 minutes after observation of a fetal bulge below the dam's anus. Immediate resuscitation included administration of oxygen. The calf remained weak, poorly oxygenated and hypoglycemic. More intensive medical management was undertaken and included placement of intravenous catheters, by percutaneous and cut-down techniques, for administration of dextrose, crystalloid fluids, plasma harvested from the dam, antimicrobials and vasopressors. The calf was stabilized with improvement in blood pressure, glucose control and ventilation parameters; however, the calf continued to demonstrate neurologic abnormalities and had evidence of sepsis on hematology. All mucous membranes were icteric and there was evidence of hemolysis resulting in anemia. Because of clinical deterioration, the difficulty in maintaining intravenous access and the immaturity of all cuboidal bones, based on radiographs of the hock and carpus, the decision was made to humanely euthanize the calf. Necropsy findings included evidence of early necrotizing enterocolitis, likely associated with birth asphyxia, and significant bony immaturity. Blood cultures were negative as were test for herpes virus. Histologic evaluation of the placenta revealed necrosis and infiltration of inflammatory cells.

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REPRODUCTION

Pregnancy monitoring and parturition prediction through hormonal analysis via urine assay in a captive African elephant (*Loxodonta africana*)

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In August of 2003 the San Diego Wild Animal Park (WAP) and the Lowry Park Zoo, under the auspices of the American Zoo and Aquarium Association's African Elephant Species Survival Program and a United States Fish and Wildlife Service permit, imported 3.8 African elephants from the small southern African country of Swaziland. The animals were scheduled for culling due to overpopulation, habitat destruction and their threat to critically endangered species such as black rhino, *Diceros bicornis minor* (IUCN 2003). Preparations for the historic transport lasted nearly two years. On August 22nd, 2003 four (2.2) of the elephants were delivered to The Lowry Park Zoo in Tampa, Florida. On the next day, August 23rd, the remaining 7 (1.6) elephants were delivered to the WAP.

At the time of their arrival all animals were estimated to be approximately 13 years old. All cows were determined to be nulliparous and one, later named Ndlulamitsi, was determined to be approximately 10 months pregnant based on trans-rectal ultrasound examinations performed during capture in Swaziland (Hildebrandt, pers. comm., 2003). Based on the ultrasound examination results and average African elephant gestation parturition was predicted to be February 20, 2003. More information was needed to follow the pregnancy and help predict parturition as it neared. In captive settings elephant managers often rely on blood serum assays to follow hormonal changes, even if they know the date of conception to more reliably predict parturition. Because the Swazi elephants were completely untrained we needed to develop a method to monitor fetal viability and predict parturition without the use of regular blood sampling.

We developed a strategy of monitoring weight gain relative to other pregnancies, conducting ethograms, trans-abdominal ultrasound examinations and the topic of this report, hormonal analysis solely through urine assay. We tested for Progestins, estrogens and corticoids in urine collected on frequent basis, typically daily. The urine was collected off the ground after the elephant urinated on either concrete or an epoxy based flooring. We compared our data to that of a urine set from an African elephant at Riddles' Elephant and Wildlife Sanctuary where urine was collected every day for the 6 days prior to parturition. We did not see in our samples the exact pattern of the Riddles' urine but in retrospect we did see a three-day marker. We were able to monitor the maintenance of pregnancy and the decline of progestins as parturition neared. With the presentation of this information we may encourage others to pursue similar urine studies thereby improving our collective abilities to monitor pregnancies and predict near term parturition through this less invasive, safer and often the only means of sample collection for hormone assay.

INTRODUCTION

African and Asian elephants (*Loxodonta africana and Elephas maximus*) have the longest gestation period among land animals, yet calves are born when relatively small, i.e., only about 3.5% to 4% of maternal mass (Benedict 1936; Moss 1988; Spinage 1994). Birth is not a prolonged process, and has taken less than twelve minutes when timed (Moss 1988). Although weighing about 100 kg at birth (Eltringham, et al, 1997; Shoshani, et al, 1992), the relatively diminutive size of calves compared to cows hampers recognition of pregnancy in cows by human observation. Some cows develop enlarged breasts during late gestation and some cows appear lethargic prior to parturition (Moss 1988). In the wild, some cows seem to isolate themselves from the herd prior to giving birth (Moss 1988), but, in general, the behavior of pre-parturient cows is not distinct from non-pregnant cows (Spinage 1994). Given that elephants in the wild ingest about 170 kg of food per day, live in herds of about one dozen animals, move together between food sources, and sleep for less than five hours per 24 hours (Estes 1991), one might expect that cows should minimize changes to their time activity budgets prior to parturition. Given all of these factors the reliable prediction of parturition is difficult based solely on conception dates and near term behavior. Animal care professionals working with captive elephants have greatly enhanced our ability to predict the onset of labor. Generally, this is accomplished utilizing a blood serum assay for progesterones and cortocoids. Through the collection of blood samples on an increasingly frequent basis (i.e., monthly, twice-monthly, weekly, twice weekly, daily, twice-daily) the hormonal level's fall to base line can analyzed and compared to the values observed in prior elephant pregnancies.

The San Diego Zoo's Wild Animal Park imported a group (1.6) of African elephants from Swaziland in August 2003. Before arrival and habituation to the facilities, one of the cows was determined to be pregnant, so we initiated a program to predict parturition through hormonal analysis and to monitor fetal development. The elephants had arrived in San Diego completely untrained and by the time of this study the behavior of voluntary blood draws had not even begun to be conditioned. We decided to attempt to follow the hormonal changes of Ndlulamitsi's pregnancy and predict parturition solely through the use of urine assays. Because urine has been used for many years to monitor the endocrinologic cycles of African and Asian elephants we believed that this was worthwhile study, and in this case we had no other option if we wanted a warning about a pending birth. In this report, we provide data about the pattern of progestins as parturition neared, how it compared to other data sets and finally appeal to the community to continue this work in order to provide another tool in our "tool box."

METHODS

Study Site and Subjects

The San Diego Zoo's Wild Animal Park (Escondido, CA) under the auspices of the American Zoo and Aquarium Association's African Elephant Species Survival Program and a United States Fish and Wildlife Service permit, imported 7 African elephants from the Kingdom of Swaziland. The animals were scheduled for culling due to overpopulation, habitat destruction and their threat to critically endangered species such as black rhino, *Diceros bicornis minor*, in the reserves. All cows were nulliparous and estimated to be 12 to 13 years old. Trans-rectal ultrasound examinations performed during capture in Swaziland revealed that one female, Ndlulamitsi, was approximately 10 months pregnant (Hildebrandt, pers. comm.).

Elephants were housed in a ~1.3 hectares outdoor enclosure containing trees, rocks, shade structures, grass, dirt, watering areas, and two indoor areas containing multiple stalls. Due to effective training using positive reinforcement any elephant, including Ndlulamitsi, could easily be shifted anywhere in the facility or separated from the herd at any time to allow for the daily collection of urine. During the study period, adult elephants were fed legume grass (*Pennisetum purporem*), Bermuda grass

(*Cynodon dactylon*), Sudan grass (*Sorghum vulgare*), alfalfa (*Medicago sativa*), various species of browse, and herbivore supplement pellet.

OBSERVATIONS AND DATA COLLECTION

To collect urine from Ndlulamitsi we would shift her every morning from her overnight yard and/or adjacent barn to a clean area where the substrate was either concrete or an epoxy coated floor. This urine was collected in a clean syringe and then frozen and stored for the assay to be run later. This process began in October of 2003, over four months prior to our predicted date of parturition. Initially the urine was assayed every few weeks and we increased the frequency of urine analysis to weekly, twice weekly, every other day and ultimately every day as parturition neared. To better understand the values that we were observing we researched published literature and requested near term urine samples from other African elephant holding facilities.

RESULTS

Our literature search turned up very little information on the prediction of parturition in African elephants using urine for hormonal assay. However, one report (Fieb M. 1999) showed that a urine assay did show a progesterone drop to baseline prior to birth just as a serum assay would (Figure 1). Fieb's study demonstrated that hormonal urinalysis could document the fall but two things were still missing for our purposes; we needed to track the progesterone cycle in real time to predict parturition (as opposed to documenting the fall post-partum) and we needed to validate a different assay. To validate our assay we acquired a preparturitional urine set from an African elephant at Six Flags Marine World. These samples were used to ensure that our assay could accurately monitor progestins as they rose from non-luteal to luteal levels (Figure 2). During these months we continued to collect daily urines from Ndlulamitsi and analyzed them every two or three weeks for at this time we were still many months from birth. We then obtained a small but important set of preparturitional urines from Riddle's Elephant Sanctuary. This set of samples from an African elephant was collected on the day of parturition and on each of the preceding five days. By analyzing these we could evaluate this crucial period of time and try to identify any marker indicating a pending birth. We again used our same assay and found that never in the last six days were progestin levels above 20 ng/mgCr (Figure 3). Based on this information, and being conservative in order to be safe, we decided that we would use any sustained drop in progesterones below 100 ppm's to alert the staff of a pending birth and to initiate the organization's Birthing Protocols. A 24 hour night watch had already begun to collect peri-parturitional activity budgets and could double as birth watch if necessary. Our results showed a rapid drop in progestins in the seven days prior to parturition from 259.26 ppm to 30.66 ppm in only four days without any leveling off period. Two days later, being the day prior to parturition, progesterone was still in the same range as birth –3 days; 30.11 ppm (Figure 4).

DISCUSSION

Although we did not see entirely similar levels of progesterone in the cow from Riddle's and Ndlulamitsi (Figure 5); we did observe two interesting trends. We noticed that the pattern of each animal's progestin fall to baseline was very similar when graphed using independent y-axis values (Figure 6) and that the absolute values were very similar for both animals in the three days prior to parturition. We observed a leveling off for the three days prior to Ndlulamitsi's progesterone fall to baseline and subsequent parturition (30.66 ppm at birth -3 and 30.11 ppm at birth -1 days) which compared favorably to a progesterone leveling off observed in Felix (10.6 ppm at birth -4 days, 10.6 birth -2 days and 08.6 ppm at birth -1 day) (Figure 5). This information will help us to better understand the urine assay values we observe during our next African elephant pregnancy and therefore be better prepared to ensure the health of the cow and calf. What we need is more information. If you are interested in helping with this study it we would welcome collaboration or if it is preferable you could perhaps simply send us urine preparturitional urine samples. Although this data may never entirely replace the need for the collection of blood samples for serum analysis, it can be an important tool not only for captive situations where collecting daily blood samples may be difficult but also for in-situ research if viable samples can be collected off the ground in the wild.

CONCLUSIONS

1. Our urine assay was able to monitor progestin as it rose to luteal levels and then fell to baseline during the prepartutional period of an African elephant.
2. Prediction of parturition is African elephants should be possible as more data is collected and statistical timelines are established.

ACKNOWLEDGEMENTS

Our thanks to Six Flags Marine World for providing urine from a preparturitional African elephant for our assay validation and to Heidi Riddle for the use of urine from a preparturitional elephant for the purpose of comparison and benchmarking. This study would not have been possible without the dedication and commitment of San Diego Wild Animal Park keepers Todd Ashker, Jason Chadwell, Keith Crew, Brian Grecko, Jim Hart, Steve Hebert, Larry Sammarco, Rick Sanchez, Traci Terrible, Bill Twardy, John Walko, Jessica Anderson, Josie Fox, Nancy Graham, and Mindy Paulsen. We would like to thank Larry Killmar and Randy Rieches for their support and encouragement.

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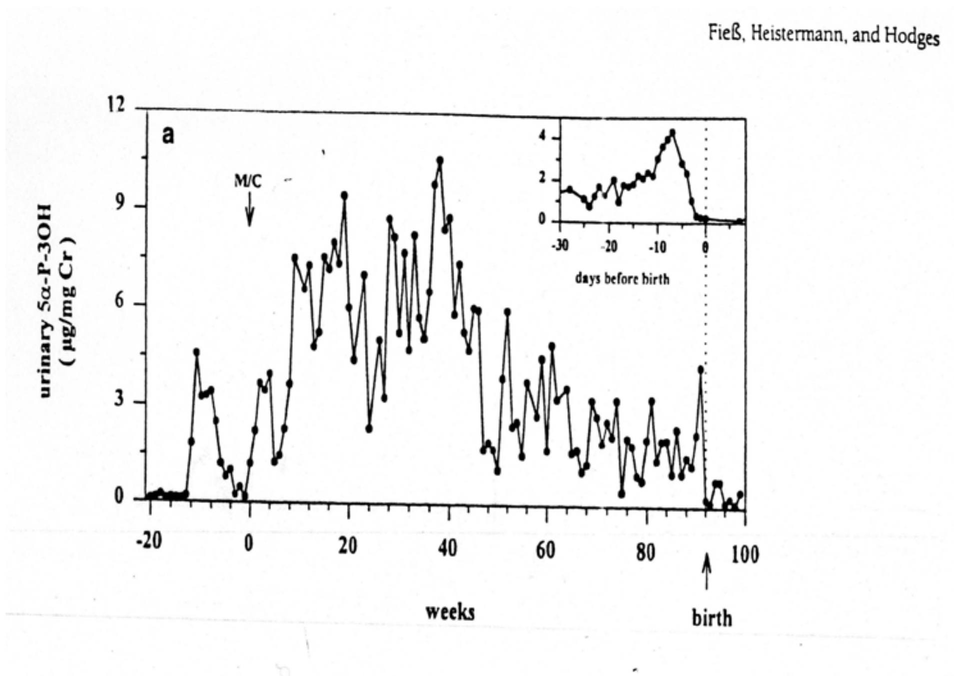

Figure 1. Preparturitional urinary hormone pattern as described by Fieb M. 1999

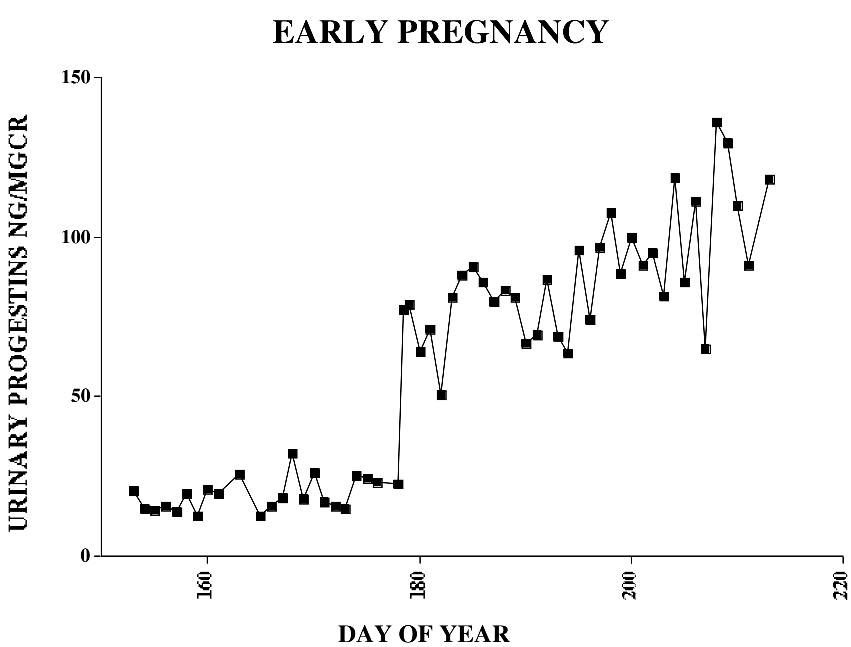

Figure 2. Results of our assay using urine from a preparturitional Six Flags Marine World cow.

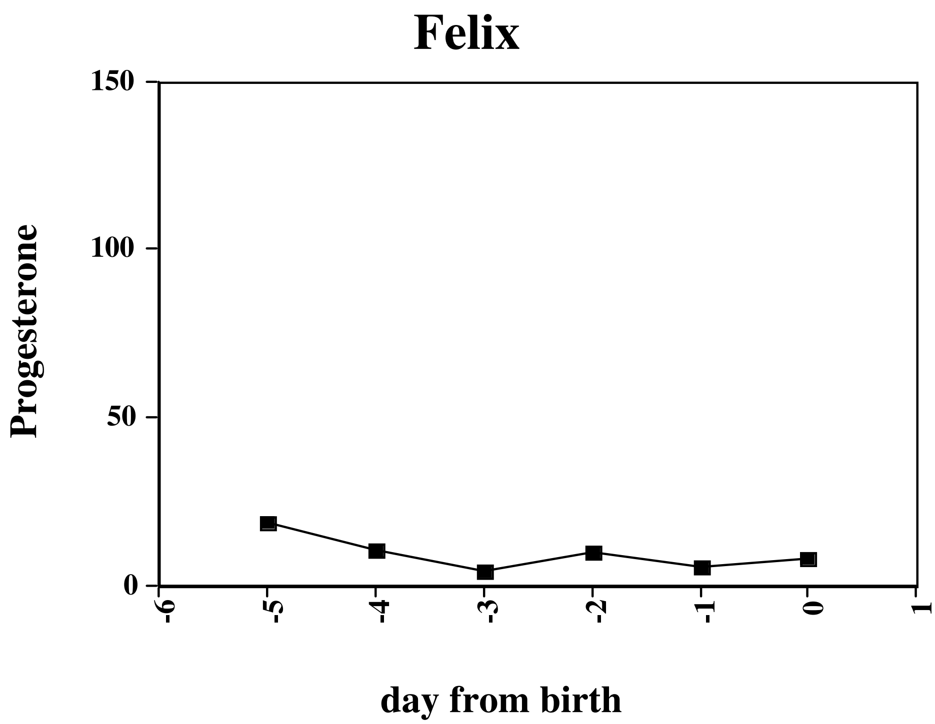

Figure 3. Results of our assay using urine from a Riddle's Elephant Sanctuary cow in the six days prior to parturition.

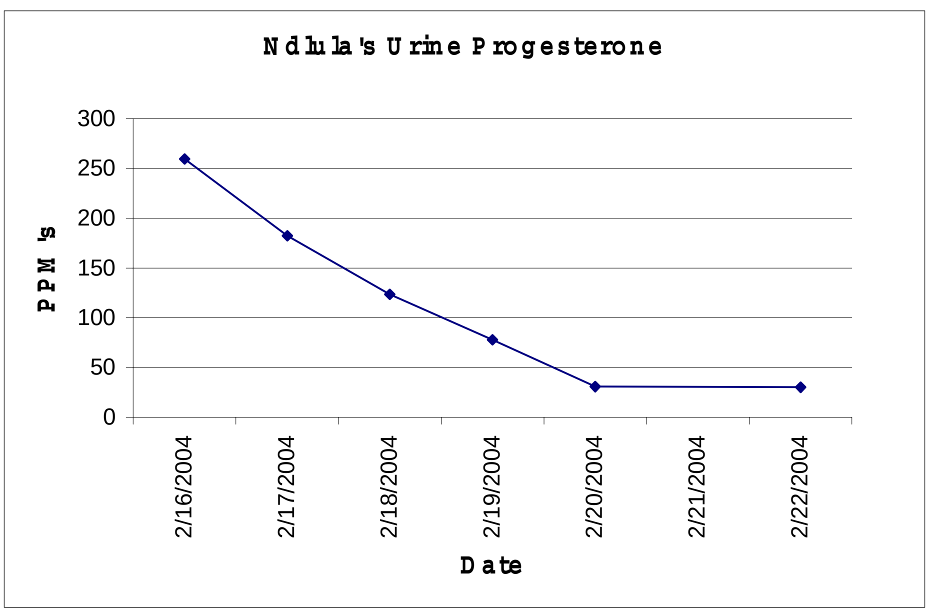

Figure 4. Ndlulamitsi's fall to baseline in the seven days prior to parturition.

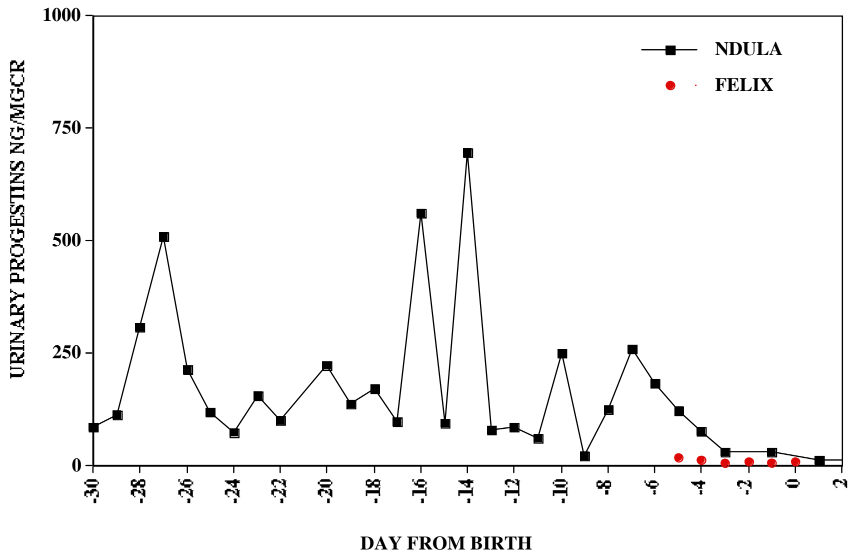

Figure 5. Comparison of the fall to baseline in WAP cow Ndlulamitsi and Riddle cow Felix; using the same progesterone values.

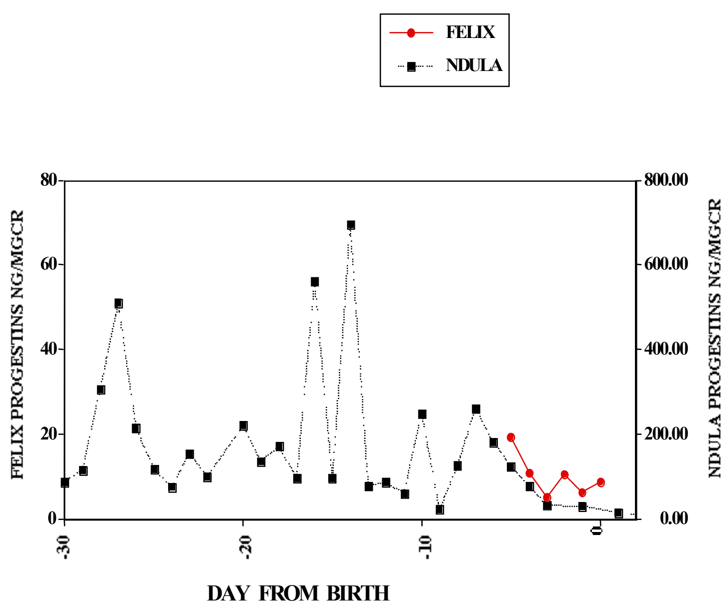

Figure 6. Comparison of the fall to baseline in WAP cow Ndlulamitsi and Riddle cow Felix; using different progesterone values to highlight the pattern of the fall.

Treatment of anestrus due to hyperprolactinemia with cabergoline in captive Asian elephants (*Elephas maximus*)

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An Asian elephant at Busch Gardens in Florida was diagnosed with hyperprolactinemia by the CRC laboratory in January 1996. She also had a number of other problems, including uterine disorders that resulted in consistently elevated progesterone. In March 2002, she was given cabergoline orally at a dose of 1 mg every three days for 6 months. Cabergoline was purchased from a local pharmacy. Serum prolactin concentrations declined almost immediately after treatment, followed about one month later by a drop in progesterone to baseline. Progesterone secretion remained low until November 2002 when she resumed cycling based on the observation of a normal luteal phase. From November 2002 through January 2004 she exhibited four normal estrous cycles. Prolactin secretion also has remained within the normal range for elephants, over one year after treatment withdrawal. This female suffered no adverse effects due to the cabergoline treatment. There were no behavioral changes noted or changes in appetite. Given the need to increase reproductive rates of African elephants to prevent captive extinction, it might be efficacious to treat genetically valuable females with cabergoline in the hope it will reinitiate reproductive cyclicity. Again, we have found that nearly 1/3 of African elephants with hormone data are not cycling normally, and 1/3 of these (11 of 30) have high prolactin. A clinical trial is now underway to evaluate the efficacy of cabergoline in 6 hyperprolactinemic elephants in North America.

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Update on the reproductive status of female Asian and African elephants in North America

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Asian and African elephant populations in North America are not self-sustaining and reproductive rates are low. One problem is that some elephant females do not exhibit normal ovarian cycles. To better understand the extent of this problem, a survey was conducted to characterize the reproductive status of the captive population. Survey response rate for facilities with Asian and African elephants was 81% and 71% for the studbook populations, respectively, and nearly 100% for the SSP facilities. Of those surveyed, 49% of Asian and 62% of African elephant females were monitored for ovarian cyclicity via serum or urinary progestagen analyses on a weekly basis. Of those, 14% of Asian and 29% of African elephants either were not cycling at all or exhibited irregular cycles. For both species, ovarian inactivity was more prevalent in the older age categories (>30 years of age); however, for African elephants acyclicity was found in all age groups. To determine if ovarian acyclicity is related to other disruptions in endocrine activity, serum pituitary, thyroid, adrenal and ovarian hormones in weekly samples collected for 6-25 months were compared between normal cycling (n=22 each species) and noncycling (n=6 Asian; n=30 African) elephants. A subset of cycling females (n=4 Asian, 7 African) also were blood sampled daily during the follicular phase to characterize hormone patterns associated with the 'double LH surge'. Serum FSH concentrations were highest at the beginning of the non-luteal phase, declining to nadir concentrations within 4 days of the second, ovulatory LH surge. FSH remained low until after the ovLH surge and then increased during the luteal phase. A species difference was noted in prolactin secretion. In the African elephant, prolactin was increased during the follicular phase, but in Asian elephants concentrations remained stable throughout the cycle. Patterns of thyroid hormone (thyroid stimulating hormone, TSH; free and total thyroxine, T4; free and total triiodothyronine, T3) and cortisol secretion were not affected by estrous cycle stage or season in cycling elephants. In noncycling elephants, overall mean concentrations of all hormones were similar to baseline concentrations in cycling animals, with the exception of FSH and prolactin. Mean serum FSH concentrations were lower due to females not exhibiting normal cyclic increases. Prolactin concentrations were increased in 11 of 30 noncycling females, 10 of which were African elephants. The one Asian elephant with hyperprolactinemia was treated orally with the dopamine agonist, cabergoline, at a dose of 1 mg every three days for 6 months. Serum prolactin concentrations declined within days of treatment initiation and 8 months later she resumed cycling based on the observation of normal luteal phases. In summary, survey results suggest that ovarian inactivity is a significant reproductive problem for elephants held in zoos, especially African elephants. There were no consistent endocrine anomalies associated with ovarian acyclicity, with the exception of hyerprolactinemia. This problem, which is a common cause of infertility in women, appears to be treatable in elephants using an established drug regimen.

INTRODUCTION

Despite the well-recognized need to establish self-sustaining populations of captive elephants (Olson and Wiese, 2000; Wiese, 2000), less than 20% of Asian and 10% of African elephants of reproductive age have produced offspring (Asian Elephant Studbook, 2002; African Elephant Studbook, 2001). The logistics and expense of transporting females to breeding facilities have hampered captive breeding efforts, but there also are reproductive problems of physiological origin. Through basic progestin monitoring encouraged by the Elephant Taxon Advisory Group/Species Survival Plan, many female elephants of reproductive age have been identified as ‘flatliners’, a term given to describe the observation of stable, baseline concentrations of serum progestins indicative of ovarian inactivity (Brown, 2000). Based on a recent survey, up to 14% of Asian and 29% of African elephants in North America are not cycling normally (Brown et al., 2004a).

There are many possible causes for ovarian inactivity, including reproductive tract pathologies (hereditary or idiopathic) and neoplasias, hormone receptor dysfunction, metabolic or nutritional deficiencies, stress, and hypothalamic-pituitary disruptions (Knobil and Neill, 1998). The probability that the etiology of acyclicity is the same for all females is unlikely, however, there may be common symptoms that can be identified. Given the complexity of the endocrine control of reproduction, it is possible that ovarian acyclicity could be related to a hormonal imbalance. Thus, analyses were conducted to determine if there are differences in hormone secretory patterns related to pituitary function (luteinizing hormone, LH; follicle-stimulating hormone, FSH; thyroid stimulating hormone, TSH; prolactin), thyroid function (free and total thyroxine, T4; free and total triiodothyronine, T3) and adrenal status (cortisol as an indicator of stress) between normal cycling and noncycling Asian and African elephants (Brown et al., 2004b). One finding of that study was that about a third of acyclic elephants exhibited continuously elevated prolactin, a condition known as hyperprolactinemia. This is a common cause of infertility in women, and now appears to be associated with reproductive problems in captive elephants.

Efforts at the Conservation and Research Center (CRC) Endocrine Research Laboratory are directed towards monitoring reproductive activity and understanding the causes of ‘flatlining’ in female elephants in North American zoos. Treating reproductive problems, including that associated with hyperprolactinemia, is a major objective of our laboratory. Through cooperative efforts of zoos and researchers, we hope to gain a better understanding of this condition so that effective treatments can be developed to allow captive breeding programs to succeed.

METHODS

Reproductive Survey

In 2001-2002, a reproductive survey prepared by the Elephant TAG/SSP was sent to all facilities in the Asian and African Elephant North American Regional Studbooks. Survey questions related to this study were: 1) management system (free contact, protected contact, other); 2) collection of samples for reproductive monitoring (blood, urine, none); 3) if yes to #3, sample collection frequency (weekly, bi-weekly, monthly, in training, collected but not analyzed); 4) estrous cyclicity status (cycling, not cycling, irregular cycles, undetermined); and 5) transrectal ultrasound results (normal, ovarian cysts, uterine cysts/tumors, vaginal cysts, other pathologies, in training, not done). Because this was the first survey, hormone cyclicity status referred to the results of all hormone evaluations for an elephant at its respective institution. Length of time elephants were hormonally monitored ranged from 6 months to 10 years. Analyses of progestagen cyclicity data were only conducted if a female had been assessed for at least a year. Future reproductive data will be based on changes in cyclicity status that occur between subsequent surveys. Animal age refers to the age in 2002 (the second year of the survey). Pregnant cows were not included in the survey results or analyses.

Animals and Sample Collection

Serum samples, collected weekly, biweekly or monthly for periods of 6 to 25 months, from normal cycling and noncycling Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephant females were obtained for this study. A subset of females were sampled daily for characterization of follicular phase hormone dynamics (Asian: n=4 females, 7 cycles; African: n=7 females, 15 cycles). In general, samples were collected from a vein on the caudal aspect of the ear while the cow was in lateral recumbency, or from the saphenous vein in the leg. All elephants were well-conditioned to the blood sampling procedure, which was part of the management routine. Blood was maintained at ~4˚C and centrifuged (~1500 x g) within a few hours of collection and the serum stored at -20˚C or colder until analysis. Samples were selected from those banked at the CRC (1991-present) or were obtained upon request. Attempts were made to analyze recently collected samples; however, for some animals samples up to 7 years old were used. Noncycling elephants were categorized based on the lack of a cyclic progestin profile for a minimum 1 year period before initiation of this study. Overall, elephants were evaluated for 12.4 $\pm$ 1.2 months with an average of 52.3 $\pm$ 4.3 samples analyzed per female.

Each serum sample was analyzed for concentrations of thyroid (free and total T4, free and total T3), adrenal (cortisol), ovarian (progestin) and pituitary (LH, FSH, TSH, prolactin) hormones. Assays were previously validated for elephants (Brown et al., 1991, 1999a,b; Brown and Lehnhardt, 1995, 1997), with the exception of those for thyroid hormones and TSH, which were validated in this study.

Radioimmunoassays

Serum prolactin, LH, FSH and TSH were measured by heterologous ^{125}I double-antibody radioimmunoassays (RIA) as described by Brown et al. (2004b). Serum steroids (progesterone, cortisol, total T4, free T4, total T3, free T3) were measured by solid-phase ^{125}I RIA (Coat-A-Count; Diagnostic Products Corporation, Los Angeles, CA) (Brown et al., 2004b). All assays were validated for elephant serum by demonstrating: 1) parallelism between dilutions of pooled serum samples to the respective standard curve preparations; and 2) significant (>90%) recovery of exogenous standard hormone added to pooled samples before analysis. Assay sensitivities were as follows: 0.3 ng/ml for LH, 0.5 ng/ml for FSH, 1.0 ng/ml for PRL, 0.25 ng/ml for TSH, 2.5 ng/ml for cortisol, 20 ng/dl for total T3, 1 μg/dl for total T4, 0.25 pg/ml for free T3, 0.25 ng/dl for free T4, and 0.05 ng/ml for progesterone. For all protein and steroid assays, intra- and interassay coefficients of variation were <10% and <15%, respectively.

Statistical Analysis

All data are presented as means ± SEM. Mean survey data were compared using Student's t-tests. Differences in survey and ultrasound results between species or cyclicity status within species were determined using Z-tests (SigmaStat v. 2.03, Jandel Scientific, 1997). Percentage data for age categories within species were tested by Chi Square analysis.

Statistical analysis of hormonal data was performed using Sigma Stat version 2.03 (SPSS, Inc.). Time series analysis was used to determine if there were cyclical patterns in hormone secretion. Overall mean values per individual were used for comparison between groups of elephants and were analyzed using One Way ANOVA. For elephants evaluated over a continuous 1-year period (Asian: 8 cycling, 4 noncycling; African: 9 cycling, 11 noncycling), means also were evaluated across seasons (Dec-Feb, Mar-May, Jun-Aug, Sep-Nov). Data were tested for normality using a Shapiro-Wilk test for goodness-of-fit. For normally distributed data, pairwise comparisons were made using Tukey’s tests. When normality tests failed, Kruskal-Wallis One Way Analysis of Ranks were employed and, subsequently, Dunn’s method for pairwise comparisons. Baseline hormonal values were calculated using an iterative analysis (Brown et al., 1999b). Means and standard deviations were calculated followed by removal of all values above the mean plus two times the standard deviation. This process was repeated until only those values that did not exceed the mean plus two standard deviations remained. Mean values were considered outliers when values were greater than 3 interquartile ranges. Linear regressions were conducted to evaluate hormonal relationships within individual females. Comparisons among animals and between species were done using ANOVA on individual means. Mean data are ± SEM.

RESULTS

Survey results are summarized in Table 1. Surveys were returned for over three quarters of the elephants in North America, with a higher ($P<0.05$) response rate for Asian than African elephants. For SSP participants, there was nearly 100% compliance. Of the animals represented in the survey responses, over half of the Asian elephants in the studbook were bled weekly (54%); however, 10 females in the SSP had samples collected that were not analyzed, resulting in a lower percentage monitoring rate. Overall, the hormone monitoring rate for African elephants exceeded that of Asian elephants ($P<0.05$) by over 10 percentage points for both studbook and SSP populations, with higher rates observed for animals managed within the SSP ($P<0.05$). When data were combined for elephants not being monitored (NM) with those where there was no survey information (Unknown - but assume they are not being hormonally monitored), the total number of females with no reproductive hormone data was higher ($P<0.05$) for Asian than African elephants listed in the studbook, although the percentages were similar ($P>0.05$). However, within the SSP, both numbers and percentages of females not hormonally monitored were higher ($P<0.05$) for Asian than African elephants (Table 1).

Tables 2 and 3 summarize survey results based on age categories. In 2002, the majority of females in the Asian population were greater than 30 years of age (67%), whereas most African elephants (72%) were less than that. This was similar for the SSP population where the majority of Asian elephants were greater than 30 years of age (64%) and most African elephants (67%) were less than 30 years of age. Excluding data for females ≤10 years of age (i.e., potentially prepubertal), average age was greater ($P<0.05$) in noncycling than in cycling females for both Asian (31.9 ± 1.1 years, range, 11-59 years versus 37.2 ± 1.7 years, 27-53 years) and African (24.4 ± 0.8 years, range 16-52 years versus 28.9 ± 1.7 years, range 14-42 years) elephants, respectively. Within age categories, there was a greater percentage of noncycling females observed in the older age groups ($P<0.05$). But, there also were larger proportions of unmonitored and unsurveyed females in these categories. Overall, the reproductive status of over half of Asian and African elephants greater than 30 years of age, and over two thirds of elephants over 40 years of age was unknown. For African elephants, a high percentage of unmonitored/unknown elephants also was observed in the 11-20 year age category, most of which were managed outside of the SSP (Table 3).

Examples of progestin profiles in cycling and noncycling Asian and African elephants are presented in Figure 1. Concentrations in acyclic females generally remain below 0.1 ng/ml. Figures 2 and 3 show the patterns of progestins, FSH and prolactin in normal cycling African and Asian elephants, respectively. A cyclic pattern of FSH secretion was identified in both species. Serum FSH concentrations were highest at the beginning of the non-luteal phase, declined to nadir concentrations within 4 days of ovulation and then increased during the luteal phase. In the African elephant, prolactin secretion increased during the follicular phase (Figure 2), but in Asian elephants prolactin remained stable throughout the cycle (Figure 3).

Overall mean hormone values for cycling and noncycling Asian and African elephants are presented in Table 4. Although baseline LH concentrations were similar between species ($P>0.05$), there was a difference in peak LH surge concentrations between species (Asian, 14.2 ± 2.1 ng/ml; African: 5.3 ± 1.1 ng/ml; $P<0.05$). When compared to cycling females, no LH surges were observed in noncycling individuals. Significant differences ($P<0.05$) were found between cycling and noncycling elephants in mean FSH concentrations, with concentrations in noncycling females being similar to baseline levels observed in cycling animals (Figs. 2 and 3). Significant differences ($P<0.05$) also were observed in mean prolactin concentrations between African and Asian elephants, and between cycling and noncycling African females. The species difference was due to the cyclic pattern of secretion observed in African, but not Asian elephants (Figs. 2 and 3). Prolactin concentrations in Asian elephants were similar to baseline levels observed in African elephants, and did not increase during the follicular phase as was observed for Africans. The difference related to cyclicity status was due to

11 of 30 African elephant females that had elevated (≥15 ng/ml) mean prolactin concentrations (overall mean of outliers, 31.97 ± 4.44 ng/ml; range, 15.5–60.41 ng/ml) (Figure 4). Excluding these data, overall mean prolactin for noncycling African elephants was 6.73 ± 0.53 ng/ml, which was similar to cycling African females (P>0.05). Three of the females with elevated prolactin exhibited occasional bouts of mammary enlargement and fluid production, whereas the others were asymptomatic.

There were no differences (P>0.05) related to cyclicity status, season, estrous cycle stage or species for overall mean concentrations of TSH, free T3, free T4, total T3 or total T4. Combining all groups, only TSH and free T3 approached significance for a seasonal effect (P=0.09 and P=0.11, respectively), with concentrations appearing to be lower during the summer months. Average correlations between thyroid hormones were significant (P<0.05) for free T3 and free T4 (r=0.28), free T3 and total T3 (r=0.41), free T4 and total T3 (r=0.22), free T4 and total T4 (r=0.49), but not between thyroid hormones and TSH (P>0.05; r<0.08 for each comparison). Correlations between prolactin and thyroid hormones or TSH were not significant (P>0.05; r<0.15).

For cortisol, there also were no differences related to cyclicity status, season, estrous cycle stage or species (P>0.05). However, five individuals exhibited overall mean concentrations that were higher on average than their cohorts. Four of these were noncycling females (n=1 Asian, 3 African). None of these outlier females had elevated prolactin. An analysis of the variation in cortisol secretion based on measures of the coefficient of variation (CV), standard deviation (SD), and difference between minimum and maximum values (DIFF) revealed no differences (P>0.05) among cycling Asian (CV, 62.3 ± 10.2%; SD, 29.1 ± 9.2 ng/ml; DIFF, 90.5 ± 31.1 ng/ml), noncycling Asian (54.9 ± 9.5%; 18.3 ± 5.1 ng/ml; 47.7 ± 18.3 ng/ml), cycling African (49.3 ± 6.6%; 16.4 ± 7.1 ng/ml; 87.7 ± 30.1 ng/ml) and noncycling African (48.4 ± 5.4%; 15.9 ± 4.6 ng/ml; 66.8 ± 17.5 ng/ml) elephants, respectively. There were no correlations between mean cortisol and prolactin concentrations (P>0.05).

CABERGOLINE CASE STUDY

A newer, more effective dopamine agonist on the market is the long-acting drug cabergoline (Dostinex®, Pfizer), which is well tolerated in patients with pathological hyperprolactinemia (Jochle et al., 1989; Verhelst et al., 1999). Cabergoline has been shown effective in reducing serum prolactin concentrations in 80-90% of these patients (Pharmacy Update, 1998). Figure 5 shows the response of an Asian elephant (SB# 31; DOB, 1969) at Busch Gardens, FL to oral cabergoline treatment for hyperprolactinemia. She was diagnosed with hyperprolactinemia by the CRC laboratory in October 1997, but differed from other noncycling elephants in that her progestin concentrations were consistently elevated (0.5-1.0 ng/ml), rather than being at baseline (<0.1 ng/ml). However, she was considered a 'flatliner' because progestin secretion was not cyclic. Beginning in March 2002, she was given 1 mg of cabergoline orally every three days for 6 months. Serum prolactin concentrations declined almost immediately after the first treatment and were followed about one month later by a drop in progestins to baseline. Progestin concentrations remained low until November 2002 when she resumed cycling based on the observation of a normal luteal phase. From November 2002 through January 2004 she has exhibited four normal estrous cycles. Prolactin secretion also has remained within the normal range for elephants, over one year after treatment withdrawal. It is important to note that this female suffered no adverse effects due to the cabergoline treatment. There were no behavioral changes noted or changes in appetite.

DISCUSSION

Based on this first Elephant TAG/SSP Reproductive Survey, 49% of Asian and 62% of surveyed African elephant females in North America were being hormonally monitored for estrous cyclicity in 2001-2002. Assuming the facilities that did not return surveys are not hormonally monitoring females, then the hormonal monitoring rate drops to 40% and 44% for Asian and African elephants, respectively. Total numbers of hormonally assessed females in the different age categories reflected the age distribution of the population, with more Asian elephants being monitored in the 31-40 year age group and more African females being monitored in the 21-30 year age group.

Results confirm earlier observations that many females in the captive population are not cycling normally (Brown, 2000). The problem is of particular significance for African elephants where 29% of females being hormonally monitored exhibited some form of ovarian dysfunction, and many of these (18%) were of reproductive age (i.e., <30 years). Given the historically low reproductive rates of captive elephants, and the need to increase fecundity to prevent demographic extinction, the Elephant TAG/SSP now recommends that all facilities holding elephants begin an active program of monitoring through routine hormone and ultrasound assessments of both males and females. Currently, the TAG/SSP makes breeding recommendations only for females that have undergone an ultrasound examination and a year of hormonal evaluations. However, even if there are no immediate plans for breeding, or females are considered post-reproductive, the TAG/SSP recognizes that life-long assessments will be critical to identifying causes of reproductive dysfunction. Until recently, it was believed that elephants exhibited either a cyclic or noncyclic progestagen profile. However, as more elephants have been evaluated for longer periods of time, it appears that some alternate between cyclic and noncyclic periods (Schulte et al., 2000), or exhibit erratic progestagen secretion. Therefore, evaluation of reproductive data collected through periodic TAG/SSP surveys could serve as a valuable management tool to help identify and understand the factors that impact reproductive health.

While the 'symptom' of ovarian inactivity in elephants is physiological (i.e., baseline progestin secretion), the 'etiology' likely involves both physiological and psychological mechanisms. In this study, a comprehensive analysis of serum hormones from noncycling Asian and African elephants was conducted to determine if acyclicity was related to any specific endocrine dysfunctions. The females in this study represented 75% and 100% of the acyclic Asian and African elephants, respectively. To permit appropriate comparisons, however, it was first necessary to develop a normative species-specific endocrine database for each of the hormones examined. In both species, FSH exhibited a secretory profile that lagged behind progestin changes by about a week. Concentrations were highest at the end of the luteal phase and decreased progressively throughout the non-luteal phase. A notable species difference in prolactin secretion during the estrous cycle was confirmed, a finding inferred from previous reports (Bechert et al., 1999; Brown et al., 1999b). In the African elephant, prolactin may be involved in follicular development because concentrations are elevated during the non-luteal phase (Bechert et al., 1999). By contrast, in Asian elephants prolactin remains stable concentrations throughout the cycle (Brown and Lehnhardt, 1997; Carden et al., 1998; Brown et al., 1999b). Prolactin has been shown to regulate ovarian function in other species (Murray et al., 1996; Gaytan et al., 1997; Clarke et al., 1997), so it is possible that the follicular phase increase in African elephants is due to a positive feedback of estrogen, as has been demonstrated in other species (Lawson et al., 1993).

Thyroid hormones have been shown to regulate gonadal function, especially in seasonal breeders (Billings et al., 2002). In addition to seasonal influences, both hyperthyroid and hypothyroid conditions have been linked to cessation of ovarian activity and anovulatory cycles in some species (Doufas and Mastorakos, 2000; Krassas, 2000). However, comparison of cycling and noncycling elephants revealed no significant differences in thyroid hormone or TSH concentrations that might explain the observed ovarian acyclicity. Cortisol measures often are used as an index of stress, and chronic elevations have been related to poor reproduction (Moberg, 1985, 1990). Indeed, four of the five females with 'elevated' cortisol were not cycling; however, these individuals represent only a small proportion of the total acyclic group and overall there were no differences in cortisol concentrations between cycling and noncycling elephants. Furthermore, evaluations of related parameters of cortisol secretory activity (i.e., CV, SD, DIFF) also suggested there were no consistent differences in adrenal function between cycling and noncycling elephants.

One potential problem identified in acyclic elephants was that of elevated prolactin. Although not as high as that observed during pregnancy (Brown and Lehnhardt, 1995, 1997), immunoactive prolactin concentrations were on average 6-fold higher in 11 of 30 noncycling African elephants. By far, the most prominent hormonal consequence of hyperprolactinemia is hypogonadism (Gomez et al., 1977; Robbins, 1986), with deficient luteal function cited as the first evidence of compromised endocrine function (Jones, 1989). That certainly was the case in this study where all elephants with elevated prolactin exhibited a lack of cyclic luteal activity. The causes of hyperprolactinemia are diverse, but most often is associated with prolactin-secreting pituitary adenomas (prolactinomas) (Jones, 1989). Hypothalamic dopamine regulates prolactin release through an inhibitory mechanism, so any lesion interfering with its synthesis, release or activity can affect prolactin secretion (MacLeod et al., 1976; Yen, 1982; MacLeod and Lamberts, 1986; Woolf, 1986; Zacur, 1998). Transient increases in prolactin can be caused by sleep, protein meals, hypoglycemia, chest wall irritation, surgical stress, pregnancy and renal failure (Woolf, 1986; Jones, 1989; Zacur, 1998). It is unlikely that any of these are causes of elevated prolactin in acyclic elephants because their condition is chronic, not transient. Estrogens can stimulate prolactin release (Jones, 1989; Zacur, 1998), but no relationship between estrogen and prolactin secretion was observed in these elephants. Hypothyroidism is another known cause of hyperprolactinemia (Woolf, 1986; Jones, 1989; Zacur, 1998). Decreased T4 results in increased TRH that subsequently stimulates TSH as well as prolactin release. However, altered thyroid function was not associated with hyperprolactinemia or ovarian acyclicity in this study.

There are treatments for hyperprolactinemia, the most common being oral administration of ergot alkaloids like bromocriptine or cabergoline which act as dopamine agonists (Zacur, 1999). While side-effects have been reported for bromocriptine, including gastrointestinal disturbances, anxiety, orthostatic hypotension and dizziness (Robbins, 1986), cabergoline has been shown to have a wide margin of safety in a variety of species (Jochle et al., 1989). The decision to treat hyperprolactinemia in women often is driven by the desire to correct infertility. Given the need to increase reproductive rates of African elephants to prevent captive extinction (Olson and Wiese, 2000), it might be efficacious to treat genetically valuable females with cabergoline in the hope it will reinitiate reproductive cyclicity. We are encouraged by the positive result on the hyperprolactinemic elephant who re-established ovarian cyclicity after treatment with cabergoline. Recently, six additional African elephants were identified for a cabergoline treatment study and the zoos have agreed to participate. If successful, at least some of these females could be scheduled for breeding.

Ultimately, more physiological studies are needed to determine the cause of reproductive pathologies in Asian and African elephants. These should include analyses of the nutritional, disease and health status of individual elephants, in addition to investigating other potential social or environmental factors as they relate to ultrasound and hormonal results. One encouraging finding was the baseline secretion of gonadotropins. In cases of hypogonadal infertility or after castration, gonadotropin secretion increases as a result of pituitary gonadotroph hypertrophy and lack of steroidal negative feedback (e.g., Wright et al., 1996). Thus, in elephants the lack of cyclic gonadotropin activity may due to inhibitory mechanisms that are not of organic origin, and therefore could be reversible. Information obtained from studies that integrate species- or individual-specific behavior with reproductive physiology could lead to the development of more appropriate management programs for successful captive breeding. Hopefully, continued studies like these will elucidate what factors are related to reproductive dysfunction in elephants in time for mitigating actions to be taken.

CONCLUSIONS

1. In a 2001-2002 survey, about 49% of Asian and 62% of African elephants in North America were being monitored for estrous cyclicity using weekly serum or urinary progestagen analyses.
2. Of those being hormonally monitored, 14% of Asian and 29% of African elephant females either were not cycling normally or exhibited irregular or no ovarian activity.
3. Reproductive problems were more prevalent in the older age categories, although for African elephants a number of acyclic females were in the younger age groups.
4. There were no consistent endocrine anomalies associated with ovarian acyclicity, with the exception of hyerprolactinemia. This problem, a common cause of infertility in women, may be treatable using cabergoline.
5. Identifying causes of reproductive problems in captive elephants will require continual investigations into the impact of the captive environment, including social and management factors, on physiology and behavior.

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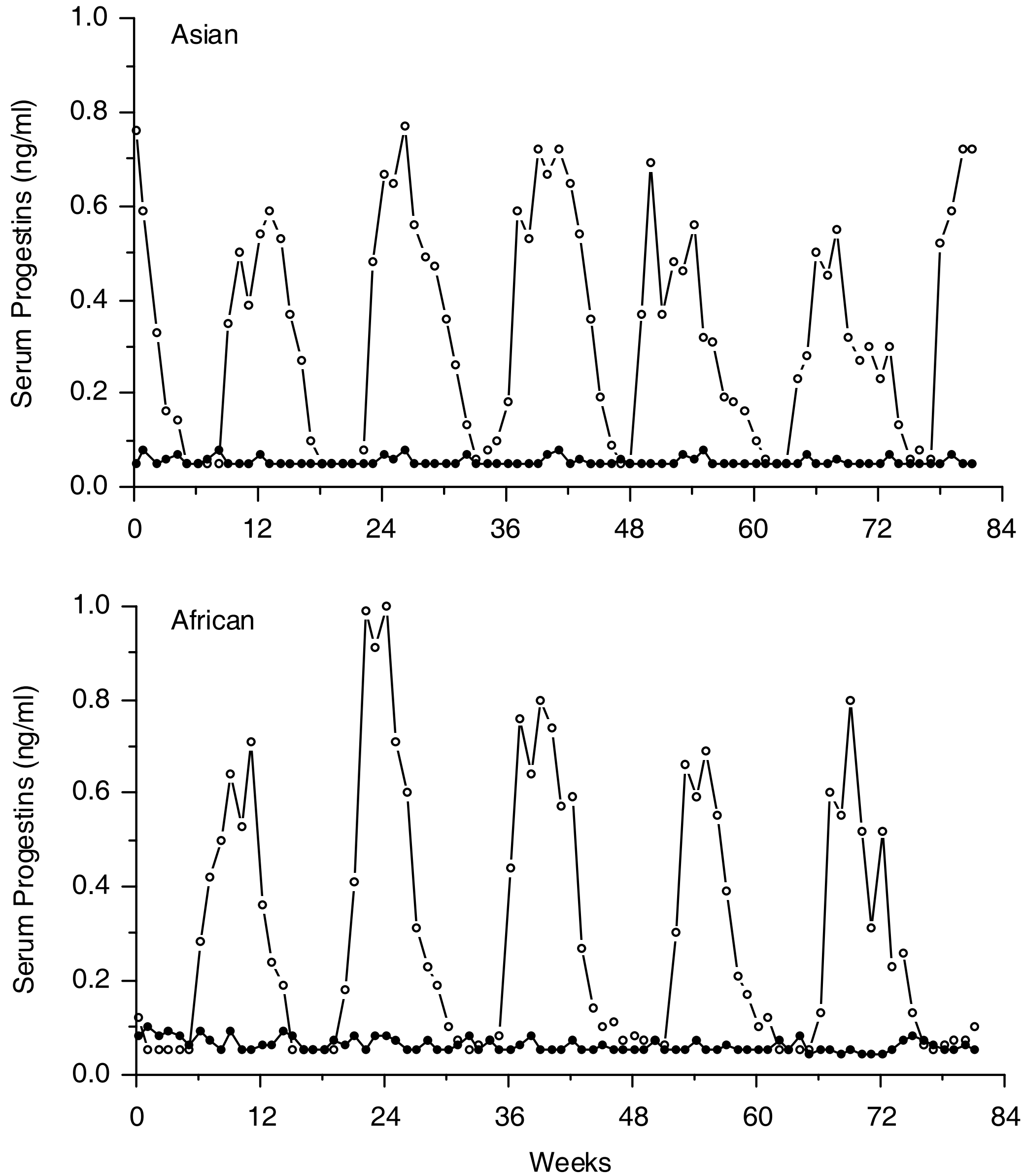

Figure 1. Representative profiles of serum progestins in a cycling (open circles) and noncycling (closed circles) Asian (top panel) and African (bottom panel) elephant female.

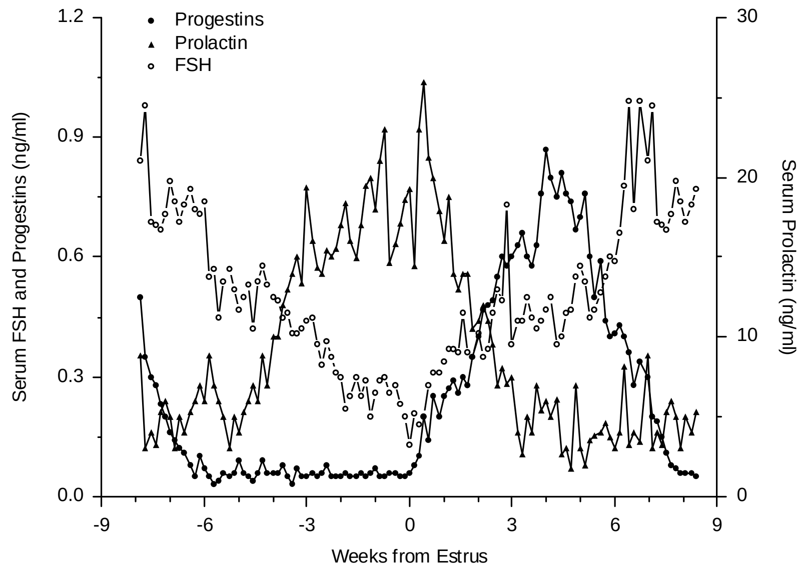

Figure 2. Mean profiles of serum progestins, prolactin and FSH in throughout the estrous cycle in reproductively normal African elephants (n=7 females, 15 cycles). Week 0 designates estrus. The follicular phase is considered the period between successive luteal phases (Week –6 to Week 0). From Brown et al. (2004b)

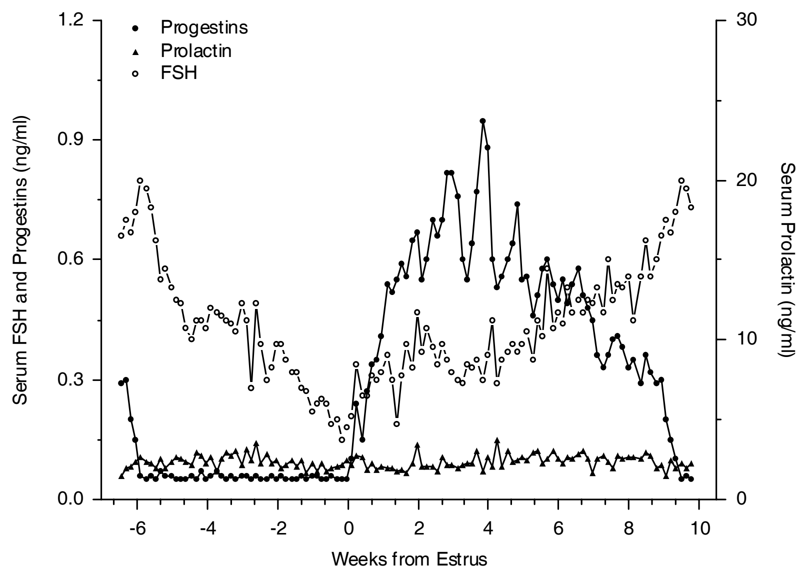

Figure 3. Mean profiles of serum progestins, prolactin and FSH in throughout the estrous cycle in reproductively normal Asian elephants (n=4 females, 7 cycles). Week 0 designates estrus. The follicular phase is considered the period between successive luteal phases (Week –6 to Week 0). From Brown et al. (2004b)

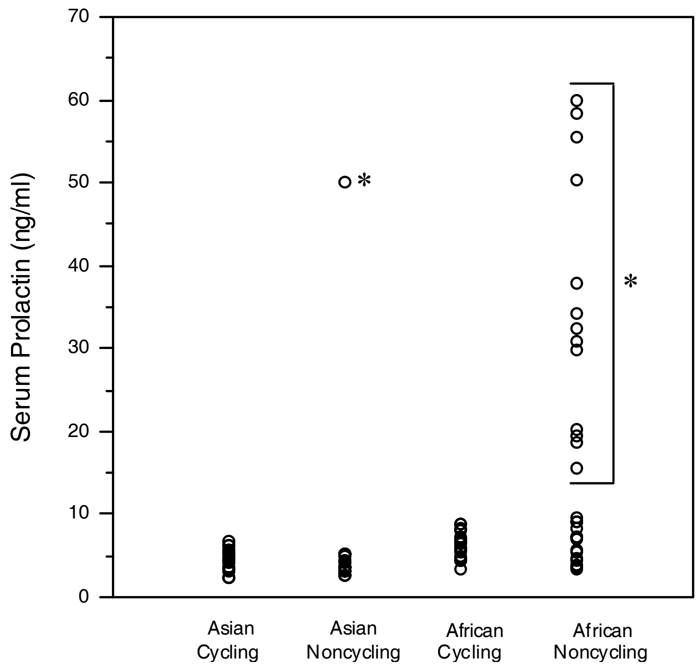

Figure 4. Scatter plot of overall mean serum prolactin concentrations in cycling and noncycling Asian and African elephant females. Asterisks and the bar with an asterisk identifies individual mean values that were determined to be outliers. From Brown et al. (2004b)

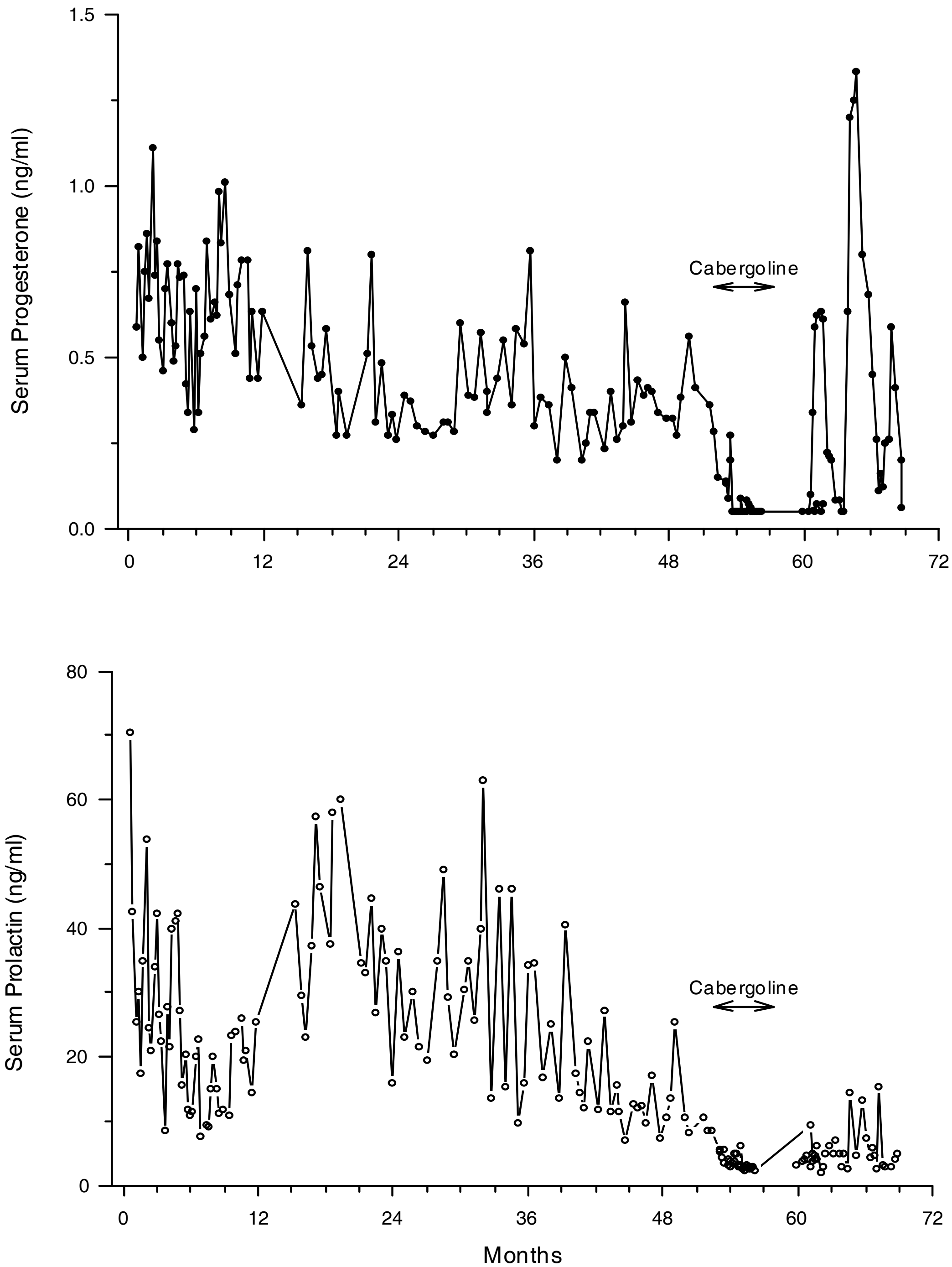

Figure 5. Progesterone (top graph) and prolactin (bottom graph) concentrations before and after treatment of an Asian elephant (SP# 31; DOB, 1969) at Busch Gardens, FL with cabergoline.

Table 1. Overall response rates and cyclicity status results of the Elephant TAG/SSP 2001-2002 Reproductive Survey for captive female Asian and African elephants in North America. Data are evaluated for total studbook (SB) and SSP populations for each species.

	Asian	African
SB population	239	206
SSP population	131	114
Surveys returned (%SB)	193 (81%)	146 (71%)
Surveys returned (%SSP)	129 (98%)	111 (97%)
No. monitored[1] (%SB responses)	95 (49%)[5]	91 (62%)
Unknown+NM[4] (%SB)	144 (60%)	115 (56%)
No. monitored[1] (%SSP responses)	75 (58%)[5]	77 (69%)
Unknown+NM[4] (%SSP)	56 (43%)	37 (32%)
Cyclicity Status (% of SB total)[2]		
Cycling	80 (84%)[a]	64 (70%)[b]
Irregular	2 (2%)	6 (7%)
Noncycling[3]	11 (12%)[a,3]	20 (22%)[b,3]
Cyclicity Status (% of SSP)[2]		
Cycling	61 (81%)[a]	55 (71%)[b]
Irregular	2 (3%)	4 (5%)
Noncycling[3]	10 (13%)[a,3]	17 (22%)[b,3]

1Reproductive cyclicity status based on weekly or bi-weekly serum or urinary progestin assessments

2Numbers are based on those monitored hormonally

3Number excludes females ≤ 10 years of age (2 Asian; 1 African)

4Unknown = no survey returned; NM = not hormonally monitored

5Does not include 10 females in the SSP that were bled weekly, but hormones were not analyzed

a,bPercentage differences between cyclicity categories are significant (P<0.05).

From Brown et al. (2004a)

Table 2. Numbers and age distribution of Asian elephant females exhibiting normal estrous cycles (cycling) or no ovarian activity (noncycling) in the total studbook (SB) and SSP populations in North America based on an Elephant TAG/SSP 2001-2002 Reproductive Survey.

	Age of females in 2002 (years)				
	≤ 10	**11-20**	**21-30**	**31-40**	**> 40**
SB population[1]	21	19	39	93	67
SSP population[1]	14	12	21	55	29
% noncycling (SB)[2]	28.6	0[a]	5.0[b]	14.3[c]	25.0[d]
% noncycling (SSP)[2]	33.3	0[a]	7.6[b]	16.1[c]	26.6[d]
% Unknown[3]+NM (SB)	66.7	47.4	48.7	54.8	76.1
% Unknown[3]+NM (SSP)	57.1	16.7	38.1	43.6	48.3

1Number of elephants in each population

2Percentage based on elephants being hormonally monitored

3Unknown = no survey returned; NM = not hormonally monitored

a,b,c,dPercentages of noncycling females between each age category with different superscripts are significantly different (P<0.05). Analysis does not include females ≤ 10 years of age.

From Brown et al. (2004a)

Table 3. Numbers and age distribution of African elephant females exhibiting normal estrous cycles (cycling) or no ovarian activity (noncycling) in the total studbook (SB) and SSP populations in North America based on an Elephant TAG/SSP 2001-2002 Reproductive Survey.

	Age of females in 2002 (years)				
	≤ 10	**11-20**	**21-30**	**31-40**	**> 40**
SB population[1]	3	72	74	45	12
SSP population[1]	3	22	52	26	11
% noncycling (SB)[2]	100	8.3[a]	19.0[a,b]	40.0[b]	50.0[b]
% noncycling (SSP)[2]	100	10.0[a]	18.9[a,b]	40.0[b]	50.0[b]
% Unknown[3]+NM (SB)	66.7	66.7	42.2	55.6	66.7
% Unknown[3]+NM (SSP)	66.7	9.1	28.8	42.3	48.3

1Number of elephants in each population

2Percentage of elephants being hormonally monitored

3Unknown = no survey returned; NM = not hormonally monitored

a,bPercentages of noncycling females between each age category with different superscripts are significantly different (P<0.05). Analysis does not include females ≤ 10 years of age

From Brown et al. (2004a)

Table 4. Overall mean (±SEM) and average overall mean range concentrations of serum pituitary, ovarian, thyroid and adrenal hormones in cycling and noncycling Asian and African elephant females.

	Asian		African		
Hormone	**Cycling**	**Noncycling**	**Cycling**	**Noncycling**	**All Elephants[1]**
LH[2] (ng/ml)	0.82± 0.06 (0.65-1.02)	0.63± 0.09 (0.39-0.93)	0.67± 0.05 (0.34-0.98)	0.73± 0.06 (0.34-1.19)	0.71± 0.03
FSH (ng/ml)	4.32± 0.29[a] (1.92-3.40)	2.91± 0.32[b] (1.51-3.51)	4.41± 0.29[a] (0.56-6.41)	2.16± 0.23[b] (0.83-3.49)	
Prolactin (ng/ml)	4.85± 0.42[a] (2.30-6.78)	4.36± 0.45[a] (2.50-6.23)	7.81± 0.54[b] (4.32-8.84)	15.19± 2.74[c] (3.33-60.41)	
TSH (ng/ml)	0.75± 0.42 (0.61-1.08)	0.97± 0.36 (0.41-2.74)	0.66± 0.15 (0.42-1.27)	0.56± 0.14 (0.37-0.86)	0.69± 0.15
Free T3 (pg/ml)	1.93± 0.26 (1.06-2.98)	1.39± 0.24 (0.73-2.86)	1.61± 0.27 (0.70-3.49)	1.41± 0.21 (0.41-3.68)	1.56± 0.12
Free T4 (ng/dl)	1.01± 0.06 (0.74-1.44)	0.87± 0.05 (0.63-0.97)	0.91± 0.03 (0.72-1.10)	0.93± 0.04 (0.72-1.46)	0.94± 0.02
Total T3 (ng/dl)	123.95± 6.25 (91.37-158.35)	126.72± 6.13 (110.65-153.95)	124.03± 4.30 (99.34-148.07)	123.27± 4.38 (89.49-177.49)	123.97± 2.62
Total T4 (µg/dl)	11.20± 0.57 (8.62-14.54)	11.12± 0.46 (9.53-12.52)	10.06± 0.36 (7.58-12.25)	10.76± 0.41 (8.45-16.56)	10.73± 0.24
Cortisol (ng/ml)	23.32±4.21 (11.13-51.55)	20.04±7.83 (7.59-73.54)	20.37±4.86 (5.74-59.63)	27.53±5.92 (4.05-110.91)	24.15±3.27

a,b,c Mean values with different superscripts are significantly different across all groups (P<0.001)

1Combined data from both species for hormones where there was no significant difference (P<0.001) between species or reproductive status groups

2Excludes LH surge data

Pilot study: Depot progesterone for potential pregnancy maintenance in an Asian elephant (*Elephas maximus*)

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Luteal deficiency has been suspected as a cause of abortions in domestic equids with the subsequent application of synthetic progestagens or depot progesterone to prevent pregnancy loss. Abortions due to unknown etiologies occur in large megavertebrates such as rhinoceros and elephants, and the use of supplemental progesterone might assist the cow in carrying the calf to term in the case of a progesterone deficiency. A 34 year old nulliparous captive Asian elephant female (*Elephas maximus*) who had a prior history of uterine leimyomas and cystic endometrial disease and was considered non-reproductive based on those findings was elected for an exogenous long-acting progesterone administration pilot study. The Asian female elephant was monitored via a daily serum progesterone assay to detect her non-luteal period of the cycle where the serum progesterone was less than 100 pg/ml. A parenteral long acting sustained release progesterone (BetPharm P4 LA 150) 0.3 mg/kg intramuscular q 10 days was given for two doses with daily blood collections for monitoring serum progesterone. The dosage rate was then adjusted to 0.15 mg/kg intramuscular q 10 days for two doses with repeated daily blood collections for monitoring progesterone levels. At the 0.3 mg/kg dosage and 10 day frequency, the serum progesterone accumulated with a peak at 2,733 pg/ml for the first dose and 3,279 pg/ml with the second dose. Progesterone levels at 10d prior to each injection were between 438-538 pg/ml at the 0.3 mg/kg dose. At the 0.15 mg/kg dose, the progesterone still appeared to accumulate with a peak dose at 2725 pg/ml after the second dose. The first dose of 0.15 mg/kg produced an aberrant curve with a more than expected diminished peak (1,582 pg/ml), but sustained prolonged drug levels were present for the 10 day interval. Progesterone levels at 10d after each 0.15 mg/kg injection were between 384-395 pg/ml.

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Relationship of environmental and captivity-related factors to reproductive acyclicity in captive African elephants

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The North American African elephant (*Loxodonta africana*) population is not self-sustaining due a lack of reproduction and a high calf mortality rate. Improving reproductive rates is hindered by the fact that ~30% of females are not cycling and thus cannot successfully breed. These animals are termed 'flatliners' because serum progesterone remains at stable, baseline concentrations. Acyclicity may be socially or environmentally mediated by captivity-related factors such as a lack of genetic relatedness, social dynamics, husbandry practices, and climate because the captive situation differs so much from the wild. As in the wild, dominance hierarchy within the captive herd is important for maintaining social harmony, even if individuals are dominant over unrelated elephants. Determination of the impact of dominance status and genetic relatedness within captive herds on reproductive status of individuals is underway. A preliminary study suggests the dominant females are more likely to be acyclic. This differs from that reported for elephants in the wild. By contrast, most facility and husbandry related factors appear to have no effect on reproductive status. Neither management style, location, nor climate appear to affect which facilities have noncycling elephants. Ruling out some captivity-related factors will allow us focus on others so that hopefully we can identify causes of reproductive acyclicity in captive African elephants. If so, it may be possible to make better management decisions that could return some acyclic females to the breeding pool before there is an irreversible decline in the zoo population.

INTRODUCTION

The African elephant population in North American is not self-sustaining, in part due to low reproductive rates (Olson and Wiese, 2000). Without a significant increase in birth rates, this population will become nonviable within about 40 years (Olson and Wiese, 2000). Efforts to increase reproduction are hindered by the fact that up to a third of reproductive-age elephants exhibit irregular or acyclic ovarian activity, identified through long-term weekly serum progestin analyses (Brown et al., 2004). Acyclic elephants are termed 'flatliners' because serum progestins remain at stable, baseline concentrations, an indicator of ovarian inactivity. Females that do not cycle regularly are reproductively compromised and cannot conceive. The cause of acyclicity is unknown and as yet no treatments have been successful in African elephants. There is speculation that the problem could be related to captive management, with elephant sociality and environmental conditions being contributing factors (Brown, 2000; Schulte et al., 2000). A recent temperament survey of African elephants in North America suggests that noncycling females rank higher within captive herds than cycling cohorts (Freeman et al., 2004). It remains to be determined if these are cause or effect relationships, but clearly it is important to understand how physical and social attributes impact physiological processes, like reproduction, in elephants.

African elephants live in complex hierarchical groups of related females. The most basic stable social group is the family unit, which consists of closely related adult females and their offspring (Douglas-Hamilton, 1973; Poole and Moss, 1989). Each individual within the family holds a status whereby age, size, kinship, and individual disposition all contribute to their social rank order (Dublin, 1983;

Thouless, 1996). Generally, the largest, eldest female is the matriarch of the family and she is crucial to the survival of the herd (Dublin, 1983; McComb et al., 2001; Poole and Moss, 1989). Several closely-related family units are often seen traveling together and socializing. This larger gathering of cohorts is referred to as a kinship group (Douglas-Hamilton, 1973) or bond group (Moss, 1988). The high degree of relatedness between individuals at the family unit and bond group level is thought to contribute to cooperative behavior (Douglas-Hamilton, 1973; Poole and Moss, 1989) and increased reproductive success (Poole and Moss, 1989).

The social structure of captive elephants differs from those in the wild in three ways: 1) groups are biased towards females because few facilities maintain bulls; 2) herds are not multigenerational and calves are rare; and 3) the groups are smaller with 75% of facilities maintaining three or fewer individuals (Schulte, 2000). While these captive groups differ from wild herds, genetic relatedness and dominance status may still be important for maintaining social harmony even if there is no true matriarch (Schulte, 2000). Additionally, the potential lack of genetic relatedness within captive herds may negatively impact reproductive success by suppressing ovarian activity. Thus, it is important to understand how relatedness within the captive herds may influence ovarian activity and behavioral interactions between individuals.

The purpose of this study was to determine: 1) if a lack of genetic relatedness within captive herds affects individual ovarian activity or social interactions among herdmates; and, 2) which captivity-related factors impact ovarian activity of African elephants.

MATERIALS AND METHODS

To determine how relatedness of individuals within captive herds impacts their ovarian activity and social dynamics, pairwise genetics data of North American African elephants generated by Lei et al. (these proceedings) was used. From the pairwise data, a relatedness index was created by calculating the mean relatedness of each female elephant to her captive female and male herdmates. Females were designated as cycling or noncycling based on the most up-to-date SSP Reproductive Surveys (Brown et al., 2004) or the most recent data generated at the Conservation and Research Center's ('CRC') Elephant Endocrine Laboratory. The sociality of females was assessed using the results of a temperament survey completed by facilities listed in the African Elephant Studbook.

Three surveys were distributed in 2003 to all facilities with African elephants listed in the North America studbook. A behavioral survey asked staff to assess the temperament of each female by answering questions about aggressiveness, affiliative nature, disciplinary nature, and responses to novel objects. Keepers were also asked to rank the relative status of each female within the captive herd. A socio-environmental survey was distributed to investigate the impact of captivity-related factors on ovarian activity. Questions investigated covered several topics such as activity level, social structure, herd demographics, interaction with handlers, and diet. Finally, a health-related survey was distributed to determine how body condition, medications and the prevalence of repetitive behaviors relate to ovarian activity. Additional information was gathered from the North American Studbook including age, number of herdmates, transfer history, and the length of time spent at the current facility. Lastly, location (longitude, latitude, elevation) and climate (30 year means on temperature, precipitation, heating and cooling days) data for each elephant facility were downloaded from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) website.

Logistic regression was run to determine the effect of genetic relatedness to female herdmates as well as genetic relatedness to male herdmates on an individual's reproductive status (cycling or not) (SigmaStat v. 3.01, SSPS, Inc.). Linear regression was used to determine the impact of the mean relatedness among female herdmates on the reproductive status of the facility (all cycling, none cycling, both cycling and not). Finally, linear regression was used to determine how an individual's mean genetic relatedness to her female herdmates affects her temperament score for each of the behavioral categories in the temperament survey.

Fifty facilities returned surveys describing 128 female African elephants. A model was designed to determine the impact the captivity-related factors investigated through the three surveys had on reproductive status (Appendix A). Cronbach's α (SYSTAT v. 9, SPSS, Inc.) was used to help determine the relationship between social, environmental, and health factors. Factors with an $\alpha > 0.70$ were combined to help create the most simplistic and parsimonious model. Logistic Regression (SigmaStat v. 3.01, SSPS, Inc.) was run determine which bivariate factors significantly impact whether or not a female is cycling. Based on the results from the bivariate analyses, the model was simplified to include only those factors that were significant at $P<0.10$, those factors that could interact with the significant bivariates, and finally any factors of particular interest towards managing captive elephants. Pearson product moment correlation was then used to investigate collinearity between the model factors.

RESULTS

Genetic Relatedness

Relatedness of individuals within a captive facility had little impact on reproductive status either at the individual or facility level. Mean relatedness of females to the their female herdmates had no effect on whether or not she cycled normally ($y = -0.567 - 0.526x$, $P=0.793$, $n=64$). Similarly, mean relatedness of females to their male herdmates also had no effect on her reproductive status ($y = -0.957 + 3.488x$, $P=0.523$, $n=25$). Finally, mean relatedness of all of the individuals at a facility did not impact whether or not a facility housed noncycling females ($y = 1.602 - 0.0641x$, $P=0.962$, $R^2 < 0.001$, $n = 27$).

Genetic relatedness also had no effect on the ability of females to get along with their captive herdmates. Relatedness of a female to her female herdmates had no impact on her display of aggressive or affiliative behaviors towards them, nor on her propensity to take on the peacekeeping role within the herd, otherwise referred to as her disciplinary nature (Table 1). Likewise, mean relatedness had no effect on her willingness to share food or her rank within the dominance hierarchy.

Table 1. Impact of the mean genetic relatedness of individuals to their female herdmates on their rank for the temperament survey (n=66).

Temperament Category	R^2	P-value
Aggressiveness towards herdmates	0.000	0.964
Disciplinary nature	0.007	0.520
Affiliative nature	0.001	0.732
Willingness to share food items	<0.000	0.996
Dominance status	<0.000	0.941

Captivity-related Factors

The majority of factors from the three surveys had no impact on whether or not a female African elephant was cycling. At the bivariate level, neither climate, location, management style, nor the presence of a male impacted ovarian activity. However, the number of years a female had spent at her facility, her age, weight, feeding a variety of hay, and using horse supplements all increased the chance that a female would be a flatliner (Table 2). Personality Index was created by summing the scores from the temperament survey on dominance status, competition over preferred food items and the propensity of a female to discipline her herdmates ($\alpha = 0.868$). Larger index scores meant females had a higher the rank, were more likely to give discipline, and less likely to share food. Females with a larger personality index score had a greater chance of being acyclic (Table 2). Finally, elephants that spent less time interacting with their keepers, and had fewer deaths within the herd over the last five years were more likely to be acyclic.

Table 2. Model factors that significantly impact reproductive status, cycling or not, using Logit Regression on the bivariates.

Model Factor	N	Wald's Statistic P-value	Sign of Regression Coefficient
Time at facility	107	0.001	+
Age	107	0.010	+
Weight	73	0.026	+
Hay index	89	0.028	+
Hrs with elephants	91	0.056	-
Deaths	88	0.066	-
Horse supplements	91	0.073	+
Personality index	90	0.090	+

Based on the results of the bivariate analyses, the model was narrowed to include all of the factors that were significant at the bivariate level, as well as the factors that may interact with those significant bivariates (Appendix B). Additional factors were left in the model that are of particular interest to captive managers such as management style, climate and location as well as the presence or absence of males. All of the remaining model variables were significantly correlated with at least one other model factor (Table 3) with the exception of the personality index. Further analyses of these interactions are currently underway.

Table 3. Correlation coefficients of factors that are significantly related (Pearson Product Moment Correlation). Factors that are not correlated are designated with an *.

	Lbs.	PI	Herd	Males	Births	Deaths	Hrs. w/	MS	Age	Years	Moves	Hay
Inch	0.553	*	*	*	*	*	*	*	0.461	0.334	*	*
Lbs.		*	*	*	*	*	*	*	0.473	*	*	*
PI			*	*	*	*	*	*	*	*	*	*
Herd				0.519	0.68	*	0.521	*	*	*	*	*
Males					0.374	*	*	*	*	*	*	*
Births						0.41	0.555	*	*	*	*	*
Deaths							*	*	*	*	*	*
Hrs w/								0.404	*	*	*	*
MS									*	*	*	-0.358
Age										*	*	*
Years											-0.38	*
Moves												*

Table 3 (continued). Correlation coefficients of factors that are significantly related (Pearson Product Moment Correlation). Factors that are not correlated are designated with an *.

	Horse	Out W	Ex	Cool	Heat	Temp	Precip	Lat	Long	El	GR
Inch	*	*	-0.362	*	*	*	*	*	*	*	*
Lbs.	*	*	*	*	*	*	*	*	*	*	*
PI	*	*	*	*	*	*	*	*	*	*	*
Herd	*	*	*	*	*	*	*	*	*	*	*
Males	*	0.384	*	0.31	-0.303	*	*	-0.345	*	*	*
Births	*	*	*	*	*	*	*	*	*	*	-0.401
Deaths	*	*	*	*	*	*	*	*	*	*	*
Hrs w/	*	*	*	*	*	*	*	*	*	*	*
MS	*	*	0.409	*	*	-0.391	*	*	*	*	*
Age	*	*	*	*	*	*	*	*	*	*	*
Years	0.444	*	*	*	*	*	*	*	*	*	*
Moves	-0.305	*	*	*	*	*	*	*	*	*	*
Hay	*	*	*	*	*	*	*	*	*	*	*
Horse		*	*	-0.329	0.355	-0.36	*	*	0.352	*	*
Out W			*	0.604	-0.649	*	*	-0.588	*	*	*
Ex				*	*	-0.305	*	*	0.422	*	*
Cool					-0.782	*	0.468	-0.83	-0.345	*	*
Heat						*	*	0.897	*	0.421	*
Temp							*	*	-0.331	-0.317	*
Precip								*	-0.713	-0.32	*
Lat									*	*	0.31
Long										*	*
El											*

In=Inches, Lbs=Pounds, PI=Personality Index, Herd=# of Herdmates, Males=Presence of males, Births=# of births in last 5 yr, Deaths=# of deaths in last 5 yr, Hrs w/=Hours spent with keepers, MS=Management system, Age, Years=Time at facility in years, Moves=# of moves, HI=Hay index, Horse=Feeding of horse supplements, Out W=Hrs spent outside in winter, Ex=Exercise, Cool=Mean cooling degree days, Heat=Mean heating degree days, Temp=Mean annual temperature, Precip=Mean annual precipitation, Lat=Latitude, Long=Longitude, El=Elevation, GR=Relatedness

DISCUSSION

A complex matrix of captivity-related factors may influence ovarian activity of African elephants in North America (Appendix I). Data are still being analyzed to create the most parsimonious model; however, some preliminary conclusions can be made. First, mean genetic relatedess of female African elephants to their captive herdmates based on mtDNA markers had no impact on which females were cycling and which facilities had flatliners. Nor did relatedness between the females affect how well they interacted socially in captivity. Second, at the bivariate level several factors related to the age and the dominance status of captive female African elephants affected her ovarian activity. Larger, older, more dominant females that were more likely to give discipline and less likely to share food tended to have acyclic ovarian activity.

In contrast to captivity, African elephants usually reproduce well in the wild. Still, the literature suggests that some wild females fail to reproduce (Foley et al., 2001; Laws, 1969; Moss, 2001) and may have abnormal hormone levels. Failure to breed has been attributed to density-related factors, such as food and water availability, that naturally regulate body condition and population levels (Laws, 1969). Additionally, reproductive rates appear to diminish with age (Laws et al., 1970; Moss, 2001) as females attain matriarchal status. Declining reproductive activity in these older, more dominant females may occur in response to environmental stressors such as rainfall (Laws, 1970). Adequate precipitation is required for elephants to calve year round because rain stimulates mating (Eltringham, 1982). Birth records show that breeding rates peak during the rainy seasons (Dublin, 1983), suggesting elephants may experience a seasonal link between reproduction and rainfall. Although the captive environment differs from the conditions elephants face in the wild (Schulte, 2000), it appears that similar factors may control reproduction in each setting. Continued analysis of factors that impact ovarian activity in captive African elephants can provide insight into just how closely *in* and *ex situ* reproduction match.

Results of this investigation will enhance our understanding of factors that impact reproduction in African elephants and have the potential to improve management strategies of the captive population. The *ex situ* population is not self-sustaining in part due to low reproductive rates, and unless this changes the population will become nonviable within the next 40 years (Olson and Wiese, 2000). With up to a third of reproductive elephants exhibiting irregular or acyclic ovarian cycles, efforts to increase reproduction are compromised (Brown et al., 2004). While the causes of this ovarian dysfunction are not known, it appears to be related to similar factors that effect reproductive success in the wild. It is our hope that understanding what factors impact reproductive activity will result in improved management strategies for captive elephants that will return noncycling females to the breeding pool before captive extinction occurs.

CONCLUSIONS

Mean genetic relatedess of female African elephants to their captive herdmates based on mtDNA markers has no impact on which females were cycling, which facilities had flatliners, or how well elephants interacted socially.

Several factors including age, size, and personality of the female relative to her captive herdmates were related to reproductive cyclicity status, whereas other captivity-related factors, such as climate, location, management style, and presence of a male, appeared to have no impact on reproductive status at the bivariate level.

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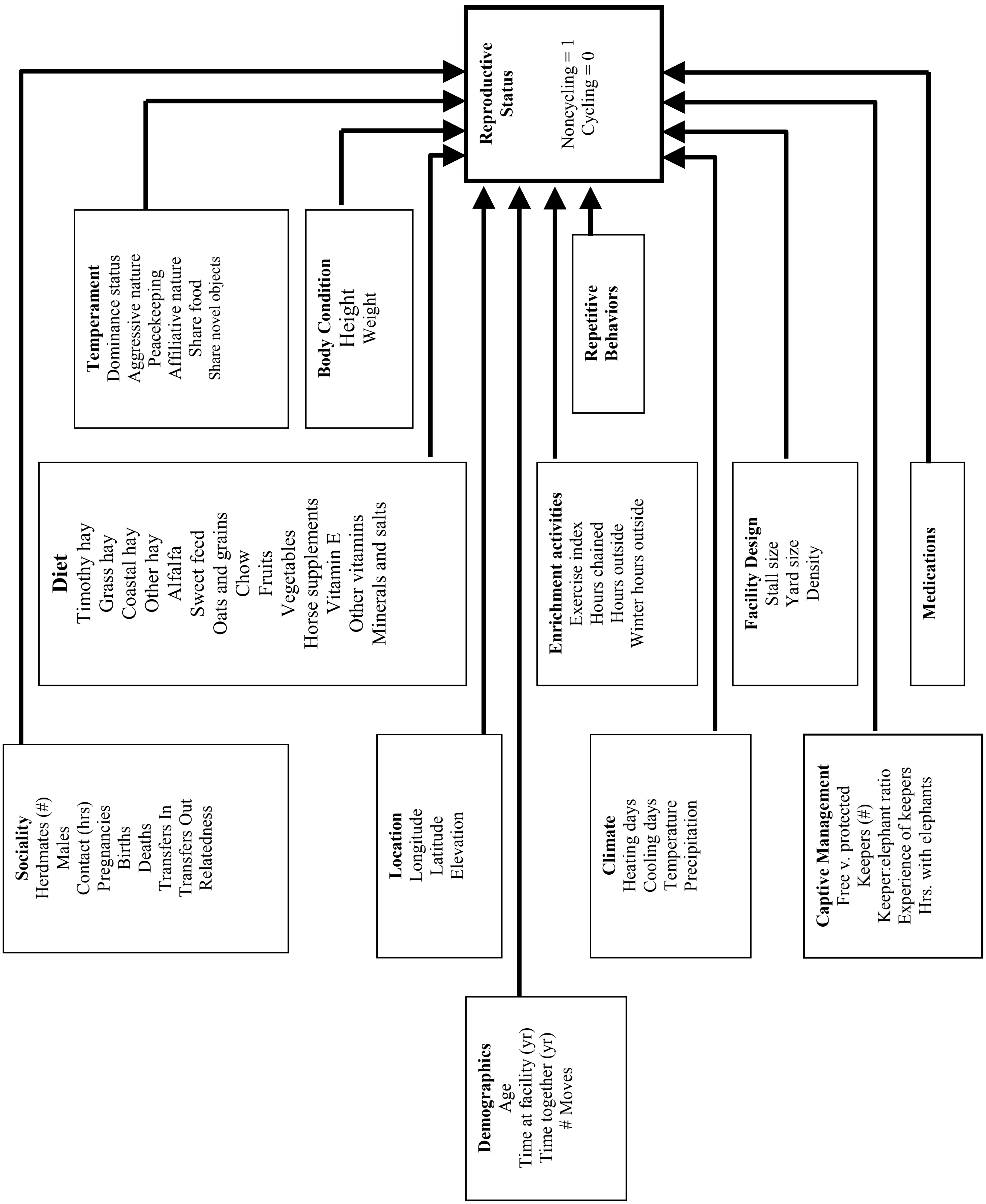
APPENDIX I

MODEL OF FACTORS THAT AFFECT OVARIAN ACYCLICITY IN CAPTIVE AFRICAN ELEPHANTS



Comparison of acrosome status in Asian *(Elephas maximus)* and African *(Loxodonta africana)* elephant sperm using spermac stain

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Semen storage in Asian *(Elephas maximus)* and African *(Loxodonta africana)* elephants has become an important research priority to enhance genetic variability and propagation of captive populations. As a result, methods to evaluate sperm viability have become a necessary method to find ideal semen donors for artificial insemination and for research in semen cryopreservation. In this study, Spermac® stain was utilized to assess acrosome status in Asian and African elephant sperm. The main objective was to i) examine whether Spermac® stain was a good indicator of acrosome status in neat semen collected from both Asian and African elephants and ii) whether there was any difference in acrosome status between the two species. Semen was collected from six captive Asian bulls ($n = 21$) and two captive African bulls ($n = 5$). Freshly collected semen was aliquoted and fixed within 30 minutes of collection. Although results demonstrated Spermac® stain was a good indicator of acrosome status in both Asian and African elephants, there was a significant difference in the percentage of acrosome intact sperm cells between the two species. Neat semen collected from African elephants exhibited a significantly greater acrosome intact percentage (66 ± 20%) compared to Asian elephants (20 ± 22%; $P < 0.001$). This study demonstrated Spermac® stain can effectively evaluate acrosome status in both Asian and African elephants. However, further research is necessary to investigate the significant difference observed between the two species and the low acrosome intact percentage observed in Asian elephant semen.

INTRODUCTION

Artificial insemination has become an important assisted reproductive technique to help propagate the captive Asian *(Elephas maximus)* and African elephant *(Loxodonta africana)* population. As a result, it has become necessary to develop methods to assess semen quality to evaluate individual candidates for semen donors and to assess the quality of semen utilized for artificial insemination.

Several parameters are often utilized to evaluate semen quality. These parameters often measure sperm viability to assess the quality of an ejaculate and to indirectly evaluate male fertility. Acrosome status is one type of parameter utilized to evaluate sperm viability. The acrosome is a sac-like structure located at the anterior portion of the sperm head and plays an important role in sperm-oocyte binding and penetration during fertilization (Cross and Meizel, 1989; Tulsiani et al., 1998). It contains various hydrolytic enzymes, including glycohydrolases and proteases, that are released during the acrosome reaction upon sperm-oocyte binding. The release of these enzymes promote penetration into the oocyte, resulting in fertilization (Abou-Haila and Tulsiani, 2000; Tulsiani et al., 1998). Acrosomes that are lost, missing, prematurely reacted, or damaged before attachment to an oocyte can permanently reduce sperm cell function and fertilizing capabilities. Samples exhibiting low percentages of acrosome intact sperm cells exhibit reduced fertilizing protential, affecting semen quality and fertility.

A variety of commercial stains and methods are available to assess the acrosome status in sperm cells. However, due to the high cost and labor intensive methods utilized for many of these stains, there are few stains that are highly favorable and practical for field conditions. Spermac® stain is a commercially available stain that is rapid, nonlabor intensive and requires only a light microscope with 1000x magnification for acrosomal evaluation. In addition to the easy visualization of acrosome status, Spermac® stain has been utilized in a variety of species due to its low cost and its simple application under variable conditions. Spermac® stain has successfully been used to assess acrosome status in sperm cells from canine (Oettle and Soley, 1985; Strom et al., 1997), feline (Baran et al., 2004; Oettle, 1986; Schafer and Holzmann, 2000), human (Chan et al., 1999; Oettle and Soley, 1986), porcine (Oettle, 1986) and nonhuman primates (Conradie et al., 1994). However, its use to assess acrosome status in Asian or African elephant semen has not yet been validated.

The objectives of this study were to: 1) determine whether Spermac® stain can effectively assess acrosome status in semen from both Asian and African bull elephants; and to 2) compare any significant differences in acrosome status from freshly collected semen from both species.

METHODS

Semen Collection

Semen was collected from six Asian and two African captive adult elephant bulls. Multiple ejaculates were collected from January 2004 through October 2004. Samples were collected using rectal palpation described by Schmitt and Hildebrandt (1998). Penile protrusion was accomplished by massaging the pelvic portion of the rectum caudal to the ampulla to promote emission and ejaculation. The ejaculate was collected using a modified palpation sleeve attached to an insulated 50 ml collection tube to minimize exposure to light and extreme temperature fluctuations. To prevent urine contamination, the collection sleeve was replaced frequently throughout the collection process. The collection tube was immediately placed in an insulated box kept between 32-35°C until evaluation. A real time B-mode hand held Sonosite ultrasound with a 2-4 MHz transducer was used to assess the fullness of the ampulla glands before and after the collection to ensure a complete collection.

Slide Preparation

Samples were assessed for acrosomal integrity using Spermac® stain (Stain Enterprises Inc., Onderstepoort, South Africa) within 10-15 minutes of collection. Slide preparation and staining methods were carried out according to the Spermac® kit manufacturer's guidelines. Slides were prepared by smearing samples in a thin feathered-edge onto a glass microscope slide. Slides were then allowed to air dry for 4-5 minutes before fixation (Fixative I) for 5 minutes at room temperature (21-22ºC). Fixed slides were immersed in each stain (Stain 1, Stain 2, and Stain 3 respectively) for approximately 1-2 minutes. Each slide was rinsed between stains by gently raising and lowering the slide vertically 7-8 times into and out of a tap-water filled beaker. Slides were allowed to air dry before evaluation.

Acrosome Evaluations

Acrosome status were assessed under light microscopy (Olympus BX40) under oil immersion (x 1,000). The acrosome, midpiece and tail were stained green. The equatorial region stained pale green. The posterior portion of the sperm head stained red-pink. Acrosome status was analyzed using criteria described by Chan et al. (1999). Sperm cells were categorized under two categories; acrosome intact or acrosome damaged. Sperm cells were considered acrosome intact when the anterior acrosome portion was stained green and the "rubber-band" thick semicircle (1-2 μm) towards the equatorial region remained continuous and unbroken. Spermatozoa were considered acrosome damaged if the acrosome region appeared swollen, peeled, spotty or irregular in stain, discontinuous color in the “rubber-band” equatorial region, or exhibited perturbations or “bubbles” at the anterior region of the acrosome. Sperm heads that were all white or stained red-pink (missing/loss of acrosome) and contained no green stain were also categorized under “acrosome damaged”.

The percentage of acrosome intact vs. acrosome damaged cells were obtained by dividing the number of cells that were acrosome intact (or acrosome damaged) with the total number that was analyzed and multiplying that number by 100. A minimum of 300 sperm cells were assessed per sample. To minimize error in subjective evaluations, the same technician performed all Spermac® stain evaluations.

Spermac® Stain validation

Spermac® stain validation was performed in Asian and African elephant sperm by exposing an aliquot of fresh semen to multiple rapid freezing and thawing then mixing controlled volumes of damaged sperm cells with measured aliquots of neat semen. The different aliquots were: 1) 100% fresh sperm; 2) 75% fresh sperm:25% damaged; 3) 50% fresh sperm:50% damaged sperm; 4) 25% fresh sperm:75% damaged sperm; and 5) 100% damaged sperm. Percentage of observed acrosome status was then compared to the percentage of expected acrosome status.

Statistical Analysis

Spermac® stain validation utilized linear regressions. The statistical significance in acrosome status was assessed utilizing a one-way analysis of variance (ANOVA). Significance was established at $P < 0.05$. Minitab® version 14 was used for all statistical analyses.

RESULTS

Spermac® Stain Validation

Fresh semen from both Asian and African elephants diluted to various ratios of freeze-killed sperm cells exhibited a decreasing trend in intact acrosome status (Figure 1). Undiluted fresh semen from Asian elephant and African elephant semen exhibited an initial 52% and 53% intact acrosome status respectively. The number of intact acrosome sperm cells decreased as the ratio of freeze-killed sperm cells increased. Samples containing 100% freeze-killed sperm cells demonstrated a > 98% acrosome damaged status. Correlation coefficients (r) between expected and observed acrosome status of intact acrosomes revealed a high correlation for both Asian ($r = 0.95$, $P = 0.005$) and African elephants ($r = 0.85$, $P = 0.025$).

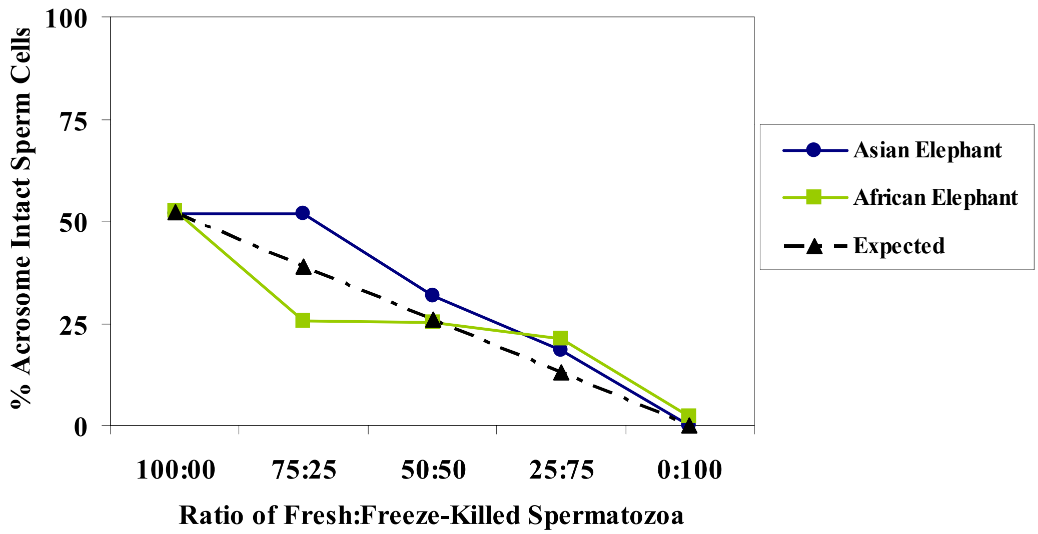

Figure 1. Validation of Spermac® stain to assess acrosome status in Asian and African elephant semen by diluting fresh semen with different ratios of freeze-killed spermatozoa. (Asian elephant: r = 0.95, P = 0.005; African elephant: r = 0.85, P = 0.025).

Acrosome Status

Neat semen samples from 6 Asian elephants (n = 21) and 2 African elephants (n = 5) were evaluated for acrosome status using Spermac® stain (Figure 2). African elephant samples demonstrated a significantly higher acrosome normal status compared to Asian elephant samples ($P < 0.001$). African elephant samples exhibited a 66 ± 20% normal acrosome status and a 34 ± 20% damaged acrosome status (P = 0.116). Asian elephant samples demonstrated an acrosome normal and acrosome damaged status of 20 ± 22% and 80 ± 22% respectively (P = 0.102).

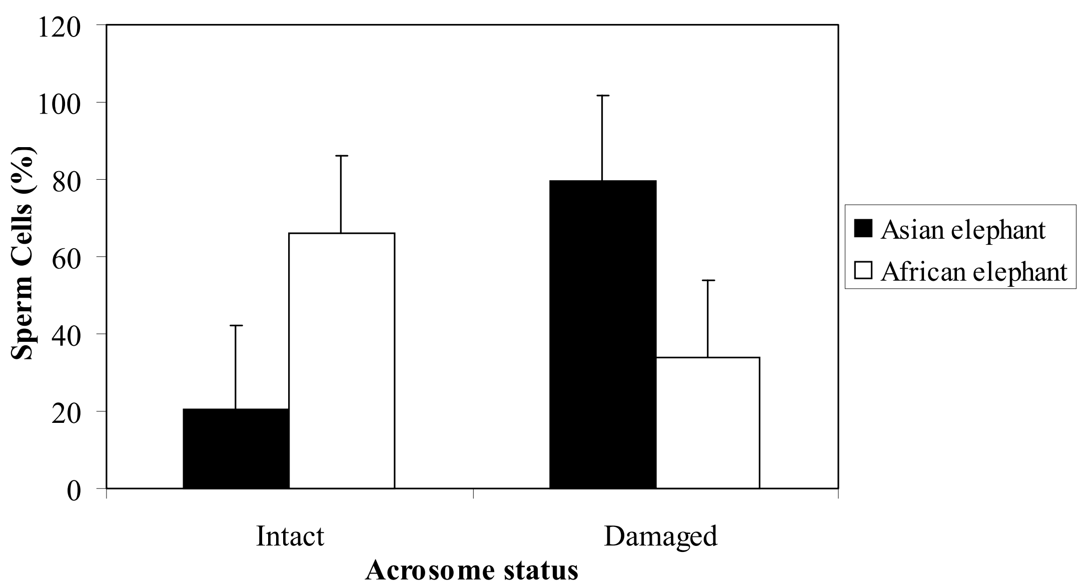

Figure 2. Acrosome status of neat semen from Asian (n = 21 ejaculates from 6 bulls) and African (n = 5 ejaculates from 2 bulls) elephant bulls.

DISCUSSION

This study demonstrated the field friendly use of Spermac® stain and its ability to microscopically visualize and differentiate the acrosome status in sperm cells from both Asian and African elephants. The high correlation between expected and observed acrosome status in the various ratios of freeze-killed sperm cells validated its use to accurately evaluate acrosome status in both Asian and African elephant sperm cells.

Spermac® stain also revealed a significant difference in acrosome status in fresh semen collected from Asian and African elephant bulls. Upon collection, African elephants demonstrated a 66 ± 20% acrosome intact status, whereas Asian elephants exhibited a significantly low 20 ± 22% acrosome intact status. When samples were compared within species, both Asian ($n = 5$; $P = 0.116$) and African ($n = 21$; $P = 0.102$) samples exhibited low variability between samples.

The World Health Organization (WHO) determined the normal acrosome intact percentage for human ejaculates is above 30%. A percentage below 30% may be a concern, due to the low amount of acrosome intact cells available for fertilization. The ejaculates from African elephants exhibited a higher average than the WHO requirement, whereas the ejaculates from Asian elephants demonstrated a value 10% below this criterion. These results may suggest a possible trend towards a higher incidence of reduced fertility in Asian bulls. However, majority of the Asian bulls utilized in this study were proven breeders through natural breeding and 12 out of 21 ejaculates were collected from one bull. Therefore, these results may not represent the whole North American Asian bull population. Nevertheless, due to the concern of reduced fertility in the Asian elephant population, additional research is necessary to further investigate these findings.

The low percentage of acrosome intact sperm cells observed in Asian elephant samples may be due to a number of reasons. Samples exhibiting a low percentage of acrosome intact cells often suggest either a high percentage of immature sperm cells or mature cells that may have become damaged due to handling error during collection. In addition, semen collection utilizing the rectal palpation method results in a sperm rich sample, contrary to an ejaculate during natural breeding that is highly diluted with seminal fluid. Therefore, the low percentage of acrosome intact sperm cells observed in the samples collected from Asian elephant bulls in this study may be a consequence of the collection methods or handling procedures utilized in this study. However, these explanations cannot justify the observed discrepancy in acrosome status between the two species since both Asian and African elephant samples were collected utilizing the same methods, technicians, and procedures for this study.

The results of this study may provide a possible explanation on the discrepancy in the success of semen storage in Asian and African elephants. Asian elephant sperm cells do not share similar sperm survival following cryopreservation compared to African elephant sperm cells. The difficulty in semen storage in Asian elephants may be attributed to the low acrosome status observed in this study. A fresh sample exhibiting a low percentage of acrosome intact cells will demonstrate a further decrease during storage and cryopreservation, resulting in a more pronounced reduction in probable sperm fertility.

Semen quality is an important evaluation for individual bull assessments and to enhance the effectiveness of artificial insemination. The ability to optimize semen storage and cryopreservation in both Asian and African elephants has numerous implications towards elephant conservation and propagation. Therefore, further research is necessary to address not only the discrepancy in acrosome status between species, but also the concerning low percentage of acrosome intact cells observed in Asian elephant semen.

CONCLUSIONS

1. Spermac® stain was validated to effectively assess acrosome status in both Asian and African elephant semen
2. There was a significant difference in acrosome status observed between the two species
3. African elephant samples demonstrated a higher percentage of intact acrosomes compared to Asian elephant samples
4. Fresh Asian elephant semen exhibited a significantly low percentage of acrosome intact status, greatly influencing fertilizing capacity
5. Further research is necessary to investigate the differences in acrosome status observed between the two species
6. Further research in Asian elephant semen is also necessary to explain, minimize and prevent samples from exhibiting low acrosome intact status
7. Future research in optimizing semen quality and storage is necessary to enhance the effectiveness of artificial insemination.

ACKNOWLEDGMENTS

This research was made possible by the endless dedication and support from the participating researchers and facilities that include Ringling Bros. Center for Elephant Conservation, Riddle's Elephant Sanctuary, Carson and Barnes Circus, Have Trunk Will Travel, Tulsa Zoo, Rosamond Gifford Zoo, and Jacksonville Zoo. This research was funded and supported by Ringling Bros. Center for Elephant Conservation and from the Graduate College of Southwest Missouri State University.

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BEHAVIOR

A search for pheromones in African elephant urine

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Although female Asian elephants are known to release a urinary preovulatory pheromone predominantly between two unique serum luteinizing hormone (LH) elevations during the follicular phase of estrus, a comparable pheromone has not yet been identified in African elephant urine. Our study uses solid phase microextraction (SPME) and gas chromatography-mass spectrometry (GC-MS) to analyze urine samples obtained temporally at the first anovulatory LH and the second ovulatory LH elevations to identify compounds that may be used in chemical communication. Bioassays are in progress on selected compounds that appear in the female urine at these critical times during the estrous cycle, or that are suggestive chemically of putative pheromones. In addition, urinary proteins, possible pheromone carriers, are being investigated by polyacrylamide gel electrophoresis (PAGE) and HPLC-MS/MS. This presentation will discuss the details of our methodology and our recent results, as well as directions for future studies in this area.

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The effect of rubberized flooring on Asian elephant behavior in captivity

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An experiment was designed to determine the effects of a poured rubber floor on the behavior of captive Asian elephants. Six elephants at the Oregon Zoo were observed using video cameras for fifteen hours a day. Three observation days were recorded for each phase of the study, in each of two observation areas (Front and Back). (Phase I - old flooring, Phase II - choice of old flooring and new Intracor Natural Path Elephant flooring, Phase III - all new rubber flooring) Five minutes of videotaped behavior and room location were coded using Jwatcher software for each subject twice per hour for each fifteen-hour observation day. In the front observation area, one of the rooms had an old rubber floor prior to the study so the animals were familiar with the flooring substrate. Baseline observations revealed that all six animals spent more time in the room with the old rubber floor. When this room was recoated with the new rubber flooring, the results were similar. In the back observation area there were four concrete-floored rooms. During Phase II of the study, half of these rooms were coated with the new rubber. Two of the six animal subjects spent more time in the two rooms with the new rubber floors. All six elephants showed an increase in locomotion once all rooms had been coated with the new rubber flooring. Initial data analysis suggest that with familiarity, captive Asian elephants at the Oregon Zoo prefer rubber flooring to concrete flooring and are more active on this type of flooring.

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Translation of basic behavioral and chemical signal research into a practical repellent system for Asian elephants

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Asian elephants (*Elephas maximus*) release and utilize a wide variety of chemical signals that widely, yet often specifically, infl uence behavior. Long-term captive and wild studies have revealed a growing array of exuded ketonic compounds whose composition changes during maturation of males. The pre-receptor biochemistry of the ketal pheromone, frontalin, reveals how these chemical signals function in the elephant olfactory system through protein-pheromone interactions, prolonging signal lifetime. Concurrently, to develop a practical olfactory-based repellent system for mitigating human-elephant conflict in southeast Asia, natural chemical products that impinge on the taste and smell sensory systems were tested through antifeedant assays, choice tests and non-choice tests at our USA site, the Riddle's Elephant Sanctuary. Although several substances were effective both during antifeedants and choice tests, no olfactory-based substances prevented elephant ingress into a ripened cornfield, indicating the necessity of a multimodal system. Knowledge of specific elephant behavior formed the basis of the subsequent invented mechanical device designed to include natural chemical products dispersion units. After extensive USA testing this system was manufactured and tested at southern India site in fall, 2003. Night-vision video records for several weeks during the height of crop ripening demonstrated 100 percent efficacy of this system. We discuss our current and future projects and their implications for long-term resolution of aspects of human-elephant conflict and the importance of basic research as a conduit to the development of such projects. Support was provided by Asian Elephant Conservation Fund, US Fish & Wildlife Service to LELR & SWR and IEF to NLS.

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The development of trunk tip behaviors and chemical signal detection in African elephants

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Chemical and tactile (chemotactile) signals play vital roles in elephant interactions. The sex, age and reproductive state of the senders and receivers in communicative interactions affect the release, detection and response of such signals. For animals such as elephants that live in quite different social worlds as adults, the development of chemocommunication is likely to reflect the developmental stages of other behaviors and physiological events. We investigated the development of chemotactile behaviors in a population of 400 wild African elephants at Addo Elephant National Park, South Africa. We examined three main developmental stages when rates of chemotactile behavior by male and female elephants may reflect those of mature animals: (1) Pre-weaning (< 5 years old), (2) juvenile (5-9 years old) and (3) pubescent or young adult (10-19 years old) elephants. We performed focal animal observations with continuous recording over nine months in 2003. We discovered differences in male and female behavior as well as between age classes and we will discuss these in light of elephant social structure. In a simultaneous study with captive African elephants, we observed the responses of males to female urine collected during luteal and preovulatory phases of the estrous cycle. Males responded more to preovulatory than luteal phase urine. We are pursuing the identity of the chemical signal that males use to distinguish among these urine types and thus the reproductive condition of the females.

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CALF DEVELOPMENT AND MANAGEMENT

Calf development and periparturitional behavior of a dam and newborn captive African elephant (*Loxodonta africana*)

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In August of 2003 the San Diego Zoo's Wild Animal Park (WAP) and the Lowry Park Zoo, under the auspices of the AZA's Elephant SSP and a USFWS permit, imported 3.8 African elephants, Loxodonta africana, from The Kingdom of Swaziland. The animals were scheduled for culling due to overpopulation, habitat destruction and their threat to critically endangered species such as black rhino, *Diceros bicornis minor*. The seven (1.6) elephants delivered to the WAP and an unborn calf are the subjects of this paper. During capture in March of 2003 one cow, later named Ndlulamitsi, was determined to be approximately 10 months pregnant based on trans-rectal ultrasound examinations. At the time of their arrival all animals were estimated to be approximately 13 years old and nulliparous. Based on the ultrasound examination results and average African elephant gestation, parturition was predicted to be 20 February 2004.

In this presentation, we provide detailed data about nursing activity around the clock and newborn calf development, describe maternal and neonatal nighttime activity budgets, and explore maternal weight changes during suckling and lactation. A program of positive reinforcement allowed us to separate the pair from the herd and the dam from the calf to collect periparturitional weight data from the dam, post-partum weights from the calf and periparturitional behavior/nursing data. Regression analysis revealed that through the first nine months of life the calf gained approximately 0.545 kg/day while suckling on a regular basis. A T-test showed that this newborn elephant suckled significantly more at night than during the day. Our data compared favorably to published information on wild elephants.

INTRODUCTION

African and Asian elephants (*Loxodonta africana and Elephas maximus*) have the longest gestation period among land animals, yet calves are born when relatively small, i.e., only about 3.5% to 4% of maternal mass (Benedict 1936; Moss 1988; Spinage 1994). Birth is not a prolonged process, and has taken less than twelve minutes when timed (Moss 1988). Although weighing about 100 kg at birth (Eltringham, et al, 1997; Shoshani, et al, 1992), the relatively diminutive size of calves compared to cows hampers recognition of pregnancy in cows by human observation, so few data are available regarding the pre- and post-parturition behavior of dams. Some cows develop enlarged breasts during late gestation and some cows appear lethargic prior to parturition (Moss 1988). In the wild, some cows seem to isolate themselves from the herd prior to giving birth (Moss 1988), but, in general, the behavior of pre-parturient cows is not distinct from non-pregnant cows (Spinage 1994). Given that elephants in the wild ingest about 170 kg of food per day, live in herds of about one dozen animals, move together between food sources, and sleep for less than five hours per 24 hours (Estes 1991), one might expect that cows should minimize changes to their time activity budgets prior to parturition.

Elephant cows sometimes assist newborn calves in standing (Berg 1987; Moss 1988). Prior to their first suckling bout, calves must be able to balance on all four limbs, and first nursing has been recorded at about two to three hours post-parturition in captivity (Berg 1987) and between 1.5 and 4 hours post-parturition in the wild (Moss 1988). In the wild, calves feed exclusively on maternal milk for the first three months of life (Lee and Moss 1986), but the actual amount of milk ingested, and the relationship to infant growth is unknown. Male calves probably have a greater intake, and grow faster, than female calves (Lee and Moss 1986).

The San Diego Zoo's Wild Animal Park imported a group (1.6) of African elephants from Swaziland in August 2003. Before arrival and habituation to the facilities, one of the cows was determined to be pregnant, so we initiated a program to document the behavior of the cow and her calf. In this report, we provide detailed data about calf growth and nursing, explore how it affects maternal expenses, and describe maternal and neonatal nighttime activity budgets during the periparturitional period.

METHODS

Study site and subjects

The San Diego Zoo's Wild Animal Park (Escondido, CA) under the auspices of the American Zoo and Aquarium Association's African Elephant Species Survival Program and a United States Fish and Wildlife Service permit, imported 7 African elephants from the Kingdom of Swaziland. The animals were scheduled for culling due to overpopulation, habitat destruction and their threat to critically endangered species such as black rhino, *Diceros bicornis minor*, in the reserves. All cows were nulliparous and estimated to be 12 to 13 years old. Trans-rectal ultrasound examinations performed during capture in Swaziland revealed that one female, Ndlulamitsi, was approximately 10 months pregnant (Hildebrandt, pers. comm.).

Elephants were housed in a ~1.3 hectares outdoor enclosure containing trees, rocks, shade structures, grass, dirt, watering areas, and two indoor areas containing multiple stalls. Due to effective training using positive reinforcement the elephants could easily be shifted anywhere in the facility or separated from the herd at any time to allow for ethogram and nursing data collection and daily weights. Weights were obtained to the nearest 2.0 kg when the elephants are stationary on the scale (Pennsylvania Scale Company, load limit 9,000 kg, serviced monthly by San Diego Scale Company). During the study period, adult elephants were fed legume grass (*Pennisetum purporem*), Bermuda grass (*Cynodon dactylon*), Sudan grass (*Sorghum vulgare*), alfalfa (*Medicago sativa*), various species of browse, and herbivore supplement pellet.

OBSERVATIONS AND DATA COLLECTION

We recorded nighttime activity budgets, nursing frequency and duration, and changes in weight in both dam and calf. Budgetary and time constraints precluded systematic collection of activity budget data over a 24-hour period. Because the animal care staff monitored the elephants during the day, time budget data was collected at night. Thirteen volunteers collected data.

Instantaneous scan samples (Altmann 1974) of behavior were recorded every minute during 30-minute sessions. Time budget data was collected in three observation shifts: 1800-2200 hours, 2200-0200 hours, and 0200-0600 hours. Data were collected in 30-minute sessions separated by 15 minutes. Observers began data collection 15 minutes after their shift began and waited 15 minutes between sessions. Each observer performed a total of five observation sessions, resulting in 15 samples per night.

Behaviors recorded were subdivided into the following categories:

- **MOVE –** Pace, Sway, Walk, Run
- **FEED -** Eat food, Drink
- **EXPLORE -** Object play, Explore environment, Throw feces
- **SOLITARY -** Dust bath, Trunk to anogenital area, Trunk to body, Trunk to temporal gland
- **AFFILIATIVE -** Touch ele in yard, Touch ele in other yard, Urine test by Ndlula, Urine test by female, Urine test by male (flehmen)
- **AGGRESSIVE -** Threat by Ndlula, Threat to Ndlula, Contact by Ndlula, Contact to Ndlula
- **REST –** Stand, Lean, Lie down
- **MISCELLANEOUS –** Urinate, Defecate, Vocalize, etc.

For purposes of analysis, we combined EXPLORE and SOLITARY into a single category of "solitary" and we combined AFFILIATIVE and AGGRESSIVE into a single category of "social".

Animal care staff and research volunteers collected nursing data 24 hours a day, seven days per week, for the first five weeks of the calf's life. Information recorded included the identity of the observer, date, time of day, duration of nursing and teat selection. Therefore we report only on activity budgets at night, but on nursing behavior throughout the 24-hour day. When we report the mean, we also give the standard deviation and sample size. Statistical analyses were conducted using SPSS 11.0 for Windows.

RESULTS

Although a parturition date was predicted and the pregnant cow's preparturition endocrinology was monitored via urine assay, the dam's exact stage of gestation at the start of the study was unknown, so we were only able to record pre-parturition behavior for one week. A male calf, Vus'musi, was born in an outdoor enclosure on 23 February 2004 at ~0935 hours following a short labor. The timing and duration of labor were based upon the observation of Ndlulamitsi without a calf and still pregnant at 0930 hours, and when next observed at 0940 hours, she was standing next to the calf. The placenta was expelled at 1157 hours. Forty minutes after emergence, Vus'musi attempted to stand with maternal assistance and was upright 16 minutes later. Two hours post-partum, he made his first attempt at suckling, with initial nursing occurring at 1542 hours. His first nursing bout was only 10 seconds in duration.

When Vus'musi was first weighed at two days of age he was 104 kg. The first postparturition weight obtained from Ndlulamitsi was when her calf was three days old and she weighed 2198 kg. Placental weight (including mucus but not including amniotic fluid) was approximately 15 kg. Therefore, calf weight was approximately 4.7% of maternal weight at birth. In the days immediately after birth, although Vus'musi regularly nursed, he sustained a slight weight loss followed by a steady weight gain. Weight was significantly coorelated with day of life ($r^2 = 0.965$, $p < 0.001$; $Y = 0.385x + 102.5$ kg.) On 23 May 2004, Vus'musi's weight had increased to 136 kg, while his mother's weight had decreased to 2156 kg. Hence, over the first three months of life, the cow lost an average of 0.47 kg/day while lactating/nursing.

Nursing occurred around the clock, with Vus'musi spending about two hours per every twenty-four hour period suckling. However, the amount of time-spent suckling was significantly greater at night (1800-0600 hours) than during the day (0600-1800 hours) (63.27 ± 14.70 vs. 55.13 ± 17.81 minutes; Paired $t = 2.340$, $df = 32$, $p = 0.026$). Over the first 33 days of life Vus'musi nursed an average of 8.3% of a 24-hour period, each nursing bout averaged 1 minute, 16 seconds (± 19 seconds), with the calf suckling an average of 101 (± 33.9) times per 24-hour period. During the first 30 days of life the calf gained 12 kg. or ~12% in body weight. The total amount of time spent nursing on a daily basis is shown in Figure 1, and the percent of time spent nursing at night was significantly correlated with the actual amount of time spent on the nipple ($r = 0.681$, $n = 14$, $p = 0.007$) which indicates the reliability of our point sampling method for constructing time budgets.

We observed that Ndlulamitsi spent less time emitting solitary behavior as the preparturitional week progressed and less time moving at night in the two nights prior to birth (Figure 2). We also noted that Ndlulamitsi spent more time resting during the preparturitional week than in the subsequent weeks, and spent much more time in social interactions following parturition (Figure 3). In addition to the calf's activity budget for his first two weeks of life (Figure 4) a first occurrence study was conducted to document milestone behavior and events. This information is not provided here so please contact the authors if interested. Teat selection was random; Vus'musi suckled from the left teat 46% of the time (n = 3376 suckling bouts) and spent 48% of his nursing time at the left teat. On day 1 of life, only 35% of nursing attempts were successful, but his success rate climbed rapidly so that by day 3 of life, he was nursing successfully on 87% of attempts.

DISCUSSION

Nighttime observations of Ndlulamitsi were insufficient for systematic analysis, but hinted at two trends. First, her general activity level was similar to that reported for African elephant cows of about the same age at Zoo Atlanta (Brockett et al., 1999). At Zoo Atlanta, females at night divided their time into resting (ca. 55%), feeding (ca. 38%), walking (ca. 3%), and other (ca. 3%), while at the Wild Animal Park, the periparturitional activity profile of Ndlulamitsi was resting (55%), feeding (25%), walking (3%), and other (16%). However, other behaviors accounted for 2% of the nightly time budget during the preparturition phase. Second, results conform to the suggestion that near-term cows in the wild are more "sedate" (Moss 1988). Between 1800 and 0600 hours, Ndlula spent 67% of the evening resting, and this fraction decreased in the two weeks following the birth of Vus'musi.

Although only 4.7% of maternal mass at birth, the calf had grown to 5.5% of maternal mass by 5 weeks of age and 6.3% of maternal mass at 3 months of age. Hand raised Asian elephants gain weight at approximately 1.0 kg/day over the first year of life (Reuther 1969), but published neonatal weight gain in African elephants is unavailable. Although the calf sustained an initial weight drop, subsequent weight changes revealed a fairly steady increase in body mass. (Figure 5). During the first 30 days of life we documented a growth rate of 0.47 kg/day ($Y = 0.466x + 100.0$ kg.), 0.39 kg/day over the first three months of life ($Y = 0.385x + 102.5$ kg.) and 0.55 kg/day over the first 9 months of life ($Y = 0.545x + 88.0$ kg.) (Figures 5 and 6). The highest growth rate per month occurred during month seven when the calf gained 0.86 kg/day ($Y = 0.863x + 18.6$ kg.).

Our nursing behavior findings can be directly compared with data reported among wild African elephant calves. Lee and Moss (1986) found that male calves nurse for an average of 86 seconds per bout, whereas we found that Vus'musi nursed for an average of 76 seconds per bout. However, they found that males suckled about once every 37 minutes, whereas we found that suckling occurred about once every fourteen minutes. Based upon their data, calves spend an average of less than 10% of the day nursing during the first three months of life and we were able to establish that Vus'musi suckled for about 8.3% of the 24-hour day. Therefore, although the growth rate of the calf was slower than that reported for hand-raised calves, the milk intake pattern was remarkably similar to that found among young calves born in wild herds in Africa.

CONCLUSIONS

1. Over the first 33 days of life the calf nursed 8.3% of a 24-hour period.
2. The cow lost an average of 0.47 kg/day while lactating/nursing during the first three months of the calf's life.
3. The growth rate of the calf was slower than that reported for hand-reared calves, but the suckling pattern was very similar to that reported for wild African elephants.
4. The growth rate of the calf during the first 30 days of life was 0.47 kg/day, 0.385 kg/day over the first three months of life was and 0.545 over the first nine months of life.

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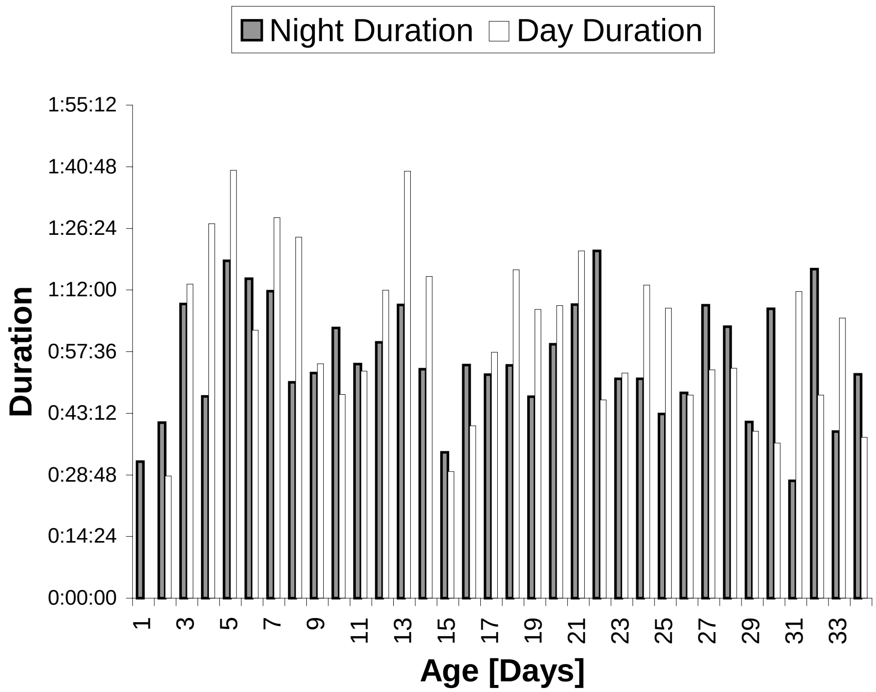

Figure 1. Amount of time spent nursing by Vus'musi during nighttime (18:00 – 06:00 hours) and daytime (06:00 – 18:00 hours). Data were recorded on a 24-hour basis, with day 1 the first day of life.

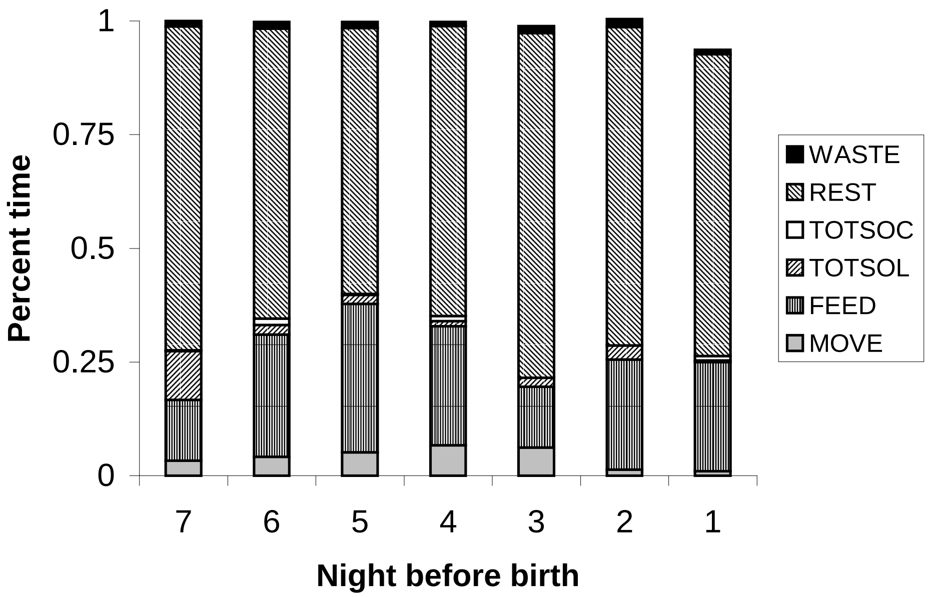

Figure 2. Ndlulamitsi's nocturnal time budget during the preparturitional week. Data were recorded from 1800 to 0600. See text for definitions of activity states.

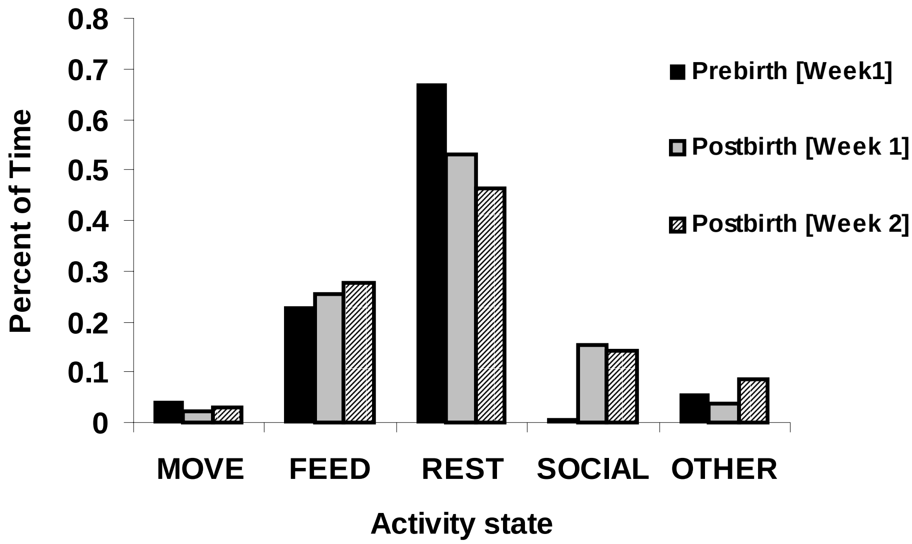

Figure 3. Ndlulamitsi's nocturnal time budget during the periparturitional weeks. Data were recorded from 1800 to 0600. See text for definitions of activity states.

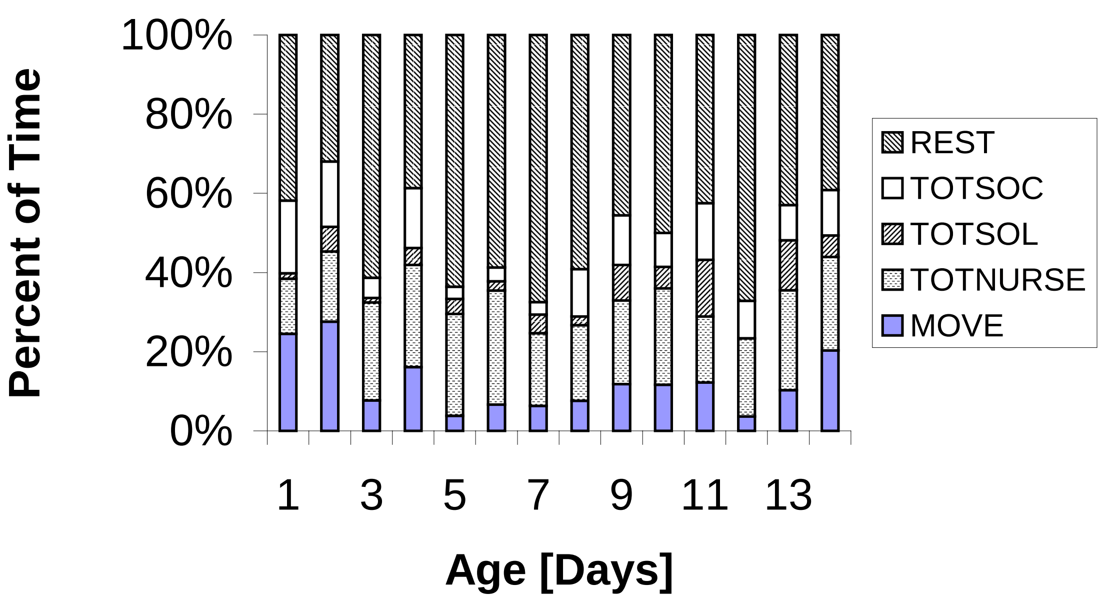

Figure 4. Vus'musi's nocturnal time budget during the first two postpartum weeks. Data were recorded from 1800 to 0600. See text for definitions of activity states.

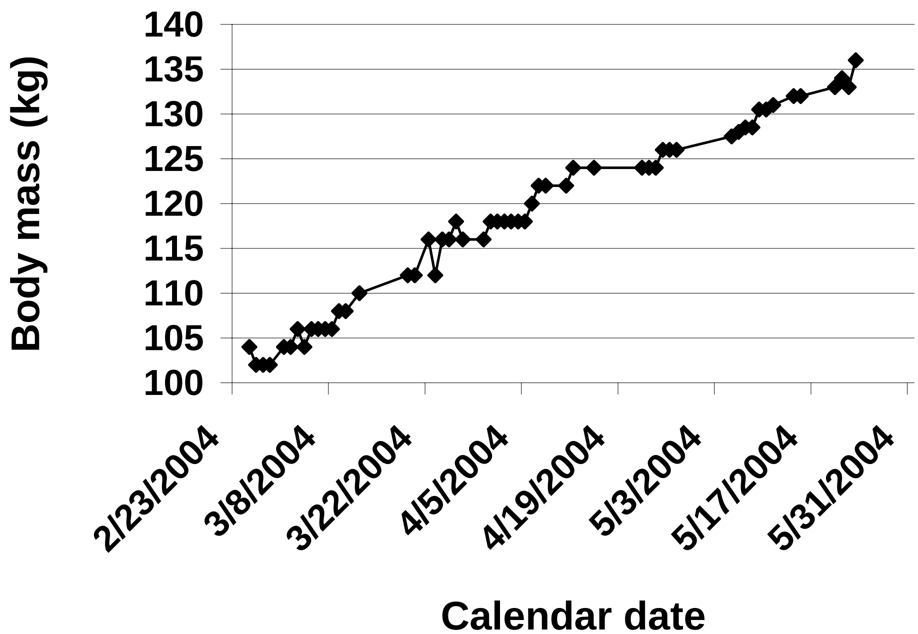

Figure 5. Growth profile of Vus'musi from 23 February 2004 through 22 May 2004. Birth date was 23 February 2004.

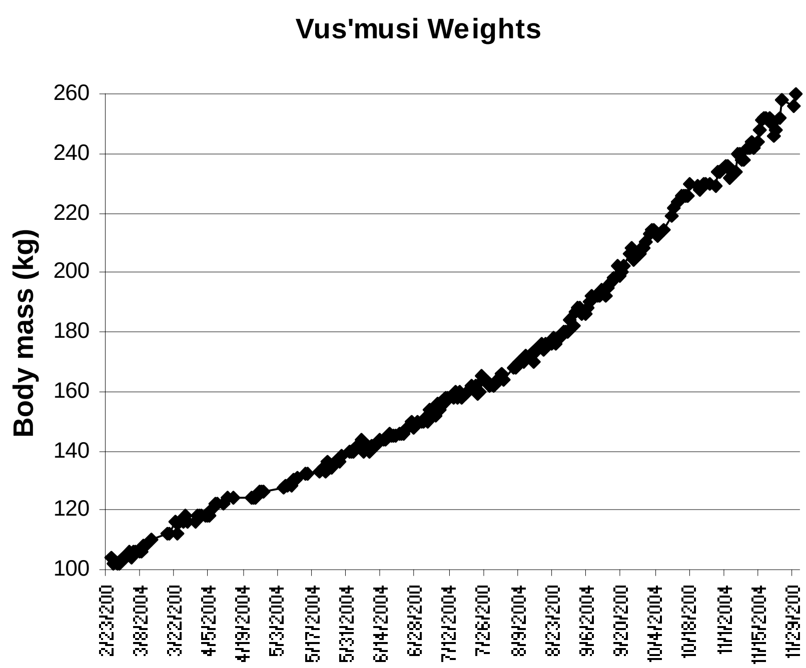

Figure 6. Growth profile of Vus'musi from 23 February 2004 through 30 November 2004. Birth date was 23 February 2004.

Previous results: Development and ontogenetic stages of African elephant calves (*Loxodonta africana*) born by three primiparous cows under human care

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Reproduction and subsequent offspring care play a central role in the gregarious lives of elephants. Under natural circumstances, females live in stable family units, which implies familiarity with the process of birth, the presence of calves, and with maternal and allomaternal care from childhood on. This is in stark contrast to the zoo situation: most elephant groups are a random mixture of unrelated as well as inexperienced individuals. Despite the increasing rate of elephant births in zoos all over the world, the ontogeny of African elephant calves is still poorly explored. There exist a few captive case studies, but there is only one detailed wild-life study from Lee and Moss provided. Five years ago the Vienna Zoo concentrated on breeding and started to build up an age-distributed elephant group. Because elephants have a long-lasting infancy, the idea was to monitor ontogenetic processes over several years. Data was collected in two different zoos. An attempt was made to clarify the influences of keeping conditions and social relationships. After more than three years of observation, this paper presents results on the calves' basic behavior elements (feeding-, comfort-, play-, suckling behavior) as well as on sleep- and activity patterns. Moreover, the paper describes conspicuous social behaviors such as covering the sleeping calves with hay, hindering them from lying down or repelling nursing behavior (which occurred in both groups). These specific social behaviors have never been described before. Ultimately, explicit correspondences between field- and zoo data were established in suckle trends and other ontogenetic processes. Scientific assistance concerning post-natal developments seems to be one reasonable way to achieve a sustained reproduction success.

INTRODUCTION

Between 1980 and 2003, the European statistics show 51 births in African (*Loxodonta africana*) and 121 births in Asian (*Elephas maximus*) elephants. 74.5% of the total number in African elephant calves were born during the last ten years (Terkel 2004). Artificial inseminations and sophisticated techniques of non-invasive hormone analyses for ovarian activity levels had improved the reproductive success slightly. But nonetheless, such successes in elephant breeding are accompanied by a variety of unexpected repercussions. Under natural circumstances, females live in stable family units, which implies familiarity with the process of birth, the presence of calves, and with maternal and allomaternal care from childhood on (Lee & Moss 1986, Lee 1986, 1987, 1991, Moss et al. 1983). Multiparous, experienced cows assist primiparous females in rearing and offspring care. Current wild life studies found out, that the knowledge of experienced family members or matriarchs is definitely important in an elephant's life (Mc Comb et al. 2001). But most elephant groups in zoos worldwide are random mixtures of unrelated as well as breeding-inexperienced individuals. This is also why, monitoring in first born calves demonstrates an important role. This study concentrates on ontogenetic stages, sleep-and activity pattern as well as social behaviors of three first born calves. Two of them are born in the Vienna Zoo (Austria), one in Great Britain at the Colchester Zoo. The observation units were shared in different life stages, over a time period of more than three years. Behavior trends showed clear accordance between field- and zoo data. Further were conspicuous social behaviors described and an attempt was made to find possible causes for these phenomenons. The realisation of a self-sustaining zoo population seems to be only possible with a permanent scientific assistance, especially on the basis: the first born calves. Because every single individual demonstrates a part of our future zoo population.

METHODS

Study animals and housing

All study animals were born by primiparous cows, which were trained and kept under a free-contact system. During summer observations, all animals were kept outside. The observation-unit at the Colchester's Zoo in December 2003, were only conducted in the inside enclosure. During this observation period, all animals were housed inside.

Table 1. Study animal information.

Calves	Sex	Birth date	Facility
Abu	M	25.04.2001	Vienna Zoo, A
Kito	M	06.12.2002	Colchester Zoo, UK
Mongu	F	25.05.2003	Vienna Zoo, A

DATA COLLECTION

All personal observations were done from the enclosure borders, to avoid any contacts or disturbances in the elephant's natural behavior. This paper only presents results from day-time observations in a timeframe between 08.00 and 19.00 o'clock. Results from Abu's nocturnal behavior were published in the past (Baldrian et. al 2003, 2004). Instantaneous and all occurrence sampling (Altmann 1974) was used as the observation method. This was followed by constructing time budgets with the behavioral index of each calf. Which have allowed following ontogenetic trends of specific behaviors for years. All behavior values are presented in percent based on the respective observation unit (per observation unit= pou).

Table 2. Observation units

Calf	Age in months	Observation period in hours
Abu	3	84.5
	4	39.0
	15	75.0
	24	42.0
	27	118.0
	40	35.0
Kito	3	52.0
	9	108.0
Mongu	1	150.0
	2	144.0
	3	160.0
	15	69.0

Table 3. Definitions of documented behaviors

Behavior	Definition
Suckling	Beginning with the nipple contact. Short breaks were not timed. A suckle bout was timed only if a duration of 30 seconds was exceeded
Foraging and Feeding	Trunk movements in connection with food providing and ingestion. Feeding with mouth or the help of the trunks and following chewing movements.
Comfort behavior	Rolling on the ground, coating their bodies with mud, substrate (sawdust) or sand. Trunk movements in connection with body-hygiene.
Solitary play	Repeated movements in connection with objects (e.g. balls, car wires, tires, branches)
Social play	Interactions with mostly closer aged play partners, chasing games, mounting games, trunk wrestling, training of social roles
Early sexual behavior	Gender specific behaviors in reference to objects (e.g. genital rubbing on branches or mounting objects)
Locomotion and Environmental Exploration	Running, walking or climbing for investigation their environment. Development for motor skills
Resting while standing or leaning	In relaxed posture, with forward sloped head and atonic trunk tip on the ground
Resting while lying	In varied forms (ventral or side position), stretched out or convolved

Behavior definitions are according to preparatory studies from Berg (1987) as well as from Lee and Moss (1986).

RESULTS

During the calves first three month of life their main behaviors are characterized by suckling, feeding and foraging as well as locomotion and environmental exploration. Time investments of these three behavior-classes are similar in all of the study animals. Concerning the calves suckling behavior, all babies were responsible for initiating the nipple contact and the following suckle-bout. Two of the primiparous cows terminated during the first month of life a majority of their nursing-activities it selves. Typical repellent nursing behavior was just ignorance or defending movements, but no cow showed active aggressive behavior (like trunk beating or foot kicking). In the case of Kito the repellent nursing behavior resulted in the fact that he suckled around 50% of all suckle bouts from an other lactating cow (during the second observation period). While the suckling behavior decreased slightly, food intake increased continuously. In the age of three month Abu, Kito and Mongu feed between 4.9 ±0.48% and 6.2±0.78 % (per observation unit= pou).

During the calves developmental stages this behavior replaced more and more other behaviors like play- or explorative behaviors. Abu for example spent 60.3 ± 5.01% (pou) in feeding and foraging in the age of 40 month. While suckling or feeding and foraging trends are rather similar in the three study animals, comfort-, resting- and play behavior continued relatively trend-less. Especially the resting behavior is one of these trend-less behaviors. In all of the three study animals time investments in resting (while standing or while lying) occurred completely different. In the case of Abu it seems to be that he major rested in lying in the age of three month and in the course of his life it changes more and more in resting while standing during the day. Mongu the second calf from the Vienna Zoo rested also mainly in lying, during her first, second and third month of life. As well as during her 15th month of life. Additionally she also rested in standing, but not during the last observation unit, when she was 15 month old. The most conspicuous resting behavior showed the calf Kito from the facility in England. As soon as Kito tried to lay down, two or three cows put him up immediately. This is why Kito showed neither during the first nor during the second observation unit more than 1.4±0.28 % (pou) resting while lying behavior. Resting prevention occurred also Vienna, but only inside the first weeks of Mongu's life. After her first month this behavior decreased down to zero. Playing with objects was also one of the trend less behaviors.

Kito's play behavior in the age of three month with 3.3±1.0% (pou) was, compared to Abu's in that age with 7.4±1.22% (pou) very low. Also Mongu showed small amounts of objects playing during that age, but Mongu was the only calf with a closer aged play-partner (Abu) since her birth. Play behavior showed especially in Abu an interesting developmental course. When Abu was about two years old, the second calf of Vienna (Mongu) was born. Before that birth Abu's object playing decreases from 7.4±1.22% down to 5.2±1.0%. After Mongu's birth object playing decreases more down to 0.2±0.15%. Object playing changed in social play, whereby a majority of all play bouts were initiated by Abu. Beside typical basic behavior developments, the animals showed also conspicuous social behaviors. Like covering sleeping calves with hay, calf shadowing or genital checks. All of these special social behaviors occurred in both study groups.

DISCUSSION

Outside zoos, there have been surprisingly few studies of behavioral development processes in elephants, Cynthia Moss and Phyllis Lee carried out one of the most detailed studies from a wild situation (in Sukumar 2003). This is why a majority all results will be compared to results from those studies.

During the first three month of life Abu, Kito and Mongu showed similar behavior trends in suckling, feeding and foraging as well as locomotion and environmental exploration. The suckle initiation of the babies accords to wild life observations from Lee & Moss (1986). Studies from the Amboseli National park have also shown, that no calf had been observed to suckle successfully from a lactating female other than its mother (Lee & Moss 1986).

This fact differs to suckle results from Kito, the calf from England. During the second observation unit (see in table 2) he suckled nearly 50% of all suckle bouts from an other lactating cow. Allo-suckling in elephants is normally rather an exception, like Lundberg (et al. 2001), Lee (1991), Garai (1993) and Sheldrick (1992) described it in the past. Also the second calf from the Vienna Zoo Mongu had during her first weeks of life, problems in her suckling success. Mongu's dam seemed similar to Kito's dam a little bit distressed or unsecured. If the babies tried to suckle the mothers ignored them, or gave their offspring no permission to suckle. The most typical maternal rejection in the wild is stepping away from the calf and pulling the nipple from the mouth (Lee & Moss 1986). This was also in the captive study animals shown. The point in those cases was that the babies did not vocalize, like suckle cries, bellowing or begging calls. The lack of the vocal trigger from this rather introvert calves could be a possible cause for repellent nursing behavior or the dam's ignorance. Also the resting prevention regarded only these "unvocal" calves Kito and Mongu. In contrast to that, Lee found out (1987), that the highest rates of calf distress-vocalisation are from babies born by inexperienced, young females.

Trying to feed began during the first month of life and rises rapidly after the third month of life according to wild life data (Lee & Moss 1986). During their third month of life, the calves spent between 4.9 ±0.48% and 6.2 ±0.78 % (pou) in feeding and foraging, which sound reasonable because the first set of teeth erupt between the 6.and 9.week. (Lang 1980). Beside the lower time consuming suckling and feeding behavior locomotion and environmental exploration was the main behavior during the early month of life.

All three study animals showed similar time investments, between 71.9±1.85% and 80.9±1.47% (pou) during the age of three month. The quality or extent of their maternal care seems to be independently related to the calves' explorative behavior. During the first month or years of life, elephant babies have to train their motor skills including coordination of trunk-movements and musculature developments. Adams and Berg (1980) suggested therefore the importance of enclosure structures (like branches, logs, stones). Also different floor qualities could simulate natural conditions. Enclosure structures may not only influence explorative or locomotional behaviors. Also the play behaviors, especially with objects could be influenced by environmental surroundings. The calf Kito from Great Britain had during his third month of life no possibility to play with objects. As mentioned in material and methods were all these animals kept inside during that observation unit. Because of the fact that the adult cows feed every thing which could be an interesting play object for Kito, no balls, car tires, logs, braches or other play items were available for Kito. This could also be a reason why Kito played a half year later also only 2.3±0.6% (pou) while he was kept outside.

Another possible environmental influenced behavior is the comfort behavior or body hygiene. Like Berg (1987) observed it, the three calves began this behavior by rolling in dirt and later dusting themselves by using the trunk. While Mongu showed a continuous positive trend in comfort behavior, Abu's body hygiene was characterised by irregularities. Between the third and 24.month of life the behavior increased from 3.6±0.68% up to 4.9±1.34% (pou). In the age of 27 month it decreases down to 4.1±0.73% and finally in the age of 40 month the behavior amount levelled off to 4.3±0.6 %. Possible cause for that apparent decline in comfort behavior could be the weather situation. During the observation unit in the year 2003 while Abu was 24 and 27 month old, it was one of the hottest summer in Vienna, with constant temperatures around 30°Celsius. One year later, during Abu's 40. month it was unnatural cold.

Kito showed during his third life month actually no comfort behavior, because inside the enclosure (inside) was no substrate (like sawdust or sand) available. Nevertheless a half year later, while the animals were kept outside Kito was able to do comfort behavior (by using the trunk) perfectly. So even through Kito had no possibility to train his trunk during his possibly imprinting first month of life, he was nevertheless able to show this behavior later trouble-free.

Finally the meaning or causes of all these specific differences or developments are still unknown. There are a lot of hypotheses what may trigger ontogenetic processes. Data from these three animals have shown that exogenous factors like enclosure structures, as well as social factors like the quality of maternal care are virtually responsible for the calves' ontogeny.

But with a random number of three it is difficult to say in what kind of dimension influences are de facto responsible. Further research with an enlarged random number could contribute the unknown mosaic of the elephant's ontogeny. Because if we keep elephants in respectable zoological institutions, does it not has to be our responsibility to monitor our calves with a scientific assistance? Only in that way, we will learn more about this complex social system and could thereby achieve a sustained reproduction success.

CONCLUSIONS

1. Data of three calves under human care showed correlations in suckling, feeding and foraging as well as in locomotion and explorative behaviors
2. Typical trend less behavior are resting, comfort and play behavior
3. Trend less behavior may be influenced by exogenous factors like the weather, or environmental components (like enclosure structures)
4. Repellent nursing or resting prevention could stand in connection with the lack of vocalizations by the calves

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A review of findings on the behavioral development of African (*Loxodonta africana*) and Asian elephant (*Elephas maximus*) calves

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Many observers have described aspects of the development of elephant calves, for both Asian elephants (*Elephas maximus*) and African elephants (*Loxodonta africana*). I have drawn from a variety of sources to produce a generic description of the behavioral development of elephant calves. The intention has been to identify developmental milestones for physical growth, sensori-motor abilities, nonsocial behaviors (such as self-grooming), and social behaviors (for example, play). Data from wild elephants, captive herds, and "tame" elephants (wild-captured, actively managed elephants with extended ranges). The extended paper provides a reference list indicating the primary sources for each observation, and indicates whether the observations were of African or Asian elephants. It complements a recent survey of the management, behaviors and physical development of African elephant calves born in captivity (Kowalski, Dale, & Hardin, 2004).

INTRODUCTION

This paper reviews the literature on elephant calf development, with an emphasis on behavioral development. Some descriptions of elephant calf development are hundreds, or thousands, of years old (see, for example, Edgerton, 1931; Groning & Saller, 1999; Spinage, 1994). According to Hediger (1952, p. 107), "Princess Alice" was the first Asian elephant to be bred and deliver a calf in the USA. The elephant calf, born in 1910, lived for only two months. Since then, however, there have been relatively few captive-bred elephants calves born in North America. The situation is severe enough that neither the Asian nor the African captive populations in North America are self-sustaining at this time (Olson, 2004b, p. 123). For example, there were only 27 births of captive-bred African elephants in the 26 years between 1978-2003 (Olson, 2000a). Survival of the captive population in North America will require a substantial increase above the current rate of reproduction. It will also be helped by an improved knowledge of the birth process and of calf development and care. However, recent work has placed the behavioral development of calves in the context of the social structure of the elephant community, and has noted some sex differences in the pattern of development (Lee, 1986; Lee & Moss, 1986, 1999; Poole, 1994). With the long-term observation of elephant populations in the wild (e.g., McKay, 1973; Moss, 1988; Sukumar, 1989), and with the close study of captive populations (for example, Kuhme, 1963; Mellen & Keele, 1994) and "tame" populations (Nair, 1989), there is the possibility of establishing "milestones" for behavioral development. The following is a list of behaviors and physical characteristics of Asian and African elephant calves cited in the literature. Many other species-specific behaviors described for adult animals are not included in this preliminary report. Other authors have described these behaviors (e.g., Dale, Kahl, Armstrong, Shyan, &Barton, 2004; Kahl & Armstrong, 2002). It is hoped that the information below will be useful for the management of captive animals, and for the investigation of wild populations. While there are several generic descriptions of the development of elephant calves (e.g., Moss, 1988; 2000; Sikes, 1971; Spinage, 1994; Sukumar, 2003), the current review reports specific behaviors, physical characteristics and developmental milestones for individual elephants - and indicates the sources of the data. The intent is to provide averages and ranges for each statistic.

In studying the life-span development of elephants, it will be helpful to settle on a standard set of age categories. Based on the work of Sukumar (1989, p. 177) and Lee (1986, p. 391; 1987, p. 279) among others, I suggest the following age categories (see also Kahl & Santiapillai, 2004, p. 2):

Neonate:	0-48 hours
Infant :	0-12 months
Old Calf:	13-24 months
Young Juvenile:	25-60 months
Old Juvenile:	61-120 months
Adolescent:	10.1-15.0 years
Sub-Adult:	15.1-20.0 years
Adult:	20.1-55 years
Old Adult:	56+ years

METHODS

There are numerous sources of information about elephant behavior, in particular, calf development. The author reviewed journal articles, books (including book chapters), newspapers, popular magazines, and Internet sites. The Internet sites were usually those of institutions housing elephants and of professional organizations devoted to elephant research and management. The review includes only information from identifiable and well-known sources. Moreover, with the exception of some generic data at the start of some sections of the appendix (e.g., Play behaviors), data were included in Appendix I only if the sources reported specific behaviors by individual elephants.

Most of the data below refer to calves in the Neonate, Infant, Old Calf and Young Juvenile categories. Where possible, I have indicated whether the observation was obtained from a male (m) or female (f) elephant, whether the animal was an African or Asian elephant, and whether it was "captive", "wild", or "tame" (Asian working elephants). Within each section of the paper, generic data are provided first, followed by specific details. Unless otherwise indicated, any generic or general information related to calf development has been obtained from one of the following six general sources: Moss, 1988; Olson, 2004b; Shoshani, 2000; Sikes, 1971; Spinage, 1994; Sukumar, 2003.

RESULTS

A summary of those calf behaviors that have been reported is included in Appendix I. There is not much published information about many of the types of behavior. Where there is information, the data for captive (*ex situ*) and wild (*in situ*) elephants are generally quite similar.

A sampling of significant findings is given in Table 1 (below). Data are presented separately for captive (*ex situ*) African elephants, wild (*in situ*) African elephants, captive (*ex situ*) Asian elephants and wild (*in situ*) Asian elephants. In many cases, behaviors are reported for animals in only one or two of these four categories. It is not clear why there is an absence of reports for the animals in the other categories: It could be due to a lack of published research, because the animals may not exhibit such behaviors under all living conditions, or because I was unable to find the relevant information.

Table 1. Estimates of some developmental milestones for African and Asian elephants.

Characteristic Or Behavior	African *In situ*	African *Ex situ*	Asian *In situ*	Asian *Ex situ*
Gestation (days/mean)	656	657	*Est.*634-664	644
Birth Weight (kg/mean) Range of weights		100 *(n=8)* 79-114		100 *(n =36)* 68-133
Birth Shoulder Height (cm/mean) Range of heights (cm)		89 *(n =8)* 82-95		88 *(n = 11)* 69-100
First Stand (minutes/median)	14 *(n = 5)*	16 *(n = 2)*		11 *(n = 5)*
First Walk (minutes/median)	49 *(n = 2)*	*Est.* 60		55 *(n = 4)*
Five-year mortality rate (%)		33		23
First trunk-to-mouth drinking (weeks)		10		12
First swallow vegetation (months)	1-4	3-4		2-4
Eat dung (weeks)	*Est.* 2-3	<10		
Chase other species (months)	5	Yes. *No age given*		10-11
Youngest Dam (years)	8			5
First successful suckling (hours)	1 *Range 0.5-1.5*	2-3 *Range 2-22*		3 *Range 2-11*
Suckling duration (minutes)	1.5			1-2
Inter-suckling interval (minutes)	37-50			30

DISCUSSION

Given the considerable amount of research published on the characteristics of elephants, it is surprising that there is so little empirical data that can be tied to specific elephants. It would be particularly interesting to compare the characteristics of the *in situ* and *ex situ* animals of each species. Evidence that captive elephants are developing in ways very similar to those of their wild counterparts would provide powerful evidence that these animals are physically and behaviorally healthy.

CONCLUSIONS

The main conclusion from this survey of published data on elephant calf development is that a lot more of the available data (presumably in various institutions, private offices and research laboratories) should be published. Perhaps it is time to develop international databases on which relevant information could be posted. Otherwise, we are at risk of relying on general estimates – and the empirical basis for these estimates is not always clear.

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APPENDIX I

Behaviors and developmental milestones reported for African elephant (*Loxodonta africana*) and Asian elephant (*Elephas maximus*) calves.

Gestation: 650-660 days

Asian captive: 664 days (Miller, 1997, p. 15)
Asian captive: 635 days, 634 days (Maberry, 1962, p. 80)
African wild (Amboseli); Mean = 656 days (Moss, 1983)
African wild: 649-661 days (n=1: Lang, 1967, p. 156)
African wild (m): 660 days (n=1: Moss & Colbeck, 1992, p. 62-64)
African captive: 21.5 mo (f), 21.5 mo (f), 21mo (m) (Berg, 1987, p. 172)

Pre-parturition:

1. Before birth - no obvious change in maternal behavior, within hours of labor (Mellen & Keele, 1994; Spinage, 1994).
2. Asian and African and: Progestagen levels drop rapidly 1-13 days before parturition (Olson, 2004b, p. 137)
3. Asian captive (n=1) - progesterone drop 3 days before birth (Miller, 1997, p. 15)

Mucus Discharge:

1. Asian captive - Mucus discharge (probably cervical plug) 107 min before calf birth (Sharma & Krishnamurthy, 1984, p. 158)
2. African captive: Mucous plug about 24 hours before birth (Lang, 1967, p. 155)

Contractions:

Asian captive - average of 5.9 min apart (Sharma & Krishnamurthy, 1984, p. 158)
African captive: 4-6 min apart (Lang, 1967, p. 155)

Birth - Seasonal:

African wild: 81% of births between November and May (n = 1030, Amboseli, Kenya: Moss, 2001, p. 150.)

Birth: Time of Day:

Captive African: 3 births, all between 3:00am-6:00am (Berg, 1987, p. 175)

Sex ratio (Male/Female):

African wild: 0.92 (n = 1162: Moss, 2001, p. 150)
African wild: 1.01 (n =614: Visscher, van Arde & Whyte, 2004, p. 113)

Twins:

Rare, <1% of births; usually only one survives (Moss, 1988)

One-year Mortality Rate/Live Births:

African wild: Calf 1-year survival rate: 64% (Buss, 1990, p. 12)
African wild: Calf 1-year survival rates (all from Moss, 2001, p. 150)
Mother under 10 years: 50% (small sample, n =4)
Mother 10-15 years: 76% (n = 144)
Mother 15-20 years: 79% (n= 70)
Mother over 20 years: 90% (n=411)

Five-year Mortality Rate/Live Births

Asian captive: 23% (n = 92:Taylor & Poole, 1998, p. 319)
Asian tame: 6-11% (Taylor & Poole, 1998, p. 319)
African captive born and bred: 33% (n = 21: from Olson, 2004a)

Dam's Birth Position

Asian captive: Crouched in defecating position after lying down (Sharma & Krishnamurthy, 1984, p. 158)
African: Normally standing on all fours (Sikes, 1971, p. 167)
African captive: Standing - bent knees, after lying down (Lang, 1967, p. 156)

Calf's Presentation at Birth

Asian captive: All tail first (n = 24) Mellen & Keele, p. 22)
African: head first (Sikes, 1971, p. 166)
African wild: Both head first and feet first (Estes, 1991)
African and Asian: Usually (rear) feet first (Olson, 2004b, p. 137)

Birth Weight:

Asian wild: Range = 75-115 kg. Shoshani (2000) estimates birth weight to be 75-115 kg for Asian elephants (pp. 46-51).
Asian captive: 119 kg (Range, for 7 females, 68-133 kg: Olson, 2004b, p. 193)
Asian captive: 118 kg (f), 144 kg (f), 125 kg (m), 133 kg (f), 130 kg (f) (Olson, 2004b, p. 145)
Asian captive: 79kg (f), 79 kg (m), 109 kg (m) (Mellen & Keele, 1994, p. 23)
Asian captive: 120 kg (f), Leighton (1994, p. A9)
Asian tame: Mean birth weight = 90 kg (n =9: 7 females & 2 males; Nair, 1989, p. 48)
Asian captive: 102 kg (f), 83 kg (f), 109 kg (f), 95 kg (f), 107 kg (f), 122 kg (f), 125 kg (m), 102 kg (m), 70 kg (m), 133 kg (m) - Reuther, 1969, p. 169.
Asian captive: 127 kg (f), Miller, 1997, p. 15
African wild: Range = 75-120 kg (The African Forest elephant, *Loxodonta africana cyclotis*, may be smaller). Male approx. 100-120 kg, female approx. 75-100 kg.
African savanna: 75-115 kg (Shoshani, 2000, p. 43)
African forest: 50-100 kg (Shoshani, 2000, p. 45).
African wild (m): 120 kg (n = 1: Moss & Colbeck, 1992, p. 90)
African captive: 91kg (f), 114kg (m), 93kg (f) (Olson, 2004b, p. 145)
African captive: 113 kg (f), 452 kg *sic* (f): Reuther, 1969, p. 168
African captive: 113 kg (f) (n = 1: Lang, 1967, p. 156)
African captive: 86 kg (f), 79 kg (f), 113 kg (m) (Berg, 1987, p. 172)

Birth Shoulder Height:

Asian: 100 cm (Shoshani, 2000, pp. 46-51)
African savanna: 100cm (Shoshani, 2000, p. 43)
African forest: 80-100 cm (Shoshani, 2000, p. 45)
Estimate African forest shoulder height (over 10 years old) about 35% less (f) or 35-40% less (m) than African savanna (Morgan & Lee, 2003, p. 342)
Asian captive: 80 cm (f), 85 cm (f), 92 cm (f), 88 cm (f), 90 cm (m), 69 cm (m),
(Reuther, 1969, p. 169)
Asian captive - 89.5 cm (m) (Sharma & Krishnamurthy, 1984, p. 158)
Asian tame: Mean = 89.9cm, Range = 70-100cm (n = 9: 7 females & 2 males; Nair, 1989, p. 48)
African wild (m): 85 cm (n = 1: Moss & Colbeck, 1992, p. 90)
African forest: Minimum observed = 69cm (Morgan & Lee, 2003, p. 339)
African savanna (Amboseli): Shortest observed = 79 cm (f) (Morgan & Lee, 2003, p. 339)
African captive: 82 cm (m), 82 cm (f), 85 cm (f), 95 cm (f) (Reuther, 1969, p. 168)
African captive: 95cm (f) (n = 1: Lang, 1967, p. 156)
African captive: 94 cm (f), 89 cm (f), 91 cm (m): Berg, 1987, p. 172

Tooth Eruption:

African wild: Lower cheek - 2 weeks (n = 1: Bolwig, Hill, & Philpott, 1965, p. 153)
African wild: Upper cheek - 4 weeks (n = 1, Bolwig et al., 1965, p. 153)
Asian captive: first tooth 6 weeks (Maberry, 1962, p. 82)

Placenta (afterbirth) Delivered:

Asian & African: 1-12 hours after delivery (typically 4-5 hours (Olson, 2004b, p. 141)
Asian captive - 5.5 hr (f), 7 hr (m), 8 hr (m) Mellen & Keele, 1994, p.23)
Asian captive - under 4 hr, Miller, 1997, p. 15
African: 0-45 min. (Sikes, 1971, p. 167)
African captive: 54 min (f): Lang, 1967, p. 156.

Meconium Passed:

Asian captive 5 hr (f), 4 min (m), 3.75 hr (m) - Mellen & Keele, 1994, p.23
Asian captive 8 min (m) (Sharma & Krishnamurthy, 1984, p. 159)
African captive: 30 min. (f). Lang, 1967, p. 156.
African wild: 63 min (f) (Poole, 1996, p. 94)

Agonistic-Aggressive/Dominant:

1. First aggression/Calf towards other:
Asian captive: 24 wk (f), 28 wk (m), 31 wk (m), Mellen & Keele, 1994, p. 23.

Agonistic - Defensive/Submissive:

1. Calf runs under mom:
African: under 1 year (Estes, 1991)
2. Calf runs to its mother:
Asian tame: Day 353 (earliest behavior for n =9: 7 females and 2 males: Nair, 1989, p. 60)
3. Runs to mother when mother gives alarm:
Asian tame: Day 360 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)
4. Rushes to adults when adults give alarm:
Asian tame: Day 489 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)
5. Push another elephant: 3 calves (Berg, 1987, p. 189)

Comfort/Distress (Berg, 1987; Lee, 1986; Nair, 1989):

1. Trunk sucking (own):
African captive: Day 3 (Berg, 1987, p. 183)
2. Calf rubs against trees:
Asian tame: Day 42 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
3. Calf rubs legs or body on the ground:
Asian tame: Day 65 (earliest behavior for any of 7 females and 2 males: Nair, 1989, p. 59)
4. Collects soil with Trunk and foot:
Asian tame: Day 26 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
5. Tries to throw grass and soil on body:
Asian: tame: Day 97 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
6. Throws soil on side of body:
Asian tame: Day 99 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
7. Throws soil on back and sides:
Asian tame: Day 239 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African captive: 1-2 months (Berg, 1987, p. 192)
8. Blows water on back and side of body:
Asian tame: day 144 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African captive: Reported, no age (Berg, 1987, p. 178)
9. Scratch ear with trunk tip:
Asian tame: Day 130 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African (f): 4-7 years (Chevalier-Skolnikoff & Liska, 1993, p. 213)
10. Swat, scratch body with vegetation:
African (f): 4-7 years (Chevalier-Skolnikoff & Liska, 1993, p. 213)
11. Roll in dirt:
African captive: Under 1 week (Berg, 1987, p. 179)

12. Rub against another elephant:
African captive: Reported, no age (Berg, 1987, p. 188)
13. Rubs cheek with object:
Asian tame: Day 549 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)

Drinking

1. Place trunk horizontally above water:
Asian tame: Day 118 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
2. Trunk in water (not suck up water):
Asian tame: Day 23 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African captive: 5 weeks (Berg, 1987, p. 182)
3. Drink by mouth (Usually kneel in water):
Asian tame: Day 9 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African wild: For first 3 months (Moss, 1988, p. 165)
African captive: Starts during first 2 weeks (Berg, 1987, p. 182)
4. Drink by trunk intake and squirt into mouth (adult style):
Asian tame: 81 days (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African captive: At 10 weeks (Berg, 1987, p. 182)
5. Touch water with trunk tip (like adult):
Asian tame: Day 149 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
6. Sprays water when standing at water's edge:
Asian tame: Day 542 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)

Ear Movements:

Asian tame: First earflap:
28 min (Sharma & Krishnamurthy, 1984, p. 159)

Eating Foodstuffs:

African wild: Observed feeding at observation time: 0% (0-3 mo.), 30-40% at 10-12 mo. (Lee & Moss, 1986, p. 355)
African captive: Three calves – Feeding time increases from 2-4 months, then constant (Berg, 1987, p. 185)
1. Completely dependent on milk/nursing:
African wild: 0-3 months (Lee & Moss, 1986, p. 355)
2. Earliest survival in the wild without milk:
African wild: 24-26 months (Lee & Moss, 1986, p. 355)
3. First eat vegetation/solid food (grass, herbs, shrubs):
African wild: 1-2 months (Lee & Moss, 1999)
African wild: "fiddles" with vegetation at 3 months (Moss, 1988, p. 163)
African wild: swallows grass at about 4 months (Moss, 1988, p, 163)
4. Pull up plants & trunk limb coordination:
Asian tame: c. 1 month (first occurrence for n=9: 7 female & 2 male; Nair, 1989, p.49)
5. Pull out grass and herbs:
Asian tame: about 6 months (Nair, 1989, p.49)
Asian tame: First vegetation feeding after 3 months. Time spent feeding increases to near 50% between 6-9 months (Gadgil & Nair, 1984, p. 231)
Asian captive: solid foods 4-5 months (Maberry, 1962, p. 82)
Asian captive: 8 wk (m), 10 wk (m), 16 wk (f): (Mellen & Keele, 1994, p.23)
6. Eats tender grass:
Asian tame: Day 158 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
7. Pull grass, shake off soil and eat:
Asian tame: Day 172 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
8. Feeds on bamboo branch, standing on it to prevent it from springing back:
Asian tame: Day 195 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
9. Bites plants:
Asian tame: Day 9 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)

Nibbles plants:
Asian tame: Day 105 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
10. Pulls grass, puts in mouth:
Asian tame: Day 25 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
11. Picks up grass with trunk, places in mouth:
Asian tame: Day 107 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
Pulls grass with force:
Asian tame: Day 32 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
Picks up grass with trunk, places grass in mouth:
African wild (m): 2 months (Moss & Colbeck, 1992, p. 114).
African captive: Leaves in mouth at 1 month (Berg, 1987, p. 180)
Puts grass in mouth with trunk. Chews and swallows grass:
African wild (m): 4 months (Moss & Colbeck, 1992, p. 1140
12. Sways grass in trunk "hand":
Asian tame: Day 79 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African captive: Shakes browse – Reported, no age (Berg, 1987, p. 178)
Collects dry grass, swings it in air and places in mouth: Tame Asian: Day 130 (earliest behavior for any of 7 females and 2 males: Nair, 1989, p. 59)
13. Pulls out and eats small herbs:
Asian tame: Day 38 (earliest behavior for any of 7 females and 2 males: Nair, 1989, p. 59)
Pulls out herbs, drops them:
Asian tame: Day 142 (earliest behavior for any of 7 females & 2 males: Nair, 1989, p. 59)
14. Eats green twigs, leaves & grass:
Asian tame: Day 109 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African captive: 3-4 months (Berg, 1987, p. 175)
15. Breaks twigs readily:
Asian tame: Day 148 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
16. Tries to break twigs:
Asian tame: Day 205 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
Removes soil from grass by rubbing on leg:
Asian tame: Day 250 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
17. Tries to catch overhead branch:
Asian tame: Day 361 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)
18. Uses hand to prevent food from falling from mouth:
Asian tame: Day 366 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)
19. Plucks grass, beats on leg and eats:
Asian tame: Day 409 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)
20. Rubs grass on cheek to remove soil:
Asian tame: Day 542 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)
21. Regularly eat vegetation: 6 months
22. Daytime food selection:
African wild (n = 8), 12-60 months: 78% grass (McKnight, 1995, p. 247)
African hand-reared (n = 8), 12-60 months: 78% grass (McKnight, 1995, p. 247)

Eating Dung (Adult Feces):

African & Asian: Presumably to acquire intestinal flora (Olson, 2004b, p. 149)
African wild: During the first few weeks after birth (Moss & Colbeck, 1992, p. 153)
African wild: 3-month-old (m) and 4-year-old (f) eat mother's dung (Moss & Colbeck, 1992, p. 153)
African captive: by 10 weeks of age (Berg, 1987, p. 181)

Eating Dirt, Rocks:

Asian tame: Day 111 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African captive: Day 4 (Berg, 1987, p. 181)

Foot Movements:

Move foot over object – manipulate object
African captive: (Berg, 1987, p. 176)
Scratch head with foreleg:
Asian tame: Day 7 (Nair, 1989, p. 59)
Kick soil like adult to loosen soil:
Asian tame: 6 months (Nair, 1989, p. 59)
African captive: 5-6 months (Berg, 1987, p. 179)

Locomotor:

Sit up on knees:
Asian captive (m): 0-1 min (Sharma & Krishnamurthy, 1984, p. 159)
Attempt to stand:
African and Asian: 5 min.-2 hours (Olson, 2004b, p. 138)
African: Almost immediately after birth (Sikes, 1971, p. 167)
African captive: 4 min. (Lang, 1967, p. 156)
African wild (f): 12 min (Poole, 1996, p. 93)
First Stand:
Asian captive: 8min (m), 11 min (m), about 60 min (f), (Mellen & Keele, 1994, p. 23)
Asian tame: Within a few minutes (earliest behavior for n=9: 7 female & 2 male, Nair, 1989, p.48)
Asian captive: 11 min (Miller, 1997, p. 15)
5 min (Sharma & Krishnamurthy, 1984, p. 159).
African: usually within 15-19 minutes (Sikes, 1971, p. 167)
African wild: 2 calves <15 min., 1 calf (m) = 3 days (Moss & Colbeck, 1992, p. 73)
African captive: under 20 min. (Lang, 1967, p. 156.
African captive: 12 min. (Berg, 1987, p. 182)
African wild: 20 min (Leuthold & Leuthold, 1975, p. 78)
African wild: 14 min (Moss, 1988, p. 152)
African wild: 30+ min (f) (Poole, 1996, p. 94)

First Walk:

Asian "tame": 1 day (earliest behavior for 7 females and 2 males: Nair, 1989, p. 58).
Asian captive: 36 min (1 step), 50 min (1+ steps) (Sharma & Krishnamurthy, 1984, p. 159)
African wild: 1 hr (Leuthold & Leuthold, 1975, p. 81)
African wild: 37 min (f) (Poole, 1996, p. 94)
African captive: 1 hour (Berg, 1987, p. 183)

First "Runs:"

Asian captive: 19.5 hr (m), 21.9 hr (m), c. 16 hr (f). (Mellen & Keele, 1994, p. 23)
Adult gait: Hindfoot in ipsilateral forefoot impression:
Asian tame: About 1 year (Nair, 1989, p.50).

Floppy run:

African wild: Head down, ears and trunk hang loose so they flop around when running. Make loud, pulsating trumpet. (Moss, 1988, p. 171)

Observational Learning/Imitation of Behavior:

Learning to eat, drink, diet selection. Sample food in mom's or sibling's mouth or trunk
Asian captive: learned to make "whistling calls" from adult before 3 years of age. Wemmer & Mishra, 1982, p. 556)
African captive: Dusting (Berg, 1987, p. 180)

Olfactory Behavior:

1. Flehmen (target not identified): First flehmen, captive Asian:6 wk (m), 6 wk (m), 17 wk (f) (Mellen & Keele, 1994, p. 23)
2. Smells grass in own mouth:
Asian tame: Day 386 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 60)
3. Smells own feet and dam's feet:
African captive: 3-4 weeks (Berg, 1987, p. 180)

Play Behaviors:

"Aggressive" and "Sexual" behaviors (Lee, 1986;Lee & Moss, 1986;Lee & Moss, 1999; Mellen & Keele, 1994; Moss, 1988; Spinage, 1994). General features: Males play more with males from other family units; females play more with both sexes from own family unit. Males play more than females; Males rougher than females at 1 year of age.
1. Chase, mount, roll on other, trunk wrestle, head spar w. trunks/tusks (Lee, 1986).
Chase children and fowl:
African wild = 5 months, chase cattle & birds = 6 months (Bolwig et al., 1965, p. 15)
Chase children:
Asian tame: Day 322 (earliest behavior for any of 7 females and 2 males: Nair, 1989, p. 60)
Chase buffaloes with spread ears, raised tail and trumpeting: Tame Asian: Day 238 (earliest behavior for any of 7 females and 2 males: Nair, 1989, p. 59)
Chases children: Tame Asian: Day 322 (earliest behavior for any of 7 females and 2 males: Nair, 1989, p. 59)
Chases birds:
African captive: Reported, no age (Berg, 1987, p. 194)
2. Climb on/Roll on/ "King of the hill" - climb on one or more animals, on ground or in wallow. Two-week-old calf (m) climbs on other elephants (Moss & Colbeck, 1992, p. 90). Six-month-old calf (m) and 15-month-old calf (m) climb on 32-month-old female (Moss & Colbeck, 1992, p. 189).
3. Mounting - usually juvenile male mounts, in sexual posture.
African captive: Male = 6 weeks, female = 10 weeks (Berg, 1987, p. 195)
4.First "play fight":
Asian captive: 4 days (m), 9 days (f), 17 days (m) (Mellen & Keele, 1994, p. 23)
5. Splash water with trunk:
African wild: 5 months (Bolwig et al., 1965, p. 153)
6. Solicit play:
African captive: Lay down until another elephant approaches, no age (Berg, 1987, 194)
7. Locomotor play - solo: Not defined:
Asian captive: 21.5 hr (m), 75 hr (m), c. 21 hr (f), (Mellen & Keele, 1994, p. 23)

Proximity Calf-Adult:

Calf < 3 months: Mom within 1m 96% of time
Calf within 2m of Mom and one other family member > 50% of time
Calf-to-Mom distance increases with age
Female and male calves spend equal time near mom
Under 6 years of age, male calves move > 5m from mom more than female calves.
Asian tame: Calf < 3 months: Mom within 2m 80% of time (Gadgil & Nair, 1984, p.228)
Asian tame: At 12 mo., calf within 2m of mother 50% of time (Gadgil & Nair, 1984, p. 228

Sexual Maturity:

Female - first estrus, 8-18 years, first calf, 10-20 years
Female - stays with natal social group.
Male - Sperm production, 17 years; Musth, 29 years
Male - Age of independence (90% of sightings away from natal herd), Mean = 14.2 years. Peripheral to family unit at 5-8 years. Seek same-sex play companions from other family units. Variable patterns of leaving.

Sleep:

Asian tame (n=1): Time spent sleeping declines from about 30% during months 0-3 to about 20% by months 10-12 (Gadgil & Nair, 1984, p. 231)
Asian tame: Standing w/o eating declines from about 70% for Months 0-3 to about 15% by months 10-12. (Gadgil & Nair, 1984, p. 231)
Standing with trunk tip touching the ground:
African captive: After Week 1 (Berg, 1987, p. 182)

Suckling:

African: Calf initiates suckling, mother responds with "leg-forward" position. (Lee & Moss, 1986, p. 355)
Males suckle more than females: similar bout length, more bouts, weaned later
Some allomother suckling, juveniles, adult females with weaned calves or no calves
Suckling of nulliparous females is briefer, 20 sec (Lee & Moss, 1986)

First Attempted Suckle:

Asian captive: 70 min (m), 2.2 hr (m), c. 60 min (f), Mellen & Keele, 1994, p. 23
Asian captive: 37 min (Sharma & Krishnamurthy, 1984, p. 159)
Asian captive: 6 hr (Miller, 1997, p. 15)
African captive: 5.5 hours (Lang, 1967, p. 156.)

First successful Suckle:

Asian captive: 2.1 hr (m), 2.5 hr (m), c. 4.5 hr (f), Mellen & Keele, 1994, p. 23
Asian captive: 180 min (Sharma & Krishnamurthy, 1984, p. 159)
Asian captive: 11.5 hr (Miller, 1997, p. 15)
African captive: 21.8 hr (Lang, 1967, p. 157)
African captive: 2-3 hours (Berg, 1987, p. 175)
African wild: 30 min (Leuthold & Leuthold, 1975, p. 78)
African wild: 96 min (Moss, 1988, p. 152)
African wild: 76 min (f) (Poole, 1996, p.94)

Suckling Duration:

Asian tame: 1-2 minutes. Suckling drops from 2 min to 1 min duration over the first year (Gadgil & Nair, 1984, p. 232)
African wild: Mean = 86 sec (m), 89 sec (f) (Lee & Moss, 1986, p. 355)

Inter-Suckling Interval:

Asian: About 30 minutes (Gadgil & Nair, 1984, p. 232)
African: Males = 37 minutes, females = 50 minutes. (Lee & Moss, 1986, p. 355)
Asian: Calves tend to alternate breasts in suckling bouts (Nair, 1989, p.50)
Young calves attempt to suckle between forelegs and between rear legs:
Asian (Sharma & Krishnamurthy, 1984, p. 159); (Nair, 1989, p.50)
African (Lang, 1967, p. 156.)

Trunk Movements:

1. Pick up object:
Asian tame: Day 9 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
African wild: One week old (Moss, 1988, p.163)
2. Manipulate (play with) object:
Asian captive: 19 hr (m), 22.5 hr (m): (Mellen & Keele, 1994, p. 23)
3. Trunk drops stick, step on one end to break stick:
Asian tame: Day 142 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
4. Trunk Wrestle (Lee & Moss, 1986; Moss, 1988; Moss, 1992, Spinage, 1994)
5. Throws object/dirt at bird with trunk:
African: 4-7 years (Chevalier-Skolnikoff & Liska, 1993, p. 213)

6. Blows on the ground to clear an area:
African: 4-7 years (Chevalier-Skolnikoff & Liska, 1993, p. 213)
African captive: Under 1 hour (Lang, 1967, p. 156)
7.Trunk scratches own cheek:
Tame Asian: Day 9 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
8. Trunk tip rubs eye:
Tame Asian: Day 64 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
9. Trunk and leg breaks stick:
Tame Asian: Day 71 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)
10.Trunk splash water, blow out water:
Tame Asian: Day 77 (earliest behavior for n=9: 7 females and 2 males: Nair, 1989, p. 59)

Urination:

1. First urination - 5 min Captive Asian (m) (Sharma & Krishnamurthy, 1984, p. 159).
2. Urine Bathing (Kahl and Armstrong, 2000a) - wild African juveniles, 2-10 years = post-weaning.
3. Urine drinking (Kahl & Armstrong, 2000a) - wild African juveniles.

Vocalizations:

1. Squeal alarm call:
Asian tame: When 10-15 m from mom (Gadgil & Nair, 1984, p. 228)
2. Snort
African: Juveniles (Berg, 1983, p. 67)
3. African wild (juveniles and/or calves): Female chorus, genital testing, greeting rumble, social rumble, roar, mating pandemonium, play trumpet, social trumpet, attack rumble, contact call, contact answer, lost call, suckle rumble, suckle cry, distress call, reassurance rumble, calf response, suckle distress scream, scream, bellow, trumpet blast, snort, female-female respect (Poole, 1994, p. 344)
4. African captive (m): between birth and 1.5 months of age: Suckle cry (just before suckling), distress call, suckle distress scream (suckling interrupted). Cries and Screams. Trumpet blasts during social fear and social excitement. Grunts and bellows while playing. (Horwath, 2002)
5. Suckle protest:
African wild (f): 3 -year-old calf protests when dam refuses to feed it (Moss & Colbeck, 1992, p. 87)

Weaning:

African & Asian: May be successful after 6 months. Recommended time for weaning in captivity is 2-3 years (Olson, 2004b, p. 149)
African wild: Male calves weaned at later age than female calves. (Moss, 1988, p, 167)

Behaviors Exhibited Towards Calves

Youngest Dam:

Asian captive: 5 years (Taylor & Poole, 1998, p. 319)
Asian Tame (working): 7 years (Taylor & Poole, p. 319)
African wild: Median age of first birth is 14.1 years (sample of n= 546: Moss, 2001, p. 149); Youngest dam, first birth 8.9 years (sample of n= 546: Moss, 2001, p. 149); Oldest dam, first birth 21.6 years (sample of n= 546: Moss, 2001, p. 149); Median inter-birth interval 4.2 years (n = 732 cases: Moss, 2001, p. 152)

Oldest Dam

African wild: Oldest dam: 5 dams over 60 years gave birth (Moss, 2001, p. 151)
Female calf/mom interaction steady with age, male calf/mom interaction declines with age (Lee, 1986).

Allomothering.

(Gadgil & Nair, 1984; Lee & Moss, 1986; Moss, 1988, 1992; Rapaport & Haight, 1987; Sharma & Krishnamurthy, 1984) - Wild African and captive Asian juvenile female relatives (2-12 years old) and adult females without calves participate in calf care.

First Aggression to Calf

1. Captive Asian: < 3.5 hr (m), 25.5 hr (m), 53 hr (f) (Mellen & Keele, 1994, p. 23).
Mom kick newborn with rear leg (Miller, 1997, p. 15)

Flehmen

(mother to captive Asian calf; Mellen & Keele, 1994, p. 23). First seen at 13 min (m), 1.5 hr (m), not in 36 hr (f).

Foot Movements

1. Foot kick "alien" calf. Not own calf:
Asian captive (Mellen & Keele, 1994)
2. Adult feeding may kick infant that approaches:
Asian wild (McKay, 1973, p. 70)
3. Foot push calf. By large male at water hole;
African wild (Kahl & Armstrong, 2000b)
4. Foot touches calf gently. Comfort.
African wild (Estes, 1991; Sikes, 1971, p. 167).
5. Dam often scrapes soil with a forefoot:
African wild (Sikes, 1971, p. 167)

Reject Nurse:

Maternal/calf (Kahl & Armstrong, 2000b)
Dam tusks own 3-year-old calf (f) when it tries to suckle (Moss & Colbeck, 1992, p. 87)

Trunk Movements:

1. Trunk touches calf gently (Sikes, 1971, p. 167)
2. Trunk used to pull calf away from water hole (Kahl and Armstrong, 2000b)
3. Trunk slap (Estes, 1991; Spinage, 1994). Mom or bulls.
4. Shepherding - pull calf under adult (Kahl & Armstrong, 2000b).
5. Grab calf's tail - to direct it. (Estes, 1991)
6.Adults use trunk to pull back calf that starts to walk away (McKay, 1973, p. 69)
7. Shove; poke calf: Mom and Bulls (Spinage, 1994).
8. Hold calf back for safety:
9. Asian wild (f) (Eisenberg & Lockhart, 1972, 1973, p. 26)
Trunk used to "guide" calf behavior by pushing it gently:
Asian wild (Eisenberg & Lockhart, 1972, 1973, p. 26)

Characteristics of African elephant (*Loxodonta africana*) calf development: From birth to three months of age

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This presentation examines the development of six captive-born elephant calves, at four institutions, from birth until three months of age. Three male calves and 3 female calves were studied. Surveys sent to participating institutions asked questions about behavior, physical development, management and health issues. For example: "When did you first observe the calf perform a headshake?" (Behavior); "When did you observe that the first set of teeth had cut through the gum?" (Physical development); "Did you experience any complications with the umbilicus (e.g., infection, hernia) during the time period indicated? (Health); and, "Have you had to bottle feed the calf in this time period?" (Management). The purpose of the surveys was to determine the "typical" features of calf development and to obtain some baseline/reference data.

INTRODUCTION

This paper reports preliminary results for a survey about the physical and behavioral development of African elephants born in captivity. Although there are many generic descriptions of the behaviors of elephant calves (e.g., Douglas-Hamilton & Douglas-Hamilton, 1975; Moss, 1988; Poole, 1994; Shoshani, 2000; Spinage, 1994; Sukumar, 2003), there are relatively few sources that describe the development of individual animals systematically (e.g., Nair, 1989; Sharma & Krishnamurthy, 1984). There is a particular shortage of data on the development of African elephant calves, with only a few summary publications (e.g., Lee, 1986; Lee & Moss, 1986; Lee & Moss, 1999) and several case studies available (For example, Leuthold & Leuthold, 1975; Mellen & Keele, 1994).

A series of surveys were conducted for 6 captive-born African elephant calves. The intention was to obtain detailed information on a variety of topics. Moreover, since all institutions received the same surveys, it has been possible to construct a preliminary idea of the “typical” pattern of development for these calves. It is hoped that these data will contribute to the establishment of a series of developmental milestones against which the progress of any specific calf may be compared. It will also be interesting and important to compare the development of captive-born calves with that of calves *in situ*.

METHOD

Based on the experience of the authors and their colleagues with elephant calves, and using summary resources like those mentioned above, a series of four questionnaires was developed. The surveys covered the following time periods: “Before birth” to 48 hours, 48 hours to 2 weeks, 2 weeks to 1 month, and 1 month to 3 months. Each survey contained about 50 questions, but new questions were added to each survey (and some “old” questions were removed) so that there was a total of 96 questions. Each survey included questions about physical development, behavioral development and management. Staff at the following institutions completed the surveys: Disney’s Animal Kingdom (2 calves), Indianapolis Zoo (2 calves), Toledo Zoo (1 calf) and Vienna Zoo (1 calf). The 96 questions are listed in the Appendix. The responses to the surveys were stored in a ClarisWorks database. The surveys were completed based on written records made by the elephant handlers, with occasional reliance on keeper memory when written records were unavailable. The vast majority of the results are based on written or videotaped records.

RESULTS

The partial listing of the results obtained using the surveys is presented in Table 1. The table includes data related to the calves' births, nursing, trunk development and locomotion.

The data on the dams' behaviors around the time of birth suggest some consistency in the time at which the pelvic bulge appears, and in the fact that every dam covered her calf with hay at some point. To our knowledge, this behavior has been reported only once previously (Moss, 1988).

The data on nursing, early locomotion and trunk development are consistent with behaviors reported in the wild (Moss, 1988; Nair, 1989; Sharma & Krishnamurthy, 1984). They provide the first group data for captive African elephants.

Table 1. Median scores on each of the survey measures, with the range of scores for the 6 calves.

Domain	Measure	Median (Range)
Birth – Dam	Time of birth	11:19 pm (7:15pm→ 7:00 am)
	Progesterone monitored (yes/no)	6 Yes
	First discomfort before birth	4.2 hours (1 hour – 2 weeks)
	Pelvic Bulge before birth	25 min. (5 min. - 2 hours)
	Dam restrained (yes/no)	4 Yes/2 No
	Dam aggressive to calf (yes/no)	3 Yes/3 No
	Dam cover calf with hay (in first month)	5 Yes/1 No
Birth – Calf	Birth weight: Male	124 kg (113-133 kg)
	Birth weight: Female	93 kg (90-104 kg)
	Birth height: Male (2 calves)	91 cm, 112 cm
	Birth height: Female (2 calves)	83 cm, 84 cm
Nursing	First attempted suckle	about 24 hours (1 – 14* days)
	First successful suckle	about 24 hours (1 – 14* days)
	Assistance with Nursing required	4 Yes/2 No
	Bottle feeding	3 Yes/3 No
Locomotion	First stand	12 min. (5 –90 min.)
	First walk	17.5 min. (10-95 min.)
	First "run"	24+ hours (4.5 hr – 8.5 days**)
Trunk development	Touch object	1 day (1-2 days)
	Suck on own trunk	1 day (1-8.5** days)
	Sniff or touch water	2 days (6 hours – 10 days)
	Suck water into trunk	2 days (1 day –60** days)
	Drink directly by mouth	3 days (1 – 60**days)
	Pick up object	3 days (1-17 days)
	Splash water	5.5 days (1-10 days)
	Step on own trunk	6.5 days (3 days – 60** days)
	Drink using trunk	45 days (2 days – 90+*** days)

**Suckling was attempted on the first day that the dam was re-united with the calf.*

*** The estimated time is the mid-point of the period covered by a survey. This time is used whenever a behavior was not reported on one survey, but then on the next survey it was said to have "already occurred" before that survey.*

****The behavior was not observed during the calf's first 3 months.*

DISCUSSION

These results provide some preliminary baselines for the physical and behavioral development of African elephant calves, both with regard to the "typical" score (median) on each measurement and with regard to the range of scores. The baseline data, which we will continue to accumulate, will allow handlers to judge whether the behaviors shown by their animals are common and whether the rate of development of their calves is in the normal range. In the future, it may be possible to compare the developmental milestones of captive-born calves with those of calves in the wild.

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APPENDIX

Calf Development Survey (Kowalski, Dale, Hardin, 2004) First THREE months only.

1. **Calf name**
2. **Institution**
3. **Birthdate**
4. **Sex of calf**
5. **BirthTime**
6. **Survey #**
7. **MomProg**: Did you collect blood from the mother before the birth and have it analyzed for progesterone?
8. **MucPlug**: When did you observe the mucus plug pass?
9. **MomDisc**: When did you observe the first signs of discomfort? First Signs? (please list)
10. **Bulge**: When did the bulge first appear
11. **MomRestr**: Was the mother restrained during the labor and birth?
12. **Method**: If so, how?
13. **MomBirPos**: In what position was the mother at the time of birth?
14. **BirMedAss**: Did the mother require any medical assistance in order to speed up the birth process (e.g. oxytocin)?
15. **WhatMed**: If so, what medicine?
16. **PullCa**: Did you pull the calf away from the mother after the birth?
17. **Plac**: When did the mother pass the placenta?
18. **ReintrCa**: If you separated the calf and mother, when did you begin the reintroduction?
19. **CaMomUnCon**: When were the calf and mother first allowed unrestricted contact?
20. **CaToOther**: When did you begin introducing the calf to the other elephants?
21. **MomCaOth**: When were mother, calf, and any of the other elephants first allowed unrestricted contact?
22. **Umbil**: Did you treat the umbilicus of the calf in this time period?
23. **HowUm**: If yes, by what method and how often?
24. **UmbCompl**: Did you experience any complications with the umbilicus (ex.: infection, hernia, etc.) in this time period?
25. **Wha**t: If so, what complications?
26. **CaHt**: If you measured the height of the calf at the shoulders in this time period, please give the measurement *(indicate whether inches or metric)*
27. **HtDate**: Date the height was measured.
28. **CaW**t: If you weighed the calf in this time period, please give the date, time (if known), and weight *(indicate whether in lb or kg)*
29. **WtDate**: Date of weighing calf.
30. **MultiWts**: Were multiple weights measured?
31. **FtCir**: If you measured the foot circumference (foot planted on ground, or from footprint) of the calf in this time period, will you please give the measurement *(indicate whether inches or metric):*
32. **FtDate**: Date foot measured.
33. **WhatF**t: Which foot was measured?
34. **FirTeeth**: When did you first observe that the first set of teeth had cut through the gum?
35. **GenDown**: When did you first observe the genitalia of the calf hanging out?
36. **CaPee**: When did you first observe the calf urinate?
37. **FirMec**: When did you first observe meconium (first stool) from the calf?
38. **MiSt**: When did you first observe milk stool from the calf?
39. **TGsec**: When did you first observe a temporal gland secretion from the calf?
40. **FirStand**: When did you first observe the calf stand on his/her feet?

41. **FirWalk**: When did you first observe the calf walk?
42. **FirRun**: When did you first observe the calf "run"
43. **FirAttSu**: When did you first observe the calf attempt to nurse/suckle from mother?
44. **FirSuccSuckle**: When did you first observe the calf nurse successfully from the mother?
45. **NurHelp**: Have you had to assist the calf to nurse in this time period because he or she could not reach (e.g. place stool for calf to nurse)?
46. **How**: If so, how did you assist the calf?
47. **BoFeed**: Have you had to bottle feed the calf in this time period?
48. **MoHelpNur**: When did you first observe the mother perform an ACTIVE cooperative response to nursing (e.g., moving foreleg forward)?
49. **CaLySL**: When did you first observe the calf lay down to sleep?
50. **CaRum**: When did you first hear the calf rumble?
51. **CaScr**: When did you first hear the calf scream?
52. **CaTru**: When did you first hear the calf trumpet?
53. **CaHdSh**: When did you first observe the calf perform a headshake?
54. **CaEarFl**: When did you first observe the calf flapping his/her ears?
55. **Ca2EarSpr**: When did you first observe the calf spread both ears (full extension)?
56. **StepTru**: When did you first observe the calf step on his/her own trunk?
57. **TruFtRoll**: When did you first observe the calf roll his/her own trunk with foot?
58. **TruToObj**: When did you first observe the calf touch an object with his/her trunk?
59. **TrPUobj**: When did you first observe the calf pick up an object with his/her trunk?
60. **SuckTr**: When did you first observe the calf suck on his/her own trunk?
61. **TrSnToFd**: When did you first observe the calf sniff or touch food with trunk (sniffing or touching)?
62. **TrSnToPoo**: When did you first observe the calf sniff or touch dung with trunk (sniffing or touching)?
63. **TrSnToWa**: When did you first observe the calf sniff or touch water with trunk (sniffing or touching)?
64. **TrSpIWa**: When did you first observe the calf splash water with trunk?
65. **CaMouDr**: When did you first observe the calf drink water by mouth independent of trunk (puts head directly into tub or other water source)?
66. **CaSwim**: When did you first observe the calf swimming?
67. **MomToCaAggr**: Have you observed aggression toward the calf by the mother in this time period?
68. **AdToCaAggr**: Have you observed aggression toward the calf by an adult other than the mother in this time period?
69. **AdPullCaTr**: Have you observed any adult grab and pull the calf's trunk with his/her own in this time period?
70. **UmbHeal**: When did you first observe that the umbilicus had healed completely?
71. **HayStool**: When did you first observe pieces of hay in the calf's stool?
72. **RockStool**: Have you observed rocks in the calf's stool in this time period?
73. **SaDiStoo**l: Have you observe sand or dirt in the calf's stool in this time period?
74. **FtPdGo**: When did you first observe the calf s foot pads begin to slough off?
75. **Ca5mMom**: When did you first observe the calf more than 5 meters from his/her mother?
76. **CaSepMom**: When was the first time the calf was physically separated from his/her mother (by barrier)?
77. **CaFooMou**: When did you first observe the calf put food in his/her mouth?
78. **CaDiSaMou**: When did you first observe the calf putting dirt or sand in his/her mouth?
79. **CaRockMou**: When did you first observe the calf putting rocks in his/her mouth?
80. **CaTrWater**: When did you first observe the calf sucking up water with his/her trunk?
81. **MomHayCov**: Have you observed the mother cover the calf with hay while the calf is lying down

in this time period?

82. **NuEllIntr**: When introductions to other elephants began how many elephants were introduced at one time?
83. **IntElRest**: When introductions to other elephants began were adult elephants restrained, if yes how?
84. **Ca2ndTeeth**: When did you first observe that the second set of teeth had cut through the gum?
85. **GenRetr**: When did you first observe the calf's genitalia retracted after urination?
86. **MilkTu**: When did you first observe the milk tusks cut through the sulcus?
87. **TrHaFood**: When did you first observe the calf using the tip of his/her trunk to gather food?
88. **FtSoil**: When did you first observe the calf use his/her foot to loosen soil?
89. **FtTrObj**: When did you first observe the calf using his/her foot and trunk together to pick up an object?
90. **FtTrSoil**: When did you first observe the calf use his/her foot and trunk together to loosen soil?
91. **TrDrink**: When did you first observe the calf successfully drink water from trunk (empty water into mouth)?
92. **CaDrPee**: When did you first observe the calf drink urine?
93. **CaAggrToOth**: Have you observed aggression from the calf toward any of the other elephants in this time period?
94. **CaDust**: Have you observed the calf dusting in this time period?
95. **BodyPar**t: If so, where?
96. **CaShkFood**: When did you first observe the calf shake food before eating it?

Documenting behavioral and physical development in two captive African elephant (*Loxodonta africana*) calves

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The birth of African elephants in captivity continues to be a rare event. To date, there have only been forty-two captive births of African elephants and of those, fewer than fifty percent have survived (Olsen, 2003). Since May 2003, Disney's Animal Kingdom (DAK) has experienced the birth of two African elephant calves with an additional two cows pregnant and scheduled to give birth in 2005. DAK's elephant and science teams have taken this opportunity to implement a study on behavioral and physical development of African elephant calves being raised in a herd of six adult female elephants. The study includes two components: 1) documenting first occurrences of behaviors and 2) systematic collection of behavioral data that will be used to develop activity budgets for the calves as they mature. Behavioral data are collected four to six times a day using instantaneous scan sampling on a focal animal. As additional calves are born, they will be incorporated into the study thus allowing us to establish a database of information on their developmental behavior. Data from this study has shown some similarities and differences between the two calves. Emphasis for this paper will be placed on creating a database of information to help with captive elephant management.

INTRODUCTION

Captive African elephant births have been rare. Since 1978 there have been a total of 42 elephants born in captivity with an approximate 50% survival rate. From 1986 to 2004 there have only been 22 elephants born with an approximate 40% survival rate (Olson 2003). If there is not a positive change in the fecundity rate of captive African elephants, population management experts estimate that in 50 years, there will only be 10 to12 captive African elephants in North America (Olson & Wiese, 2000).

To date very few wild African elephant births have been described in detail (McKnight, 1992). In wild births that have been observed, calves are able to stand around twenty minutes after birth with some standing as early as twelve minutes. They usually take their first steps by forty minutes after birth and begin suckling within ninety minutes (Leuthold & Leuthold 1975, Moss 1988). Major activities of wild elephant calves include feeding, resting and traveling which account for over 80% of their activity. Mother-son proximity decreased over time while mother-daughter pairs maintained a closer physical proximity for a longer period of time (Lee 1986). Thus, there were differences between the sexes early within social and behavioral development.

Data on physical development with wild African elephant calves are also rare. Due to constraints on collecting weight information, most studies documented shoulder height and foot size (Lindeque & Van-Jaarsveld 1993, Lee & Moss 1995). However, wild elephant calves are estimated to be about 118 kg at birth (Moss 1988).

While there have been some studies on captive African elephant birth and development (Berg 1987, Styles 1982, Parrot 1996, Lang 1980, and Reuther 1969) there is still a large gap in our knowledge that needs to be filled to better understand these unique animals. Information gathered in the wild, while limited, has provided the most detailed information about African elephant calf development to date.

Lee & Moss (1999) described the first two years of an elephant's life as most critical due to high mortality rates (~20%). Our study was designed to gather information on captive African elephant calf physical and behavioral development within the first two years of their lives. While it is not expected to answer all the questions about such a complex time period, this study can provide information for captive elephant management by creating a database, which can be used as a tool to make informed decisions.

METHODOLOGY

Subjects

The focal elephants for this study are a male calf (Tufani) and a female calf (Kianga). The male calf was sired by Maclean and his dam is Moyo. The female calf's dam is Vasha and the sire is Jackson. The herd at Disney's Animal Kingdom is comprised of six adult females and the two calves (Table 1). All of the adult females in the herd were born in Zimbabwe. Males are housed and exhibited separately from the females and calves.

- Housing and Maintenance:

The facility includes a barn in excess of 10,000 square feet with eleven stalls. Two stalls are separated by a concrete wall and serve as bull stalls but could also be used for quarantine purposes. The nine cow stalls are interconnected by a series of gates. The largest stall was used as the maternity stall and this is where most of the indoor calf observations were conducted. Three holding yards are connected to the barn and to the exhibits. Each holding yard has sand substrate and shade structures. Various enrichment devices are rotated on a random schedule into each of the yards. The largest holding yard was retrofitted with a shallow pool to provide a controlled area for the calves to learn to swim. Three outdoor exhibits all have natural features including trees, rocks, grasses, mud wallows and pools. The calves were introduced to the herd in the barn initially, then into the holding yards, next the one and one half acre outdoor exhibit and finally were given access to the three and one half acre main exhibit once the calves appeared confident. The main exhibit is the primary location for midday observations.

The elephant management goal for Disney's Animal Kingdom is that elephants be maintained as a socially stable, multigenerational herd. The elephants are managed in a progressive contact system, utilizing tools from both free and protected contact. Husbandry training is conducted with the goal of achieving uncompromising care and includes daily baths, footwork, cooperation in reproductive procedures and annual physical exams. The calves have been introduced to increasingly structured husbandry training since birth.

Study Phases

- Phase One

Seventy-two hours of continuous observations were conducted on each calf immediately following birth. Exact date and time of post-partum "first occurrences" were recorded (see Table 2). After the first seventy-two hours, exact date and time for all witnessed behaviors were recorded.

- Phase Two

Over the first 24 months post-parturition, data on selected developmental and social behaviors were collected 4-6 times per day using an instantaneous scan sampling technique. Data were recorded at one-minute intervals for thirty minutes (see Table 3). Major categories of behavior include active/inactive, feeding, social interaction, exploration/manipulation, and hygiene. Proximity, defined as less then four meters, and physical contact to other elephants was also recorded. Observation times were 0300, 0700, 1100, 1500, 1900 and 2300. However for the purpose of this paper, results will focus on the 1100 and 1500 observations in the main outdoor exhibit for the first three months of the female calf's life and the first eighteen months of the male calf's life. Inter-observer reliability was 90% and was assessed every six months with a maximum of eight observers. Long-term observations were used to determine an activity budget for the elephant calves. Throughout this time frame, measurements of physical parameters such as height and weight were also routinely recorded.

RESULTS

First Occurrences

Details of first occurrences for both calves are in Table 4. A comparison of the two calves showed both similarities and differences. Both calves had a majority of the first occurrences happen within the first four hours following birth. One of the main differences between the calves was the onset of nursing. This occurred for the first time at 3 hours and 40 minutes post-partum for the female calf, while the male calf didn't successfully nurse until almost two and a half days following birth.

Weight Gain

At birth the male calf weighed 134.26 kg while the female calf weighed 104.33 kg. During the first 11 days following birth, both elephant calves lost between 2.3 – 5.2% of their total body weight. Between Weeks 2 and 3, weight increased to an average gain of 1.25 kg/day. Following Week 3, both elephants weight gain leveled off to an average of .57 kg/day though Week 17 (Figure 1). Throughout the first four months both calves had a similar linear pattern of growth (r sq linear = 0.992 and 0.987).

Activity Budget - Both Calves (0-3 Months)

Behaviorally, both calves were similar over the first three months of life although some differences were observed. Both calves were active an average of 95.6% of the time spent outside on the main exhibit. The male calf later increased to 98.4% active during Months 3 through 6, and remained active in the mid to high nineties during the first eighteen months of life. Time active over the first three months of life for both calves included 12.2-13.6% of the time feeding and 21.5-29.8% of the time traveling. Nursing accounted for 6.9% of the total behaviors for both calves (Figure 2). The other similarity between the two calves was that they spent an average of 21.1% of their time interacting with exhibit elements. The main differences seen between the two calves were; 1) the female calf spent more time in affiliative interactions with other elephants (♀ 13.3%; ♂ 4.9%) and, 2) the male calf spent more time interacting with tactile enrichment (♂ 16.6%; ♀ 6.4%).

Proximity - Both Calves (0-3 Months)

The average percentage of time spent between the calves and mothers was 64.0% over the first three months of life and remained constant for the male calf through Month 18 (Figure 3). The average percentage of time calves spent alone was also similar within the first three months at 22.0%, however that percentage for the male calf increased to 42.0% for Months 4 through 18. Percentage of time within the proximity of the unrelated female, Rafiki, was 29.3-32.4% for both calves. The male calf spent between 20.7-31.2% of the time near Thandi, another unrelated female, compared to only 3.4% for the female calf.

Activity Budget Male Calf (0-18 Months)

During Months 6 through 18, there was an increase in the overall percentage of time feeding for the male calf. This increase to 24.9% consisted of an increase in grasses/plants and provided food (7.7% and 10.8%). However there was a slight decrease in percentage of time nursing from 6.6% down to

3.1% of the time (Figure 4). While there was some fluctuation, traveling remained relatively consistent at an average of 21.6% while time spent interacting with exhibit elements was relatively constant at an average of 25.0%.

DISCUSSION

During the first three months of life there were many similarities between the two calves, with each spending a majority of their time near their respective mothers while gradually integrating into herd life. Behaviorally, both calves were extremely active during the time they spent outside on the main exhibit. Spending approximately the same amount of time nursing in addition to other feeding behaviors, a large percentage of time was also spent traveling and manipulating exhibit elements. Although there was a slight decrease in nursing with the male calf after the first three months, this was supplemented by an increase in consumption of provided food and grasses. The similarities in feeding behaviors and activity levels coincide with the similar physical development and weight gain. This was very similar to information found on the three calves from San Diego Wild Animal Park with an increase in feeding on provided food and grasses at month four (Berg 1987).

Similar to the findings of Lee (1986) for wild elephant calves, there was a greater percentage of time travelling for the female calf when compared to the male calf. While this could be attributed to gender this could also be individual differences. A similar comparison can be made between the two studies on percentage of time the male calf was solitary compared to the female calf in addition to the greater percentage of time performing affiliative behaviors. Throughout the first three months of life for each of the calves there was a large amount of time spent near their respective dams. There was also a large percentage of time for the male calf in proximity to the unrelated individual that was brought to the park as a pair with his dam. However, there was one unrelated female that has shown typical allo-mothering behavior and is seen within proximity of both calves at a higher percentage then any of the other unrelated females.

Creating a database of information on the behavioral development of calves over the critical first two years (Lee & Moss 1999) provides information to enable managers to make educated elephant management decisions. Sharing of information between institutions will also continue in the development of resources to increase our knowledge. In the future, additional elephant calves will be added to the study as they are born to increase the amount of information in hopes of finding significant changes in development and establishing a range of normal values. The ultimate goal of having real-time analysis of behavioral information to make informed management decisions will be pursued as well with the addition of digitally acquired information via handheld application to increase the timeliness of information.

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Table 1. Subjects

Sex	House Name	Estimated Birth Date	Years at Disney's Animal Kingdom
M	Tufani [1]	22 May 2003	May 2003 – Current
F	Vasha	~ Jan 1986	November 2000 – Current
F	Thandi	~ 1980	June 1997 – Current
F	Moyo	~ 1981	June 1997 – Current
F	Rafiki	~ 1979	October 1997 – Current
F	Ibala	~ 1979	October 1997 – Current
F	Donna	~ 1988	November 2003 – Current
F	Kianga [1]	6 July 2004	July 2004 – Current

1 Focal Elephants for Study

Table 2. First Occurrence Behaviors

Post-Parturition Behaviors	
Attempt to right itself	First attempt to remove contact of its side with the ground.
Attempt to stand	First attempt to remove contact with body from the ground.
Successful assisted standing	No part of body contacting ground with assistance.
Successful standing on own	No part of body contacting ground on its own.
Introduction to dam	Time of first contact with dam either assisted or on its own.
Flap ears	First time elephant calf flaps one or both of its ears.
Moves trunk	First time elephant calf moves trunk.
First step	First step either assisted or on its own.
Coordinated walk	Two or more coordinated steps without assistance from animal care staff.
Attempt to nurse	First noted attempt to suckle
Successful nursing	Successful nursing attempt where calf is seen suckling on nipple of its dam.
Defecation	First noted feces.
Urination	First noted urine.
Vocalization	First noted vocalization.
Drinking	First time drinking by putting mouth directly on water source, or using trunk to assist.
Mouthing objects	First time using mouth to explore items.
Pool use	First time submerged in pool.
Tooth eruption	To be determined by Zoological Manager.
Other interaction	Any first behavior seen that is not listed that seems critical in development of elephant calf.

Table 3. Ethogram for Elephant Calf Development/Activity Budget Study

Behavior	Description
Active/Inactive:	
Rest/Sleep—Standing	Standing with trunk tip resting against the ground.
Rest/Sleep—Lying Down	Lying down in a position varying from curled up to stretched out.
Locomotion	Any movement (walking, trotting, etc.) in a forward or backward direction.
Other	Any other behavior not described in ethogram.
Feeding:	
Nursing	Successful nursing attempt where calf is seen suckling on nipple of its dam.
Provided Food	Chewing movements of provided food.
Grass/Plants	Chewing movements of grass/plants from the exhibit.
Drinking	*BRINGING WATER TO THE MOUTH WITH TRUNK OR ACTIVELY PLACING MOU DIRECTLY TO WATER SOURCE.*
Enrichment	Chewing movements of provided enrichment (browse, produce, etc.).
Dirt/Sand/Gravel/Other Substrate	Chewing movements of dirt/gravel/sand/other substrate from the exhibit.
Feces	Chewing movements of feces from self or other elephant.
Social Interaction:	
Aggressive	Aggressive behavior that involves contact between multiple animals. Includes attacks with trunk, mouth, body or legs; sparring, head butt, pushing, tusking. Does not include aggression to keepers.
Affiliative	Prosocial behaviors such as social play, trunk tangle, or caressing with another animal.
Exploration/Manipulation:	
Exhibit Elements	Manipulating or moving the trunk, body, mouth or feet over exhibit elements.
Enrichment	Manipulating or moving the trunk, body, mouth or feet over provided enrichment items.
Self	Exploration of the body using the trunk.
Body Hygiene:	
Water	Splashing water onto its body with its trunk or kicking water with their feet; immersing itself in body of water.
Dust Bathing	Coating its body in dirt (or other substrate) by rolling on ground or bringing dirt to the body with its trunk.
Proximity/Contact:	
Contact	Animal is physically touching another animal. May be active contact such as play-fighting, or passive contact such as resting against another animal.
Proximity	Animal is within one body length from another animal. May be stationary or locomoting.

Table 4. First Occurrences of Calf Behaviors (Latency from Birth)

Behavior	Female Calf			Male Calf		
	Days	**Hrs**	**Mins**	**Days**	**Hrs**	**Mins**
Moves trunk	00	00	<1	00	00	<1
Attempt to right itself	00	00	05	00	01	00
Defecation	00	00	05	00	00	<1
Attempt to stand	00	00	12	00	01	00
Successful assisted standing	00	00	12	N/A	N/A	N/A
Successful standing on own	00	00	12	00	01	00
First step	00	00	15	00	01	01
Coordinated walk	00	00	20	00	01	18
Vocalization	00	01	00	00	00	05
Introduction to dam	00	01	10	00	00	17
Urination	00	03	30	00	02	10
Attempt to nurse	00	03	40	02	07	42
Successful nursing	00	03	40	02	07	57
Flap Ears	00	04	32	00	01	42
Mouthing objects	01	04	45	00	01	04
Attempt to drink	02	20	15	01	14	05
Pool use	12	00	00	16	00	00
Tooth eruption	15	00	00	23	00	00

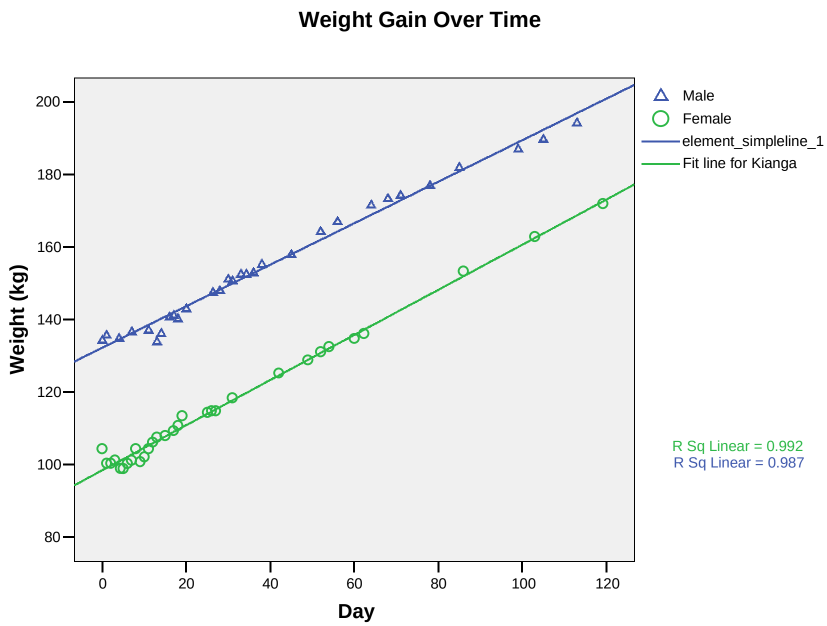

Figure 1. Weight gain of two captive African elephant calves between birth to four months.

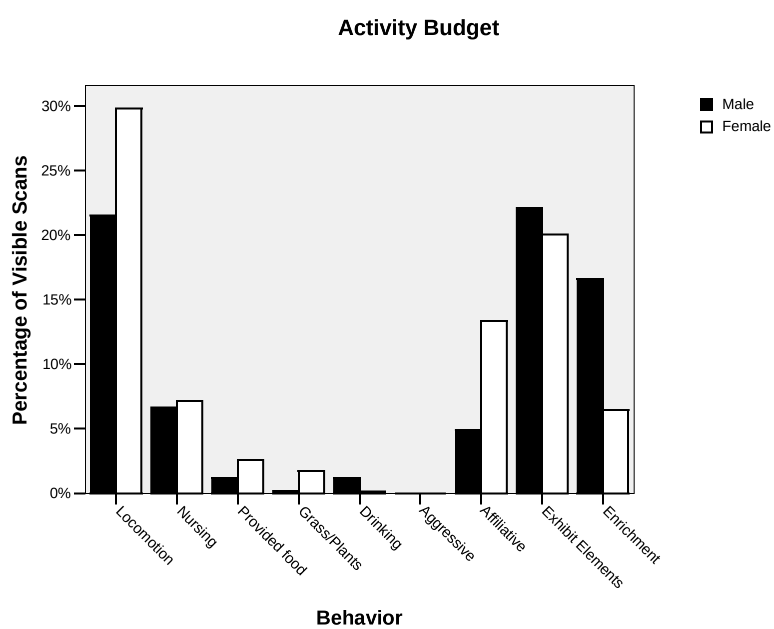

Figure 2. Percentage of visible scans each calf was observed engaged in specific activities (Averaged over first 3 months).

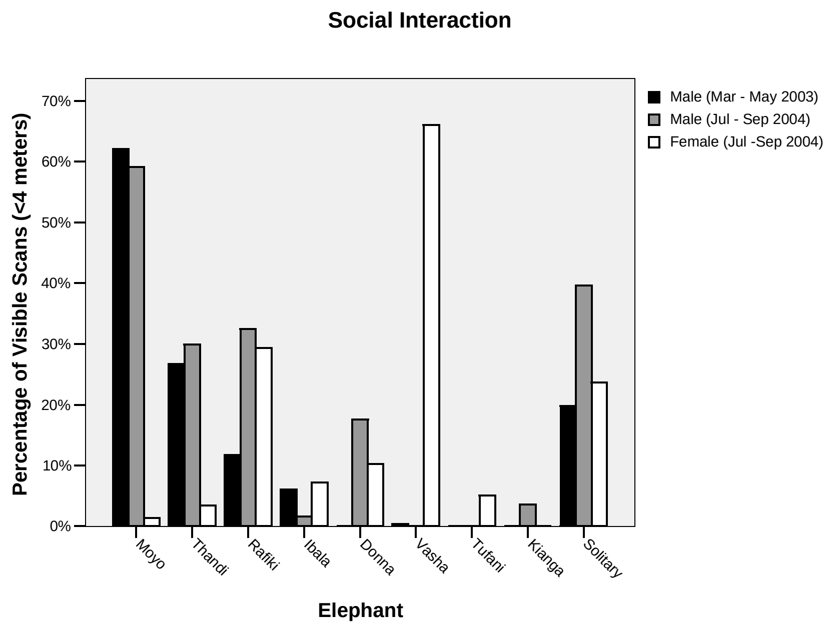

Figure 3. Percentage of visible scans for two African elephant calves within proximity of other herd members

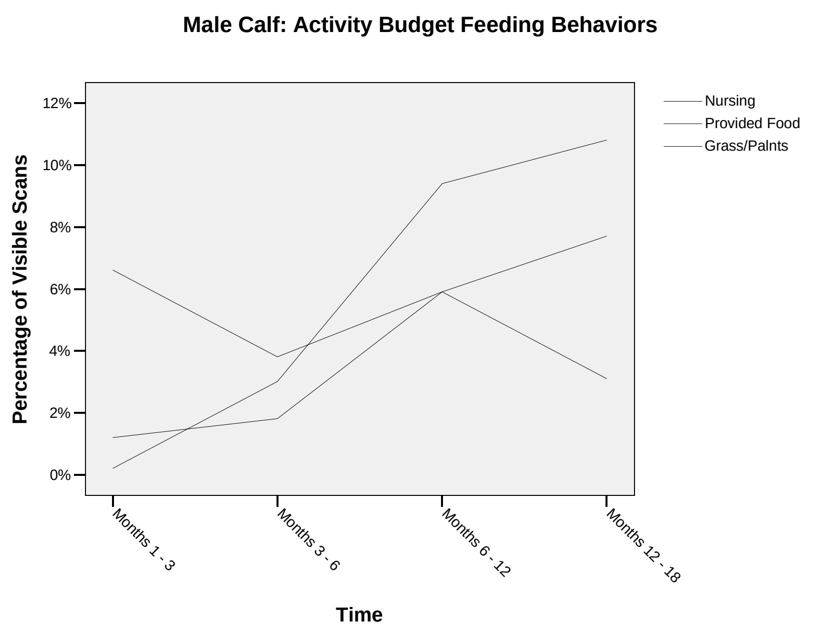

Figure 4. Percentage of visible scans for male African elephant calf engaged in feeding behaviors over first 18 months.

IN SITU CONSERVATION AND MANGEMENT

Understanding the habitat usage pattern of the Asian elephant (*Elephas maximus*) and the resultant human – elephant interaction through rapid trail and village surveys: An experience from Bannerghatta National Park and its environs, southern India

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Exploring human-elephant interactions is critical to the conservation of the Asian elephant. Understanding habitat usage particularly in narrow strips of forests dotted with human settlements is challenging and crucial in determining the status of human-elephant interaction. This requires a protocol of rapid seasonal surveys covering habitat and habitations simultaneously.

Here, we present our experience from a narrow stretch of forest (average width of 2 km & length of 25 km) connected to a large forest cover, surrounded by human settlements. A combination of rapid trail (for habitat usage) and village (for elephant straying) surveys were carried out simultaneously in the month of June 2004. Nineteen prefixed trails (179 km) covering all forest types, different microhabitats and administrative zones within the 104 Km^2 habitats of Bannerghatta NP and its environs were surveyed along with 111 villages (located within 5km radius from the park boundary) were visited by vehicles.

A total of 222 dung piles were encountered resulting in an overall encounter rate of 1.24 dung piles/km and an average encounter rate of 1.42 (SE=0.4)/km/trail. Overall elephant density appeared low (0.19 animal/km2) during the survey period. Encounter rate of old dung piles (week to month old) dominated (1.24/km and 77%) and 90% of the trails covered had old piles. Encounter rate of fresh dung piles was only 0.2/km (13%) and only 52% of the trails had fresh dung piles. Although 96 % of the surveyed villages are reported to have elephant problem, only 30 % of the villages reported visit of elephants at the time of the survey.

The results indicate a low elephant density (23% of the actual) and a specific seasonal pattern of habitat usage and human-elephant interaction. The results suggest further surveys covering different seasons for a better understanding of the subject.

INTRODUCTION

The Asian elephant (*Elephas maximus*) and its survival is mainly threatened today by dwindling of it's habitat due to loss of forest and encroachments (Daniel 1980, Desai 1991, AERCC 1998). In addition to this, the human-elephant conflict has been of great concern among conservationists as an indirect threat to the survival of the elephants today (Sukumar 1989). Elephant-human conflict refers to negative interactions between wild elephants and human beings such as crop raiding by elephants, human deaths and injuries caused by elephants and also killing of elephants (Nath & Sukumar 1998). The study of Human-elephant conflict issues has been of great interest and such interactions have been documented in several Asian countries (Sukumar 1989, Balasubramanian *et al*. 1995, Easa & Shankar 1999, Desai & Baskaran 1996). Understanding habitat usage particularly in narrow strips of forests dotted with human settlements is challenging and crucial in determining the status of human-elephant interaction. This requires a protocol of rapid seasonal surveys covering habitat and habitations simultaneously. Bannerghatta National Park is a narrow stretch of forest (average width of 2 km & length of 25 km) connected to a large forest cover, surrounded by human settlements. The objective of this study was to carry out a combination of rapid trail (for habitat usage) and village (for elephant straying) surveys simultaneously to look at the status of elephant and its distribution within and out side the park. The survey is part of the on going study on human-elephant conflict at the Bannerghatta National Park, southern India.

STUDY SITE

The Bannerghatta National Park (BNP) covers an area of 104 km^2 and is situated about 20 km south of Bangalore City of south India. It is a long narrow stretch, 25 km in length and 0.3 km^2 to 5 km^2 in width (E-W). The terrain is undulating with low hills not exceeding an altitude of 1100 m above sea level. Mean annual rainfall is around 900 mm. The highest elevation within the park is 1034 m above m.s.l. granite sheet rocks characterises the higher hills and quarrying is rampant in the areas around the park. An unusual feature of the park is the presence of 23 water holes distributed unevenly throughout the park. Most of these provide water throughout the year, which contrasts the park from the southern Hosur division where water is scare during the dry season. The vegetation is of Dry deciduous & dry thorn forest types. The terrain is undulating with low hills, rocky knobs & outcrops. The minimum elevation is at 740m and the maximum elevation is at 1034m.

METHODS

The method has 3 distinct components namely training/capacity building, trail survey and village survey. Using 35 volunteers and 25 forest staff as escorts, different forest trails (20) villages (111) were surveyed simultaneously for data collection**.**

Training and Capacity Building

A training program was carried out prior to the survey, primarily to bring together the varied backgrounds of the volunteer surveyors and expert field team to a common understanding of the objectives and approaches to be followed. This training was also designed to support the state Forest Department staff by training them on different techniques in field data collection. The program started with a presentation on the overview of the project and its objectives, followed by experiences from other similar studies by experts. The field training sessions focused on methods to study the status of elephants and human-elephant conflict issues. Volunteers were given training on the use of the survey forms and tips were given on field observations.

The training program was followed by a combination of rapid trail surveys (for habitat usage) and village surveys (for elephant straying), which was carried out simultaneously in the month of June 2004. The study site comprises of three administrative ranges and the volunteers were divided accordingly so as to cover all the ranges simultaneously during the survey.

Trail Survey

Twenty prefixed trails (179 km, mean distance/route 9 (SE = 07) km) covering all forest types, different microhabitats and administrative zones within the 104 Km^2 habitats of Bannerghatta NP and its environs were surveyed (appendix 1 for route and distance covered). One observer and field tracker(s) walked in these routes. Whenever elephant signs (track, dung, feeding and other signs) were located, time of sightings, location, forest type, number and the status of the sign (fresh or old) were recorded. While walking, a uniform pace was maintained to calculate the sighting intervals (in minutes) of each sign. At regular time intervals (30 minutes), nearest 4 tree species were identified for associating with the forest types surveyed (see appendix 2 for trail survey data sheet).

Village Survey

While 20 volunteers covered the forest for elephant and habitat survey, another set of volunteers visited 111 villages (located within 5 km radius from the park boundary) by vehicles. Data collection included name of the village, distance from forest, forest type, and report on over all and elephant visit during the survey period. Information on elephant visits was supported by the incidents of crop and house hold damage, elephant and human death and injury, and elephant barriers found close to the given village (see appendix 3 for village survey data sheet).

Data Processing

Encounter rate of signs (mainly of dung piles) was calculated by dividing the total distance covered by the number of dung piles encountered for each route. The frequency of occurrence of elephant signs was calculated through sighting interval. Survey routes were considered to be independent of each other. For each route, the encounter rate data (of dung piles) was analysed and results were incorporated to develop the patterns of habitat usage and distribution. For village survey, elephant visit for given village was assessed, based on this elephant visit only during the survey period was identified.

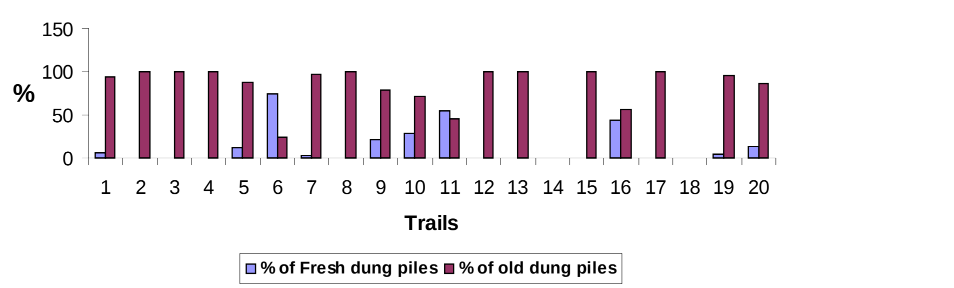
RESULT & DISCUSSION

Trail Survey

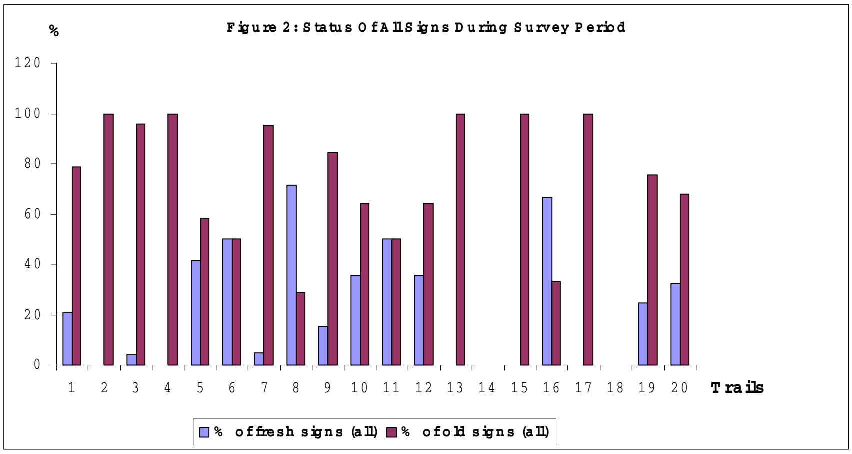
A total of 222 dung piles (average 11.1 SE = 2.32/route) were encountered resulting in an overall encounter rate of 1.24 dung piles/km and an average encounter rate of 1.42 (SE=0.4)/km/trail. Encounter rates of old dung piles (week to month old) dominated (1.24/km and 77%) and 90% of the trails covered had old piles. Encounter rate of fresh dung piles was only 0.2/km (13%) and only 52% of the trails had fresh dung piles (figure 1). Number of old dung piles encountered/route was 9.75 (SE = 2.2)/route and only 1.35 (SE = 0.43)/route for fresh dung. On average every 54.5 (SE = 15) minutes old dung piles are seen, but frequency of sighting fresh dung piles were every 189 (SE = 37) minutes.

Average number of fresh feeding signs were only 0.30 (SE = 0.2)/route and 0.35 (SE = 0.2)/route for old signs. Most elephant tracks (footprints) were found to be old ones (1.85 SE = 0.5 for old and 1.80 SE = 0.5 for fresh).

Figure 1: Status of dung Piles During Survey Period



Mean number of old signs (all the signs combined) encountered/route was 13.7 (SE = 2.6), an average of 67% (SE = 7.0) was old signs/route, fresh signs were only 4.85 (SE = 1.2)/route and an average of only 23% (SE = 5.0) fresh signs/route were encountered. Figure 2 indicate the percentage of fresh and old sings for all the routes.

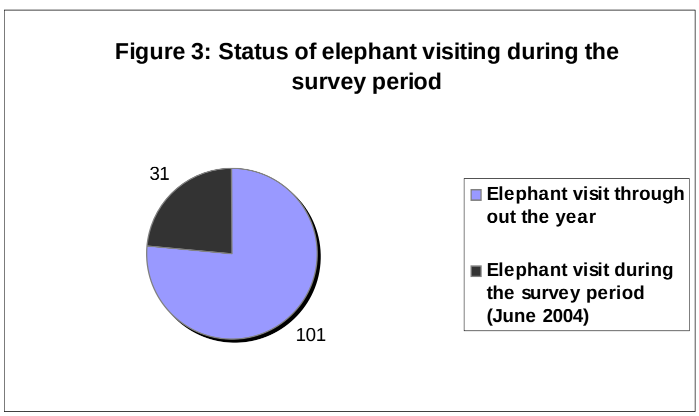


Estimation of Elephant Density

The estimated encounter rate was also used for estimating elephant density during the survey period. Comparison of the results of encounter rate of elephant dung piles with that of prime elephant habitat shows (Sukumar 1986) that encounter rate of the dung piles for the park is very low (11.05 times lower then that of prime elephant). This indicates that the park supports a relatively low density of elephants during the survey period. Assuming a similar daily defecation rate of elephant and dung decay rate, if the density of 1.74 animals/km^2 (Varman, et al 1995) is divided by the factor of 11.05, the park estimates a density of 0.16 elephants/km^2. Estimated elephant density for the park during 2002 elephant was 0.68 elephants/km^2 (AERCC 2002). Given this overall elephant density appeared low (only 23% of actual density of the park) during the survey period.

Village Survey

Number of villages visited during the survey was 111 and 91 % (n= 101) of the surveyed villages are reported to have elephant problem and only 30 % (n=31) of the villages reported visit of elephants at the time of the survey (figure 3).



During this period, average distance from the forest to the villages where elephant were reported was 2.3 (SE = 0.7, N=21) km, Ragi (Elusine coracana), rice (Oryza sativa), pulses, jack fruit (Artocarpus heterophyllus), banana (Musa paradisiaca), coconut (Cocos nucifera) and mango (Mangifera indica) were reported to be damaged by elephant during survey period. Among these crops, banana was damaged more followed by ragi and jack fruit. On an average, minimum number of elephant visited was 2 (SE = 0.6, N =22) and maximum number of elephant visited was 35 (SE =10, N=22).

Insight from Rapid Surveys

The results indicate that the all the routes surveyed had only old elephant signs. The results also showed a low elephant density (23% of the actual) and only 30 % villages surveyed had elephant visit during the survey period. The results suggest a specific seasonal pattern of habitat usage and human-elephant interaction. The results also imply the need of further surveys covering different seasons for a better understanding of the subject. Based on this experience we strongly recommend such rapid surveys, which are quite competent to fulfil specific objectives. It helps in identification of crucial conflict zones for long term studies. It should be noted that rapid surveys are less time consuming, save manpower & resources, provide results equivalent to long term studies and are therefore recommended when resources for research and conservation are less.

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Appendix 1: Details of route, distance covered and encounter rates of fresh and old dung piles.

Routes	Distance covered (km)	Number of dung piles (all)	Encounter rate/km	Encounter rate of fresh dung piles/km	Encounter rate of old dung piles/km
1	9	15	1.67	0.11	1.56
2	13	14	1.08	0.00	1.08
3	8	12	1.50	0.00	1.50
4	10	9	0.90	0.00	0.90
5	12.5	8	0.64	0.08	0.56
6	12.5	4	0.32	0.24	0.08
7	9	30	3.33	0.11	3.22
8	8	4	0.50	0.00	0.50
9	7	14	2.00	0.43	1.57
10	6	7	1.17	0.33	0.83
11	7	13	1.86	1.00	0.86
12	8	6	0.75	0.00	0.75
13	15	1	0.07	0.00	0.07
14	10	0	0.00	0.00	0.00
15	9	12	1.33	0.00	1.33
16	10	9	0.90	0.40	0.50
17	11	2	0.18	0.00	0.18
18	2	0	0.00	0.00	0.00
19	7	40	5.71	0.29	5.43
20	5	22	4.40	0.60	3.80
Mean	8.95	11.10	1.42	0.18	1.24
SE	0.69	2.32	0.35	0.06	0.33
Total	179	222		27.00	195.00

Appendix 2:Trail Survey Data Sheet

Elephant and habitat survey – through trail survey
Bannerghatta National Park, southern India

Date: Observer:

Name or number of the trail:
Location/name/GPS :
Starting :
Closing :
Time Starting: Closing:

Distance covered (km) :

Details of the signs encountered:

Vegetation				Elephant signs				
Sl. No	Time interval[1]	Name of the plant (local) [2]	Remarks	Sl. No	Time of sighting	Type of sign[3]	State of sign[4]	Remarks

1: Time interval: Approx 30 minutes **2: Name of the plant:** identify nearest 4 trees **3: Type of signs**: Elephant dung, track, feeding, sound (of elephant) and others 4: **State of Sign**: <u>Very Fresh</u> (VF one day old) <u>Fresh</u> (F 2 to 3 days old) <u>Old</u> (O above 3 days).

If the distance covered (for plant data) and number of signs encountered are more than the space available in this datasheet, please use a separate blank sheet to complete/continue the records.

Appendix 3: village survey data sheet

Village Survey for elephant distribution and human-elephant conflict in Bannerghatta National Park, southern India.

Date: Name of the observer:

Village Name: Name of the Villager:
Age: Sex:
Direction of village (from the forest) :
Distance of village (from the forest) :
GPS Location: Forest type:
Status of the forest:

Elephant visit: Yes/ No - If Yes, last 2 years information

SL. No.	Date/ Month	Min. individual.	Max. individual	Male	Female	Others	Remarks

<u>REASONS FOR ELEPHANT VISIT</u>: FOR CROP/ SALT/STORED RICE/ WATER/ LIQUOR/ OTHERS:

Name of the nearest village elephant reported:
____

DISTANCE OF THE VILLAGE FROM CURRENT VILLAGE:
____
Direction & location of the village from current village:
____

Human death due to elephants

SL No.	Date/ Month	Sex of the person	Age	CAUSE & PLACE OF THE INCIDENT/IN FOREST/IN SETTLEMENT/BY ROGUE/OTHERS	Remarks

Household damage

SL No.	Date/ Month	NAME OF THE STRUCTURE	No	Remarks

Crops damage

SL No.	Name	Month/ yr	Frequency of visit/season	Damage/crop/ season (Area)	Economic loss/crop/ season	Remarks

Elephant death:

SL No.	Month/ Yr	Sex	Cause	Remarks

Remarks

Elephant barrier:

Sl. No:	Name of the barrier	Location	Distance	Status	Remarks

Note: List the name of the barrier within the village limit

Mention location with in the village (may be a landmark or direction), Distance/length of each barrier (in Km) , Status: functioning, not-functioning/broken/repaired etc.

Establishing a model to develop local institution and individual capacity to contribute in an effective and sustainable manner to long-term elephant conservation

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In the efforts to conserve the elephant some of the biggest and pressing issues are:

1. How can the need to conserve and protect the elephant and the resolution of conflict be reconciled with the needs and aspirations of the local people who are most impacted by the elephant and vice versa.

2. How to develop economically and logistically feasible sustainable solutions that is also in confluence with the lifestyles and culture of the people of an area.

3. How to protect the last remaining habitat of elephants within and outside the protected areas.

At present most conservation measures have been developed in response to the proximate issues of elephant conservation, which are: protection, management and establishment of protected areas. Most of these efforts though have been applied in an ad hoc manner and has not contributed greatly to resolve HEC or conserve the elephant. Providing protection to humans and elephants can be very costly. This cost factor becomes a major issue when developing solutions. Even when pilot projects have proved to be successful, the funding to apply the proven techniques has become impossible due to lack of funds. Another mostly ignored issue is how to sustain projects that are initiated with donor funding. While donor funding is critical to keep the processes of conservation moving forward and to initiate new projects, it would be a misjudgment on our part if we believe that this periodic infusion of donor funds dispersed annually would suffice to protect elephants or help maintain projects over the long term. Currently there is a tendency to focus solely on projects and their immediate outcomes and ignore other issues such as: institutional infrastructure, individual researcher capacity, operation overheads, institution capacity building, long-term funding and sustainability. As much as there is a need to help the elephant, there is a critical need to develop a new model to help the individuals and organizations that are committed to long-term elephant conservation. The Sri Lanka Wildlife Conservation Society (SLWCS) has over 8 years of experience conducting in-situ conservation developing a sustainable model for elephant conservation in Sri Lanka. Based on our experiences the SLWCS is proposing the following: that the international elephant conservation forum, in addition to the grants they disperse, considers establishing a revolving operations grant. These grants can be given to proven institutions or individuals for a period of up to 3-5 years. During this time these organizations or individuals will use these grants to meet their operational needs while developing their infrastructure and capacity to sustain their projects and operations over the long term. At the end of the 3-5 year period the grants will be given to another group of organizations and individuals. This will ensure that the efforts to conserve and protect the elephant will have a solid and well-developed regional institutional foundation.

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Human-elephant conflict in the southern western Ghats: A case study from the Peppara Wildlife Sancutary, Kerala, India

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Human-elephant conflict in Peppara Wildlife Sanctuary (8o 34' to 8o 42' N and 77o 7' to 77o 14' E) and adjacent areas was studied based on observational methods during the year 1993 to 1996 as a part of project studying the large mammals in the sanctuary. Peppara Wildlife Sanctuary situated at an altitude ranging from 98 to 1594 m above MSL in the southern Western Ghats, India has diverse habitats like tropical moist deciduous and evergreen forests and plantations. Elephants were located 73 times during the period of study and altogether 217 elephants were seen, the male to female ratio was 1:6 (N = 217). Mean herd size was 10 individuals per herd and maximum numbers was sighted in the moist deciduous forest followed by eucalypt plantation, swampy areas, semi evergreen forest and evergreen forest. Plant species used as food by elephants was also recorded, when they were not involved in crop raiding. Major animals engaged in crop damage were wild boar and elephant. The animals involved in crop damage were mainly lone males, in the case of elephants and most of the raids were at night. It was observed that substantial amount of crop was damaged as compared to what was consumed by the animals. Coconut was mainly damaged by elephants and the damage was confined to the trees less than 20 years. Coconut trees less than 10 years were pushed down and the central rachis and shoots were consumed. Plantains were also attacked by elephants, the leaves were discarded and the central portion of the stem consumed. Elephant also destroyed paddy, rubber and pineapple by trampling. While damage by wild boar was recorded throughout the year, the attack from elephants was related to the species of crops cultivated. Besides crop damage instances, four human slaughters were also recorded. Crop damage is linked to the cropping pattern and location of settlements and it is one of the problems, which severely deprive the economic status of tribals.

INTRODUCTION

Wildlife of southern Western Ghats in India is unique with several rare, endangered and endemic animals. Many of these are facing extinction due to habitat deterioration and poaching. The State of Kerala is very rich in the diversity of animals and has a long history of protecting wild animals. As per the recent information seventy-five species of mammals have been reported from this region, of this 47 species are considered as larger mammals with a size larger than mouse deer. Among this, 14 species of mammals are found only in the Western Ghats.

Crop damage by Asian Elephants, has been studied extensively all over the Asian Countries. Studies on crop depredation by elephants are also well documented in India. No extensive studies were carried out in Kerala on the problem of crop damage by Asiatic elephants Elephas maximus. Many such works were published from other Indian States and from the Asian and African countries. A recent survey on crop depredation by wild animals in Kerala revealed that crop damage is heavy (Veeramani and Jayson, 1995). A study conducted in 10 villages along the Karnataka, Tamil Nadu border estimated that the total loss to agricultural crops by elephants was about Rs.1.5 lakhs per year (Sukumar, 1989; Sukumar, 1990). Similarly, man-wildlife interaction in Karnataka State has been reported by Appayya (1992). Mishra (1971) and Datye and Bhagwat (1993 a) have reported the economic loss due to the crop raiding elephants in the State of Bihar. Balasubramanian et al. (1993)

and Ramesh Kumar and Sathyanarayana (1993) also carried out identical works in the Nilgiris, India. In Peninsular Malaysia the economic loss to a single agency from destruction of oil palm and rubber plantations by elephants was estimated to be US $ 20 million per year (Blair et al., 1979). Similarly, many studies were reported from African countries (Tchamba, 1995 and Ngure, 1995).

Human-wildlife interaction in Karnataka State, especially the conflict between elephant and man has been studied by Sukumar (1988, 1989, 1991, 1994) and Appayya (1992). According to Santhiapillai and Jackson (1990) elephants kill about 100 to 200 people each year in India. Human deaths due to elephants have been reported from parts of Central India by Datye and Bhagwat (1993). Injury to human beings from wild animals is common as shown by Mohan (1994) and Tiwari (1994) in Garhwal area. Conflict between humans and elephants in Northern Kenya was reported by Thouless (1994). In the same way conflict between wildlife and local people living adjacent to protected areas in Tanzania was given by Newmark et al.(1994). No similar data were reported from the State of Kerala so far.

Study Area

Situated in the southern tip of Western Ghats in the Agasthiamalai ranges Peppara Wildlife Sanctuary comes in Kerala State, India (Figure1). It is located between 8^o 34' to 8^o 42' N latitude and 77^o 7' to 77^o 14' E longitude and the extent of the sanctuary is 53 km^2. The altitude varied from 98 to 1594 m above M.S.L and all the sides of the sanctuary are surrounded by forests. The highest peak is Athirumudi Peak (1594 m).

- Climate and vegetation

Sanctuary has a tropical hot and humid climate with a dry summer. Daily temperature varied from 32^o C to 20^o C in plains whereas it varied from 25^0 C to 16^0 C in high altitude. Average rainfall was around 4810 mm in the catchments area of Peppara Dam. The Peppara Wildlife Sanctuary has all typical vegetation types found in tropical areas like tropical moist deciduous forests (29 km^2), tropical evergreen forests (10 km^2), tropical semi evergreen forest (14 km^2), shola forests (0.79 km^2), reed brakes (2 km^2), bamboo areas (0.5 km^2) and grass lands (2 km^2) (Menon, 1997). A recent floristic study by Mohanan *et al.* (1997) documented 1084 species of flowering plants from the area.

- Tribals

There are seventeen Kani tribal settlements inside the Peppara Wildlife Sanctuary. They are distributed in the buffer zone as well as in the core area of the sanctuary. Like the other aboriginal hunting and gathering tribes, Kanis also have the primitive history of hunting, gathering and shifting cultivation (Thurston, 1909).

METHODS

The study was mainly based on observational methods. Status of larger mammals was assessed by direct and indirect methods. In addition to this, preferred habitats of elephants were recorded to understand the habitat use.

Direct Sightings

To record the presence of larger mammals different trek paths in the sanctuary and adjacent areas were surveyed by walking. Observations were made in the morning and evening and whenever an animal was sighted the species, sex, group size, activity, time and vegetation type were recorded. To record the presence of larger mammals, different trek paths in the forests and adjacent areas were surveyed by walking.

Line Transect Method

To document the status of larger mammals six transects were laid through different vegetation types. The first transect was in a moist deciduous forest (2 km). The second was in an evergreen forest (1.7 km). The third transect covered mixed vegetations such as deciduous, moist deciduous and semi evergreen forests (2 km). Fourth transect was laid again a moist deciduous and semi evergreen forest (2 km). The fifth transect was laid between through the moist deciduous and semi evergreen vegetation (1.6 km). The sixth transect was (1.7 km). This was also through the moist deciduous and semi evergreen forest. Out of these six transects, three were of two kilometres in length and others were not having 2 km length because of the reservoir and the undulating terrain. Due to heavy rainfall, growth of grass was rapid and both the direct and indirect sightings became rare in the transects. In the subsequent surveys, it was found that sufficient sighting of large mammals was not available and the data could not be processed, using the program DISTANCE, hence after an year this method was abandoned.

Indirect Evidences

As an alternative to the line transect method, quadrates of the size of 10 m x 10 m were laid for assessing the indirect evidences of large mammals. These quadrates were taken randomly on both sides of major trek paths. At every 50 m, quadrates were laid on the opposite side of the trek path. The quadrates were made in all the vegetation types such as moist deciduous, semi-evergreen and evergreen forests and in eucalypt plantation. Samples were taken from each vegetation type depending on the extent of vegetation. From these quadrates, indirect evidences left by the wild animals such as scats, droppings, diggings, feeding signs and scratching marks were identified. In doubtful cases, scats, hair and other materials were taken to the laboratory and compared with the known samples for identification.

Socio-economic Status of Tribals

Since the tribal population inside the sanctuary was in 160 families and in 13 settlements, the survey method was followed to study the socio-economic condition. A detailed interview schedule was prepared to gather information on demography, settlement details, educational status, migration patterns, family constellation, cropping pattern, infrastructure and human-animal conflicts. Pre-test: A pre-test was carried out to assess the validity and reliability of the questionnaire. The questionnaire prepared initially for this pre-test was used to collect data from the Chemmankala settlement. This settlement was selected purposely due to the low intensity of outside influence. Based on the preliminary survey, necessary modifications were made in the interview schedule and the final schedule was formulated.

Human-elephant Conflict

All the settlements inside the sanctuary were visited for recording the crop damage during the initial period of the study and Chanthakode tribal settlement was selected for regular and systematic observation by purposive sampling. Three households were selected, based on the location of the cultivated fields. One was in the periphery of the settlement and the other was in the middle of the settlement. The third one was near the reservoir. Members of each house were met once in a week and data were collected on the species of crop damaged, quantity, phenology of crops and the species of animals. Animals were identified from the indirect evidences left during the raid and from the report of members who have sighted or chased the animals. The terrain of the area and the distance from the forest border were also recorded. In addition to this, all the other settlements were visited once in a month and information on crop damage was collected from the settlers. If any severe crop damage was reported from any other settlement, it was visited immediately and detailed information was collected in a format. Data on various indigenous techniques for preventing crop damage by wild animals used by the tribals were also recorded. Detailed studies on wildlife attacks were carried out by visiting the place of incidents and recording details, regarding the animal involved, location, mode of attack and the social and economic background of the victim.

RESULTS

Population of Elephants

Asian Elephant was located 73 times during the period of study. Altogether 217 elephants were seen and the male to female ratio was 1:6 (N = 217). Mean herd size was 10 individuals per herd (Figure 2) and maximum were sighted in the moist deciduous forest followed by eucalypt plantation, swampy areas, semi evergreen and evergreen forests (Table 1). They were recorded from eleven localities within the sanctuary. Elephants uprooted trees like Eucalyptus, *Careya arborea, Dillenia pentagyna, Emblica officinalis, Helicteres isora* and *Terminalia paniculata*. Food species of elephants recorded from Peppara Wildlife Sanctuary is given in Table 2. This was done to identify the natural food of elephants when they were not involved in crop raiding.

Table 1. Habitats where elephants were sighted in Peppara Wildlife Sanctuary.

Month	EG	SEG	MD	Swamp	EP
January	7	0	35	52	11
February	-	8	21	0	41
March	-	8	17	1	1
April	-	-	28	-	22
May	-	-	8	-	15
June	-	-	11	-	11
July	-	-	23	11	23
August	-	22	12	1	11
September	9	-	27	-	14
October	-	-	44	1	14
November	-	-	8	-	1
December	-	8	22	9	11
Total	***16***	***46***	***256***	***75***	***175***

- = No sighting; EG= Evergreen; SEG= Semi evergreen; MD= Moist deciduous; EP= Eucalyptus plantation.

Table 2. Food plants of elephants in the Peppara Wildlife Sanctuary.

Plant species	Part of tree used	Remarks
Erythrina variegata	Lower bark	After pushing down
Pandanus sp.	Tender shoots	-
Pennisetum polystachyon	Leaf blades	Extensive feeding
Careya arborea	Tender shoots	
Bamboo	Shoots	
Helicteres isora	Leaf	tender shoots bark
Ochlandra ebracteata	Leaf shoots	
Ochlandra travancorica	Shoots	Feed extensively
Artocarpus hirsutus	Fruits Bark and tender shoots	
Ficus glomeratas	Tender shoots	
Shuminianthus virgatus	Leaf and shoots	
Pinanga dicksonii	Shoots	

Cultivation

All the tribal families own land and most of them acquired it initially by clearing the forest (91). Some of them got it as dowry (24) and others as compensation from the Govt. when they were evicted from the original settlements. Tapioca, dry land paddy, cereals as Italian millet, common millet, Indian corn and plantain were the main crops. However, at present most of them have abandoned the traditional cultivation and were practicing a mixed cultivation or in a transitional stage (153). Only four families practiced the traditional cultivation and others preferred modern cultivation (149). Due to various reasons, most of them did not utilise the whole area for cultivation (108). Main problems were the destruction of crop by wild animals and the absence of working people. Only few families (10) used pesticides, fertilizers or seeds from the outside.

Cultivation pattern: In the yester years, Kani tribals practiced shifting cultivation. Nevertheless, due to various reasons, they have abandoned this form of agriculture. At present, they cultivate in lands adjacent to their settlements only. In habitations, which are along the periphery of the sanctuary, modern methods of agriculture were practiced. Perennial crops were more extensively cultivated than the seasonal crops. Paddy was cultivated in the monsoon season. This was mainly done in Podiakala, Chemmankala, Mlavila, Kamalakam and Paranthode. Slash burning was carried out in April -May and sowing in June - July. One peculiarity noticed in the cultivation of cassava was that, two methods were adopted in its production. If the crop was meant for their own consumption, not all the plants were harvested simultaneously. In this method whenever a culm was removed, the stumps were again planted in the same place. Due to this method, they were able to harvest crop at any day of the year. Intermittent rain obtained in all the months, supported this mode of cultivation.

Crop Damage

All the families reported crop damage problems due to wildlife (Table 3).

Table 3. Mode of crop damage by different animals in Peppara Wildlife Sanctuary.

Species of animal	Crops damaged	Mode of damage
Wild boar	Tapioca, tubers, paddy	Digging
Elephant	Coconut, tubers, paddy	Trampling
Porcupine	Tapioca	Browsing
Blacknaped hare	Tubers, paddy	Cutting & feeding
Bonnet macaques	Tapioca	Pulling out
Mouse deer	Tubers, tapioca	Browsing
Barking deer	Tapioca, tubers	Browsing
Palm civet	Pineapple	Feeding
Bandicoot rat	Tubers	Digging

Most of the people were aware of crop damage compensation, but rarely applied for it. Only six families so far applied for compensation. Majority of the families have some livestock and poultry was main (116) followed by goat (73), cow (6) and buffalo (1). Hundred and thirty people reported that their livestock were attacked by wild animals. Maximum of the attacks were on fowl followed by goat and dog.

Table 4. Crops damaged by wild animals in Peppara Wildlife Sanctuary.

	Common name	Scientific name
1.	Cassava	*Manihot esculenta*
2.	Paddy	*Oryza sativa*
3.	Plantains	*Musa* sp.
4.	Rubber	*Hevea brasciliensis*
5.	Pineapple	*Ananas comosus*
6.	Coconut	*Cocos nucifera*
7.	Taro	*Colocassia esculenta*
8.	Elephant foot yam	*Anorphophallus companulatus*
9.	Sweet potato	*Ipomea batatus*
10.	Arrow root	*Maranta arundinaceae*
11.	Ginger	*Zingiber officinale*
12.	Cocoa	*Theobroma cacao*
13.	Jack tree	*Artocarpus heterophyllus*
14.	Mango tree	*Mangifera indica*
15.	Lesser yam	*Dioscorea esculenta*
16.	Black pepper	*Piper nigrum*
17.	Areca nut	*Areca catechu*
18.	Medicinal plants	many species

However, when the yield was meant for market, simultaneous harvesting and planting was practiced. In this mode of cultivation, if an attack of wild boar occurs at the time of maturity, the economic loss was heavy. In the past, Kanis cultivated crops for their consumption only, but now they cultivate crops for sale as well.

Animals Involved in Crop Damage

Crop depredation has been recorded in all the 17 tribal settlements. Seven species of animals were damaging 18 crops. Main crops destroyed were tapioca, plantain and coconut (Table 5). Maximum occurrence of crop damage was recorded in the month of June followed by May (Table 6).

Table 5. Incidence of crop damage during different months.

Months	Tapioca	Plantains	Coconut	Betalnut	Pineapple	Rubber	Paddy	Tuber crops	Others	*Total*
Jan.	16	1	1	1	2	3	-	5	1	*30*
Feb.	10	1	-	-	2	-	-	3	-	*16*
Mar.	13	2	-	-	-	-	-	-	1	*16*
Apr.	4	1	1	-	-	-	-	-	-	*6*
May	31	1	1	-	3	-	-	-	-	*36*
Jun.	19	6	6	1	2	3	2	1	1	*41*
Jul.	27	-	-	2	-	-	3	3	-	*35*
Aug.	25	-	1	1	-	-	-	-	-	*27*
Sep.	8	-	-	-	-	-	-	1	1	*10*
Oct.	23	-	-	-	1	-	-	1	-	*25*
Nov.	23	-	-	-	1	-	-	1	-	*25*
Dec.	6	1	-	-	-	-	-	-	-	*7*
Total	205	13	10	5	11	6	5	15	4	

- = No raids recorded

Similarly, wild boar attacked crops more, than any other animals. This was followed by elephants and hare (Table 6).

Table 6. Number of raids recorded for each animal from the Peppara Wildlife Sanctuary.

Months	Animals					
	Wild boar	**Elephant**	**Hare**	**Deer**	**Others**	***Total***
January	11	8	4	6	-	*29*
February	16	-	-	-	-	*16*
March	15	-	-	-	-	*15*
April	2	4	-	-	-	*6*
May	30	4	1	-	1	*36*
June	14	22	1	-	4	*41*
July	31	3	-	3	-	*37*
August	21	3	-	-	-	*24*
September	8	2	-	-	-	*10*
October	3	8	3	-	-	*14*
November	17	3	3	-	-	*23*
December	4	3	-	-	-	*7*
Total	*172*	*60*	*12*	*9*	*5*	

- = No raids recorded.

Nine settlements experienced highest crop damage and in other settlements, it was negligible. Moreover, among them, Chemmankala recorded the highest number of attacks by wild animals. Major animals engaged in crop damage were wild boar and elephant. Apart from these, the Indian porcupine, barking deer, sambar, blacknaped hare and bonnet macaque also destroyed crops. The settlements, Erumbiyad, Pothode, Amode, Cherumangal, Mlavila, Pattinipara and Paranthode are in a cluster and the agriculture was not much advanced. Due to these reasons, crop damage was less (Table 7).

Table 7. Incidence of crop raiding recorded from the Peppara Wildlife Sanctuary during the period of study.

Name of settlement	No. of raids	Animals	Time
Chemmankala	87	El, WB, P, BD, BNH	Midnight, morning, evening, day time
Podiakala	47	El, WB, BNH	Night, midnight, evening, morning
Chathankode	27	El, WB	Night, late evening, early morning
Podium	15	El, WB, BD	Night, evening
Ottakudi	19	El, WB	Night
Kochukilikodu	5	El, WB	Night
Cherumangal	4	El, WB	Night
Valiakala	4	El, WB	Night
Kunnatheri	1	El	Night

El - Elephant; WB - Wild boar; BD - Barking deer, P - Porcupine; BNH - Blacknaped hare

The quantum of money claimed by the tribals was higher than the actual loss calculated from the field observations (Table 8).

Table 8. Economic loss claimed by the tribals in the different settlements for crop damage.

No.	Name of settlement	Economic loss claimed (Rs.)	Economic loss assessed (Rs.)
1	Amode	11000	-
2	Chathankode	-	9000
3	Chemmankala	9050	6563
4	Chemmankala II	6300	-
5	Cherumangal	23670	1300
6	Erumbiyad	18865	-
7	Kamalakam	45540	-
8	Kochukilikodu	-	1800
9	Kombodinjal	12850	-
10	Kunnatheri	22325	700
11	Kuravampara	38675	9000
12	Mlavila	25575	-
13	Ottakudi	-	6000
14	Paranthode	11410	-
15	Pattampara	19255	-
16	Pattinipara	11650	-
17	Podiakala	44450	8332
18	Podium	39765	3400
19	Pothode	16325	-
20	Thondankal	1640	-
21	Valiakala	-	1,400

- = No data

Mode of Damage

The animals involved in crop damage were mainly lone males, in the case of elephants and most of the raids were at night. It was observed that more quantity of crop was damaged than, what was consumed by the animals. In the case of tapioca, a preference was shown for tender shoots and tubers. Coconut was mainly damaged by elephant and was confined to the trees below 20 years. Trees below 10 years were pushed down and the central rachis and shoots were consumed. Plantains were also attacked by elephants and discarding the leaves, the central portion of the stem was consumed. Paddy was lost due to wild boar, elephant, blossomheaded parakeet and jungle fowl. More waste was due to trampling and rolling by the animals in the field. Elephant also destroyed paddy by trampling.

Pineapple was destroyed by elephant, wild boar, and palm civet and palm squirrels. Elephant and wild boar preferred fruits and central rachis of the pineapple, where as palm civet and squirrel consumed only the fruits. Elephants trampled and uprooted rubber samplings and they fed on the basal portion of the plants. Cashew trees and betel nut trees were not damaged by any of the animals. No distinct pattern was observed in crop raids. While damage by wild boar was recorded through out the year, the attack from elephants was related to the species of crops cultivated. Whenever palatable crops like, plantain, coconut and areca nut were planted, elephants attacked them.

Preventive Measures for Crop Damage

- <u>Indigenous methods</u>

Indigenous and modern methods were employed by the tribals and local people for the protection of crop. Thirteen indigenous preventive measures were identified from the area, which are listed below.

Application of Bar soap, Kerosene, human dummies, Cloths and plastic bags, Areca nut sheaths. They trap the animals, which come to the vicinity of settlements; for which many death traps are designed by them. Locally available materials like stone, bamboo, reed poles and plant fibers are utilized for making these traps. The skills of hunting and trapping of wild animals are still utilized by them to control the crop raiding animals.

Table 9. Preventive measures used against different animals.

Preventive measures	Animals
Bamboo fence	Wild boar
Bush fence	Barking deer
Line fence using banana fibre	Wild boar
Reed line	Wild boar
Cracker line	Wild boar
Cables	Wild boar
Sound from bamboo pieces (Kottumula)	Barking deer, Mouse deer
Sound from old metallic parts	Wild boar
Cover	Wild boar
'Dalle' (Deadfall trap)	Palm civet, Porcupine, Mouse deer
Trap	Blacknaped hare porcupine
Dogs	Wild boar
Fire line	Wild boar
Kerosene	Wild boar
Plastic bags	Wild boar
Cloths	Wild boar
Chasing	Wild boar

- <u>Modern methods</u>

Trenches, cracker lines and live wire fencing are the modern methods applied by the tribals and local people for controlling the crop damage. In addition to this, electric fence with energiser were also erected by the Kerala Forest Department to control the crop damage, in some tribal settlements.

Trenches: Tribals of Paranthode settlement employed trenches for protecting the crop. But later they have abandoned it due to the difficulty in maintaining. Maintenance of trenches was laborious due to the loose soil structure and intermittent rainfall in all the months.

Cracker lines: This is a common method in which a bit of gunpowder is packed in a paper and kept under a stone. When an animal touched the lead line from the cracker assembly, it triggered a mechanism by which the stone placed above the gunpowder falls on it creating a loud sound. This noise functioned as a warning to the watchers and as a threat to the marauding animals. Local people widely applied this method and tribals employed it, when intensive cultivation was going on. One disadvantage of this method was that, as these lines provide only warning, people have to go to the field to drive away the animals. Deviarkunnu and Pannikuzhi were some of the locations, where this method was prominently used.

Live wire fences: Connecting AC current directly to barbed wire fencing or to the iron wires is known as live wire fencing. The connection may be either from domestic wiring or directly from 220 KV lines. In many areas, local people have adopted this method, which is highly lethal to humans and to the wild animals. This method was not employed permanently but whenever threat of wild animals was anticipated, live wire fencing was made active. This was mainly practiced to save the coconut palms against the attacking elephants. No human or animal casualties were detected due to this method, during the period of study.

Electric fences: Electric fence with energiser has been very efficient in controlling the crop damage all over the world including India. A solar electric fence with energiser was constructed at Chemmankala settlement. Electric fence considerably reduced the attack of elephants on crops at Chemmankala. An instance of breakdown of electric fence was observed during March. This was due to an elephant running amok, and entering the settlement destroying the fence. In the case of small animals, the fence was not effective. As the terrain was undulating with small creeks and ditches, wild boar entered the settlement through the fence.

Problems encountered in managing the electric fence: Though the electric fence was effective in controlling the elephants and other large herbivores many problems were encountered in its maintenance. It was observed that, when intensive cultivation was not practiced by a family, they were not interested in maintaining the fence. Due to this, it is not advisable to leave the responsibility of fences to individual families. As the rainfall in this area was heavy and occurs in all the months, the growth of vegetation was heavy. Due to this, one labor was required to remove the vegetation at least on alternate days. With the fast growth of vegetation, lower line of the electric fence used to touch the vegetation, which caused a drop of voltage from the fence. Due to the insufficient sunlight, battery was not fully charged during the months of monsoon. This has caused depletion of voltage in the fence and a fence with low voltage was not a barrier to wild boar.

Human Slaughter by Elephants

Many instances of attacks by wild animals on people were recorded during the period of study. Among them, the prominent was manslaughter by elephants. Four human deaths were recorded in five encounters (Table 10). In the first incident, a lady was killed by a tusker, while she was collecting firewood along with her husband and friends. It happened adjacent to the sanctuary boundary in the Agasthiavanam Biological Park. Vegetation type where this happened was moist deciduous forest with *Helicteres isora* bushes. While the victim was going for collecting firewood, two sub adult tuskers suddenly appeared after a curve. One tusker charged the group and when the women fell down, while running for life, the tusker lashed the women with trunk, killing her instantly. After some time the elephant left the area leaving the body of the victim. Due to the incident, laborers abandoned the area for a month. The cause of attack was identified as close encounter with the tuskers.

The second manslaughter by an elephant occurred in a eucalypt plantation. A man was killed by a female elephant from a herd. Initially the group of people comprising the victim threw stones at the elephant herd, to chase them away from the forest path. After some time when they moved through the way thinking that the elephants have left the area, elephants suddenly attacked them and the victim was beaten up with the trunk. No visible injury was seen on the body and he died in the hospital after three days. In the third event, a lady was slayed by a lone tusker. A group of five women was going for fire wood collection. While they were moving through the forest, talking loudly a tusker turned up and chased the women. While running most of them fell down. The victim was attacked with the trunk and died of excessive bleeding. In the fourth case, a male belonging to Aryanad was put to death while he was collecting fiber from *Helicteres isora*.

Table 10. Human-slaughter by elephants in Peppara Wildlife Sanctuary (March 1993 to March 1996).

Group composition of elephants	Victims age	Sex	Time	Date	Vegetation type	Location of incident
Two tuskers (Sub adults)	52	Female	10.30	9.8.93	Reed brakes	Third block of Agasthiavanam Biological Park
Herd	56	Male	16.30	17.7.94	Eucalyptus plantation	Chembuthangi
Lone tusker	35	Female	11.00	8.12.94	Moist deciduous forest	Agasthiavanam Biological Park
Lone tusker	53	Male	11.00	April 1995	Swamp and eucalyptus plantation	Kollotupara

DISCUSSION AND CONCLUSIONS

Elephants were mainly sighted in moist deciduous forest and eucalypt plantations. Male to female ratio of 1: 58 showed the good representation of males in the population. An average of 4.3 people live in each house. The settlement Pattinipara has the maximum illiterates and Pothode and Kuravampara has high literacy rates. The peripheral settlements have more educated people, they were practicing modern agriculture with cash crops, and the incidence of crop damage was more. They become less interested in employing the traditional methods of crop protection such as keeping watch and ward. As cultivation was their main occupation, any incidence of crop damage will seriously affect them.

Crop damage incidences can be correlated to their economic condition also. When the families are in debt trap or with low income, they initiate commercial cultivation of cash crops at the instigation of outsiders. This leads to increased crop damage and more frustration. Another social custom, which promoted the incidence of crop damage, was the custom of marriage with people other than the Kanikkar. Outsiders begin to stay in the settlements when they marry a tribal girl. With their educational background, they initiate cultivation of crops like plantains and coconut. This will lead to more crop damage. Amode, Kunnatheri and Cherumangal are examples. With the adoption of modern way of lifestyle, there is a increased chance for human-elephant conflict.

Since the cash crops are more nutritive, elephants prefer them (Sukumar, 1991). This may be the reason, why the wild boar also attacks the cash crops extensively. One difference noticed in the crop damage between wild boar and elephant was that damage from elephant was seasonal, where as in the case of wild boar it occurred in all months. Seven species of wild animals were involved in crop damage at Peppara. Among them, elephant and wild boar inflict maximum damage. Main produce destroyed was tapioca and plantains. Crop damage by wild boar can be considered as severe where as from elephants it was only moderate. Thirteen indigenous preventive measures were used by the Kanis. Since all the settlements were situated inside the sanctuary, animals attacked the crops regularly. However, where the settlements were in cluster and the agriculture not much advanced the crop damage was low.

Since the Kanis have evolved various "Chattu pattu" (Magical songs) to prevent the crop damage from time immemorial, It is believed that crop damage was experienced by them from ancient times and they have accepted it as a natural calamity. Careful selection of crops and planting strategy is necessary to reduce the crop damage. Cultivation of crops like medicinal plants and rubber will reduce the problem and increase the income of people where as crops like, plantains and coconut in monoculture will increase the crop damage. When they were practicing shifting cultivation, coconut or plantains were not cultivated. Cassava and cereals were cultivated for sustenance. However, with the change in cultivation pattern they initiated the cash crops, which are highly vulnerable.

It was found that indigenous methods used for crop protection is effective to control the animals up to certain extent. Electric fence with energiser was useful in controlling the elephants. Nevertheless, maintenance of electric fence was a problem. Tribals did not have the organizational initiative or enthusiasm to maintain an electric fence. If day-to-day instruction was not given, they lose interest in maintaining the fence. Solar electric fence was effective with proper maintenance and it completely stopped animals like elephant, sambar and gaur. Electric fence is not a permanent solution, since the sanctuary is having intermittent rainfall in all the months and the growth of vegetation is fast. In order to keep the high voltage in the line, day-to-day removal of tree branches and other vegetation is must. Due to the crop damage, tribals were not able to increase their income from agriculture. Only by increasing the crop area with the monoculture of cash crops, they will be able to increase the income but this is not possible under the present conditions. When Kanis attempt more cultivation of cash crops to increase their income more crop damage is experienced.

There are different hypothesis on the reasons for crop damage. Kushalappa (1990) described that, summer is the critical period for wild elephants, when they attempt to raid nearby agricultural crops. In such period, most of the trees in the forests are with out leaves, the grasses are dead and burnt with little or no water in streams and tanks makes the animal to move on to cultivation. The destruction is particularly severe in areas adjoining to the forests with animals such as elephant, tiger, deer, primates and wild pigs. Another hypothesis is the "high risk high gain" strategy of elephants in which males are supposed to make high risk on their life for the reciprocal gain of access to the highly nutritious food which will further increase their chances of having more progenies and thus better transfer of their genes (Sukumar and Gadgil, 1988).

Main conflict of wild animals was with the local people. Regarding man-wildlife conflict, tribals are experiencing only less of it, where as local people are severely affected. Of the four human deaths, in none of the cases a tribal was involved. All the victims were local people, who went to the forest in search of livelihood. Local people rarely cared for the elephants and took least precautionary measures. While considering the preventive measures, Sale and Berk Muller (1988) suggests that most of these conflicts can be alleviated, if wild animals can be confined to areas set aside for them and conversely domestic stock can be prevented from entering National Parks and sanctuaries, where they have no legitimate place. Programmes that are more educational should be introduced for the local people to reduce human casualties.

Providing compensation is not a permanent solution to the problem. Andhra Pradesh, Arunachal Pradesh, Manipur and Rajasthan do not pay any payment. Among the States which pay compensation, it varied from Rs.2,000/- to Rs.10,000/- (Kothari, et al., 1989). Even in Kerala, adequate compensation was not given for the crop damage. Human - wildlife conflicts can be reduced, if more tribals are engaged in forest works than the non-tribals, who came from far away places.

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Threats to the recovery of elephants in Southern Queen Elizabeth Conservation Area

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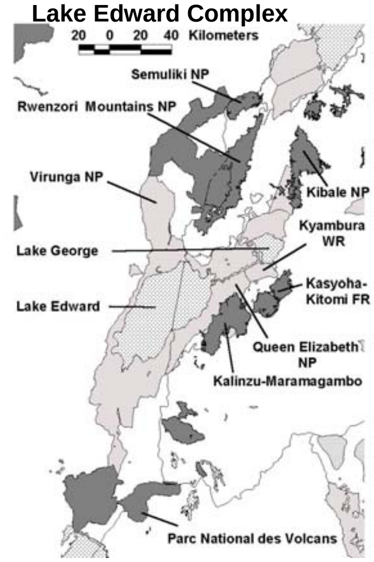
The Ishasha Sector of Queen Elizabeth Conservation Area in South West Uganda is one of the most wild and biodiverse regions along the Albertine Rift system. It also forms the largest and most viable connection between the Democratic Republic of Congo's Parc National des Virunga, and Uganda's QECA and its various adjacent protected area. The variety of habitats that the protected area complex includes is extreme and many are highly threatened, including a World Heritage site, a Ramsar Site and QECA, a Biosphere Reserve. The effects of armed conflict and resident armies are a continuous threat to the border regions and subsequently to its wildlife and habitats. Past research and management have focused on the accessible northern extremities of QE. Little was known about the status of and threats to the elephants in the inaccessible and larger land area in Southern QECA. However, it was known that the region also experienced some of Africa's most severe poaching pressure. ECP has found a young and recovering populations of elephants that are now confirmed as the largest concentration remaining within the Albertine Rift system. However, the threats to them are serious and growing. When in the DRC, elephants continue to be poached; and in QECA, the elephants are being poisoned by the communities in revenge for crop raiding which the farmers are having to endure, without resolution. The loss of land and connections to protected areas and their habitats are fast becoming an issue as is the continual demand for bush-meat. ECP, as a management – oriented research project has particularly concentrated on challenges in the area which are achievable within the constraints of the regions problems.

INTRODUCTION

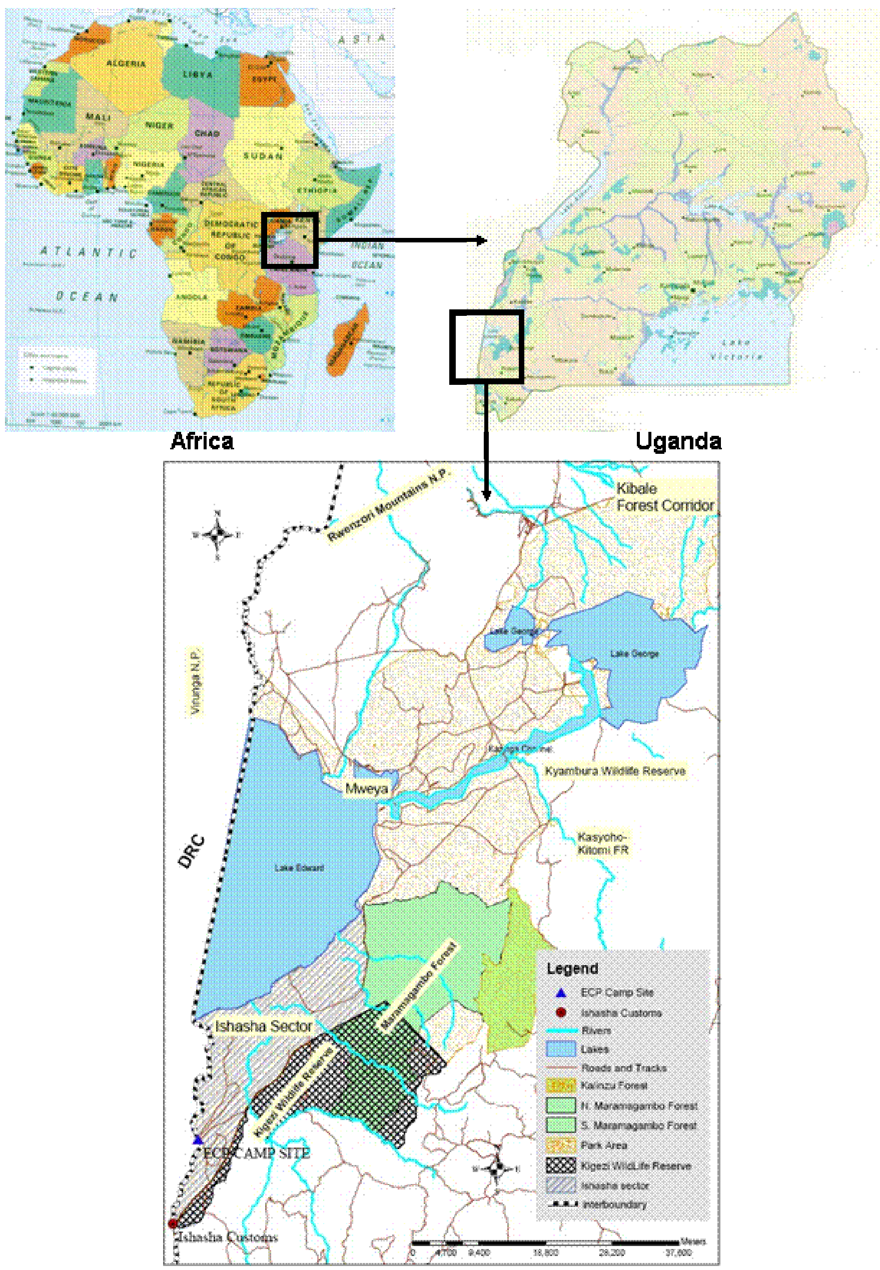
The status of elephants (*Loxondata African* (Blumenbach)) in the Albertine Rift has changed markedly over the past century. From hosting the highest mega herbivore biomass (Petrides & Swank, 1963; Coe et al, 1976) and stimulating the need for population control, the wildlife was then ravaged by severe poaching. The region as a whole is still under considerable strain from human population growth, the demands for land, civil unrest and of course, poaching pressure. The objective of the Elephants, Crops and People (ECP) project was to support the Uganda Wildlife Authority (UWA) to conserve elephants in Southern QECA. In doing so ECP has been providing UWA with management orientated research information on the ecology of Southern QECA's elephants and, present and potential threats to their future. The foremost threats were identified as viability of the remaining elephant populations, poaching pressure, land and habitat availability, transmigration between the vulnerable Park National de Virunga in the Democratic Republic of Congo, elephant – human interaction and potentially low levels of management. With regional unrest ever present, many of the above are issues beyond the realms of wildlife management.

Map 1: The Network of Protected Areas within the Lake Edward Complex



Location

The Queen Elizabeth Conservation Area (QECA) is found in South West Uganda and includes Queen Elizabeth NP (2080km²), Kyambura (154km²) and Kigezi Wildlife Reserves (265km²). Along with the other adjoining protected areas including Kashoya – Kitomi, (399km²) Maramagambo (152km²) and Kalinzu (141km²) Forest Reserves, Kibale NP (795 km²), the Kibale Corridor, Bwindi Impenetrable (321 km²), Rwenzori (998km²) and Semliki (221km²) National Parks, Semliki Valley Wildlife Reserve (558km²) and the Park National des Virungas (10,703km²) in the DR Congo. The area forms the largest network of protected areas within the Albertine Rift. The system is very diverse in landform, habitat and subsequently biodiversity. Surrounding Lakes George and Edward the network includes a World Heritage and a Ramsar site as well as QECA being designated a Biosphere Reserve in 1979.



Queen Elizabeth Conservation Area

ELEPHANTS

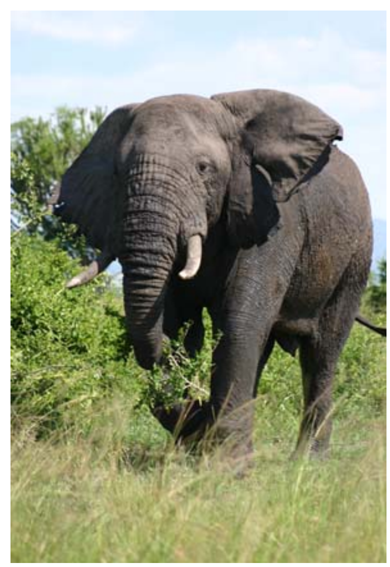
▫ Historical Context

The number of elephants in Uganda has declined drastically over the past century. Until the late 1920s, elephants ranged over 70% of the land area of Uganda; by the 1960s the figure was 17% (May, 1977). As a result large numbers of animals moved into the protected areas increasing densities within the protected areas to such an extent that habitat were great altered. In the 1960s Uganda's elephant population was estimated at 60,000 (Laws *et al,* 1970, Eltringham, 1991) and in an attempt to reduce the impact of the high densities some 2000 elephants were culled in Murchison Falls NP between 1965 – 67 (Laws *et al* 1970).

Akiki and her Family Group of 9. Note the scar on her side. (M. Keigwin, 2001)

Throughout the 1970s there was intensive hunting for ivory caused by a rapidly expanding international ivory market (Eltringham and Malpas, 1980). Then, during the 1970s and 1980s came civil chaos, stemming from civil wars and political instability. Uganda's wildlife was then slaughtered commercial poachers and heavily armed army militias using automatic weapons (Edroma, 1984). Elephant populations in QECA declined from a maximum count of 4,755 in 1967 (Eltringham, 1977) to just 150 (Douglas – Hamilton *et al* 1980). However, during the later aerial survey it was also recognised that 350 elephants were in the adjoining Parc National des Virunga in the Democratic Republic of Congo.

With renewed management, as with other protected areas in the late 1980s, total counts recorded some 400 – 500 elephants (Olivier *et al* 1989; Olivier 1992). With QECA more controlled, elephant numbers continued to increase throughout the 1990s to an estimated 1100 (Lamprey and Michelmore, 1996). Since then Uganda has been benefiting from continued political stability, whereas the adjoining PNV in the DRC has experienced the opposite and so continued heavy poaching pressure. In 2002 another aerial survey was undertaken and some 998 elephants were recorded (Rwetsiba *et al*, 2002). At this number the population constitutes the biggest discrete population of elephants in both the Albertine Rift and in Uganda.



Izinga, one of the Northern QECA bulls. (M. Keigwin, 2004)

ELEPHANT METHODOLOGY

One of QECA's senior bulls, Rob. (M. Keigwin, 2004)

The objective of this section was to ascertain the viability and potential recovery, the ecology, distribution, movement patterns and incidents of elephant deaths in SQECA.

Elephant encounters were recorded whether from direct or indirect observations. From direct observations 'senior' elephants were identified and the numbers of elephants counted. Where possible elephants were aged and group numbers and structures recorded. With very limited road coverage many areas were very inaccessible, however, the team whether in a vehicle or on foot covered as much of Southern QECA as possible across the seasons. We also made great efforts to move into the far corners and more inaccessible regions of the protected areas. All elephant 'interactions' were recorded.

ELEPHANT RESULTS

ECP has identified that the elephant population is viable and recovering. The age structure is skewed towards younger animals, with few between 40 and 60 years old. Judging by past research and by the sheer number of young and baby elephants ECP believes that the elephants are breeding at their optimum rate. Some 1500 elephants are estimated to be a resident population within QECA. However that number can and does rise well over 2000 through transmigration from the DRC and movements from the adjoining forested areas. The greatest number of elephants seen together in one aggregation was 700 in March 2003 along the Northern Ishasha River. At this time ECP confirmed another two aggregations of over 120 elephants in each further north and further 80 in the Southern Ishasha River.

The elephant's behaviour remains very nervous towards any human related circumstance. This reflects the past and continued human pressure that they have experienced. As a result the elephants are very uneasy around people and prefer to be hidden in the forests during the daytime. At night they enter the open savannah's to feed. These elephants are much more likely to run away or defend themselves in any encounter with people.

Elephants are well distributed across SQECA. Areas closer to the community boundaries (notably Kigezi WR) are often only used during the night and used as a dry season. The most limited distribution is in Kalinzu Forest Reserve. However, ECP has found that the adjacent Kashoya – Kitomi FR is used on a seasonal basis by the elephants south of the Kazinga Channel.

We have not found evidence of elephant poaching in SQECA. However, elephants are getting caught in snares set for other mammals and communities are killing elephants in revenge for crop raiding using poisoned fruit and spears. We believe that in SQECA alone, 12 - 20 elephants are killed per year through interactions with humans. The numbers being lost in PNV is unknown but is likely to total over 40 to 50 per year.

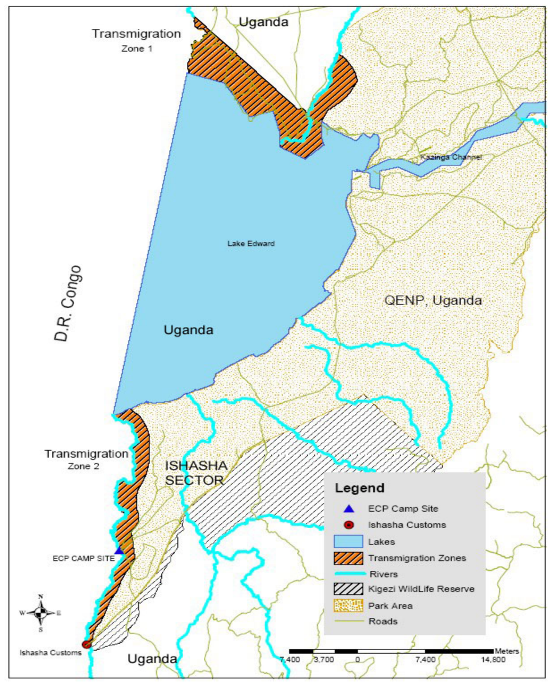
Transmigration

▫ Methodology

Elephants move between PNV and QECA through two zones, the most viable of which is in SQECA (Mubalama, 2000; Keigwin, 2001). Numbers of elephants continue to crash in PNV with the most recent counts giving a mere 486 and 286 (Mabalama, 2000; Hillman Smith et al, 2003). With severe disruption continuing the objective of this section was to ascertain the threat level to the viability of the elephants of QECA through their transmigration into the PNV. ECP looked to understand the proportions of the elephant populations transmigrating as well as their annual and seasonal trends.

Weekly walks were undertaken along the Ishasha River between Jan 2001 and Dec 2004. The walks were from near the Ishasha Customs border post to the end of the River Track game track. They were carried out in two parts, Southern and Northern, with the cut off point being the central Ishasha Ranger post. Some 13 crossing points were identified and both direct and indirect evidence of crossings were recorded. For the analysis the 13 crossing points were grouped according to topography. The date, location, frequency, direction and number of elephants were recorded.

The Transmigration Zones in QECA. ECP focused on the Transmigration

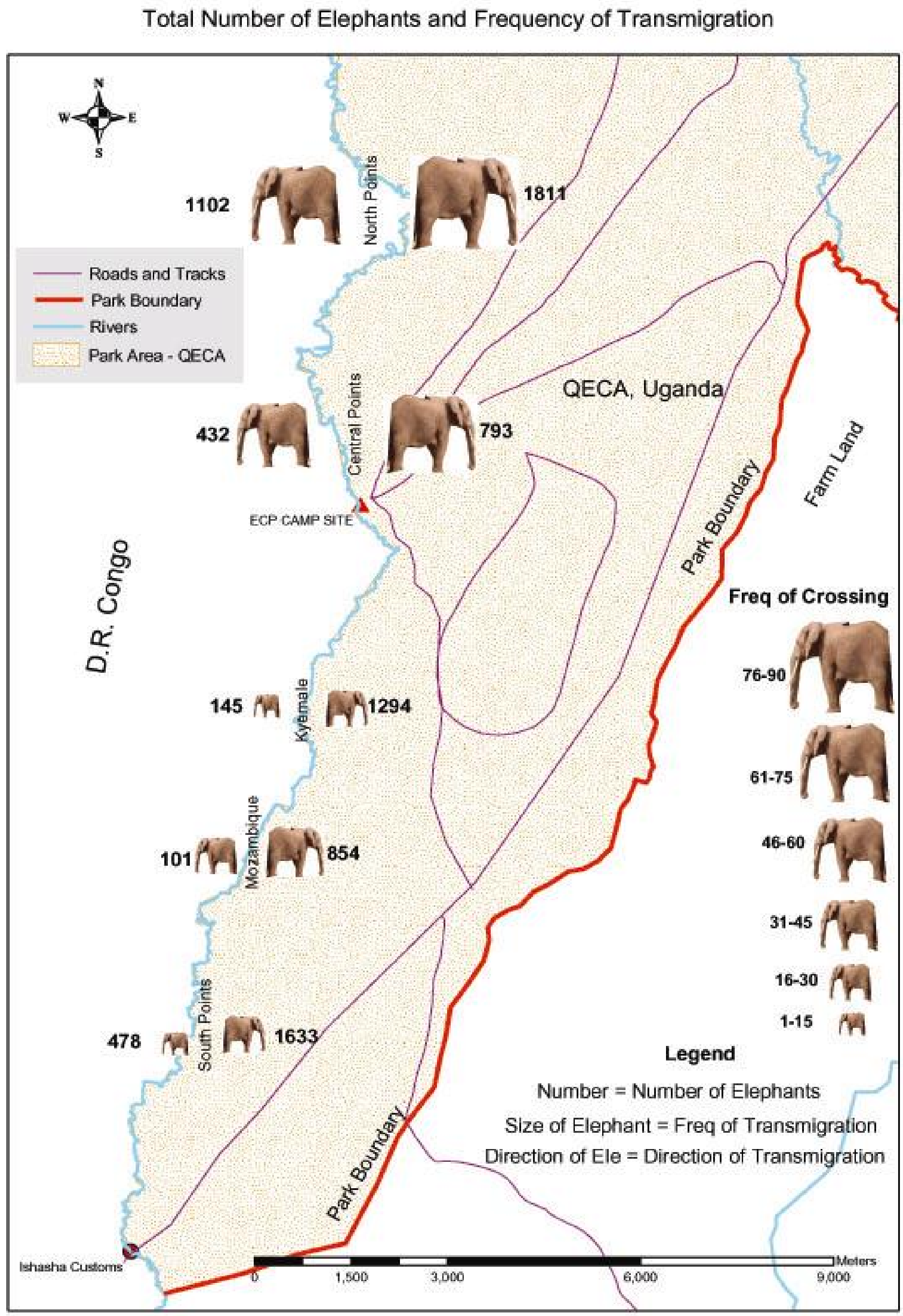


▫ Transmigration Results

During the research period ECP has found that the elephants regularly transmigrate to and from the DRC, with the greater frequency number of elephants crossing to Uganda. However, elephants do still use the PNV but ECP believes that they are spending more time in QECA than they used to. ECP has also recorded an annual increase on the number of elephants crossing to Uganda.

Seasonal transmigration has followed a trend. During the beginning of the year through the Dry and Wet season (Dec / Feb, March / May) and during the last wet season (Aug / Nov) elephant crossings numbered over 2500. However, in the second dry season (June / July) crossings dropped to just over 660.

The increase in usage of QECA by the transmigratory elephants will increase their security and continued recovery. With the elephants still moving into the DRC (just less frequently) the elephant populations will be able to repopulate PNV when increased security and improved management does eventually come.



The direction, frequency and number of elephants transmigrating across the Ishasha River between 2001 and 2003.

Elephant – Human Interaction

- Methodology

The objective of this section was to provide irrefutable evidence of the crop raiding situation in order to supply UWA, the local communities and the potentially supporting organisations the information required towards the mitigation of the crop raiding.

Along the SQECA eastern border there is a hard edge of subsistence farming communities. By 1998 this border region had been experiencing serious crop raiding for over a decade, resulting in losses to the farmers and revenge killings of elephants. By ECP's feasibility study with UWA, little recognition of the growing problem had been given to the issue by the relevant authorities. Subsequently there was little or no emphasis placed on developing and implementing plans towards the reduction and mitigation of the conflict.

Alongside the local communities and UWA, ECP set up a monitoring system to record every crop raiding incident in detail. Community parishes and local council cells between Ishasha Customs post and Kafunjo were monitored. For our own administrative purposes the area was divided into two regions, the Ishasha and Ntungwe River Regions. Local farmers affected by crop raiding were selected by and represented their own communities according to their administrative parishes. In each parish ECP trained one enumerator and reserve to record details of the EHI. Each crop raiding incident was then recorded and confirmed.

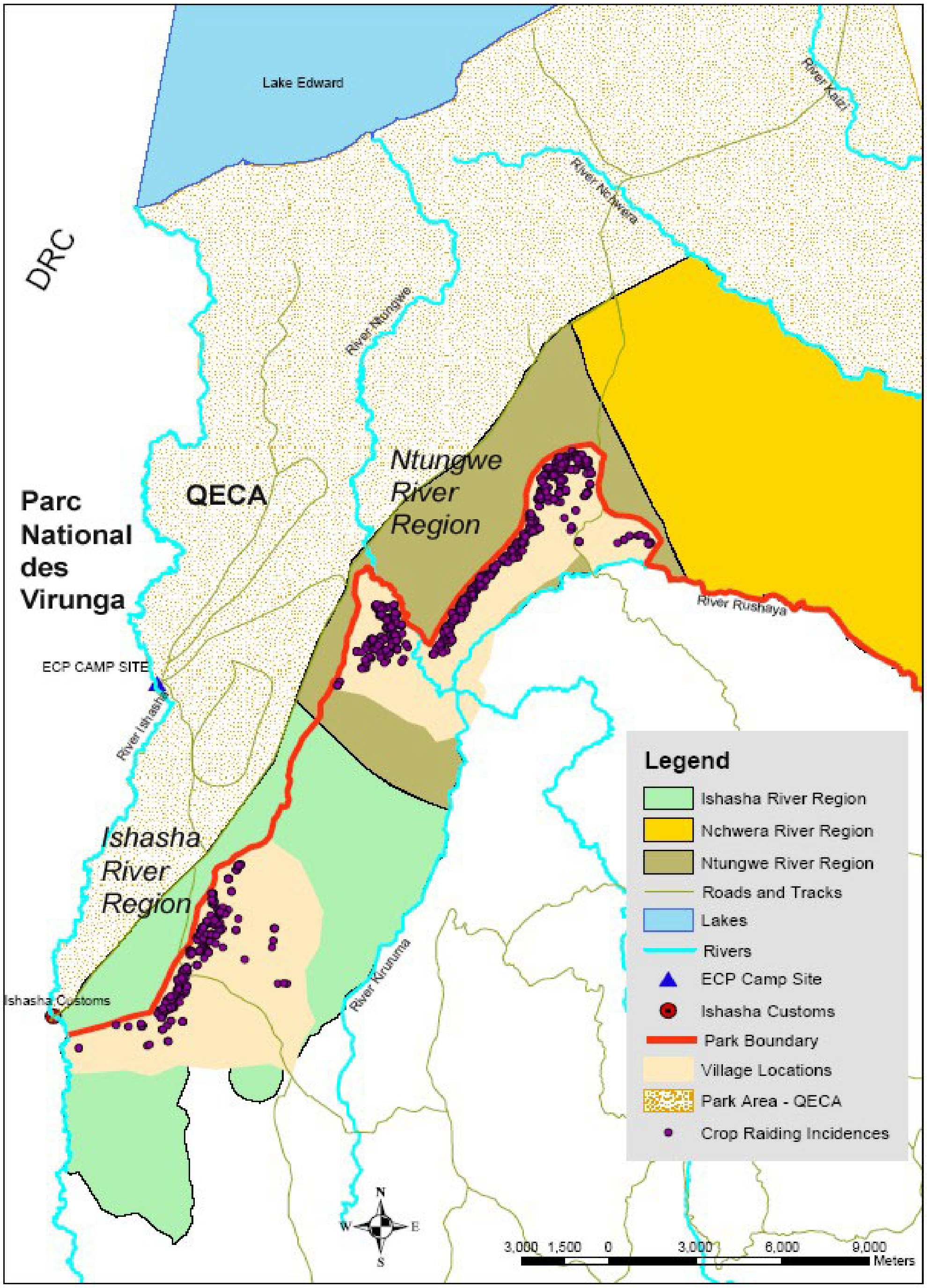
Many details relating the EHI incident were recorded including the date, location, time and duration of the incident. The system was based on the African Elephant Specialist Groups data collection protocol for human – elephant conflict in Africa (Hoare, 1999).

- Results Negative Elephant – Human Interaction: Crop Raiding

The EHI monitoring system recorded and confirmed some 1403 crop raiding incidents between April 2001 and July 2003, at an average of 52 crop raids per month. The most crop raids recorded per month was 192, and the least was 5. The Ntungwe River region experienced 76% of the crop raids and the Ishasha River Region 24%. The average number of crop raids in the Ntungwe RR was 39 per month and 19 in the Ishasha RR.

Table: Crop Raiding in Southern QECA with reference to the Villages within the River Regions.

Region	River Region	Village	No. of Crop Raids	Percentage %
Southern QECA			1403	100
	Ntungwe RR		1064	74
		Kameme	208	15
		Garuka	212	15
		Nyakatembe	153	11
		Nyabugando	73	5
		Nyakabungo B	107	8
		Nyakabungo A	64	5
		Kafunjo	228	16
		Kahimbi	5	0.5
		Rwesigiro	15	1
	Ishasha RR		339	24
		Ishasha Customs	8	0.5
		Burambi	12	1
		Bukorwe	110	8
		Kazinga Lower	121	9
		Kazinga Upper	57	4
		Kyumbungu	22	1.5
		Kibimbiri	5	0.5
		Nyarurambi	3	0



Crop Raiding According to the River Regions of Southern QECA.

The adjacent community land forms a hard edge of subsistence agriculture dominated by palatable 'non cash' crops. Subsequently there is a great attraction for wildlife to feed on the crops. The crops most damaged were maize (24%), cassava (15%), finger millet (11%), beans (8%), sorghum (6%), sweet potatoes (6%) and matoke (6%).

Some 100% of crop raids were found to happen at night with an average of 91% of the incidents taking less than two hours. There were no records of human casualties directly from crop raining, although one boy was killed when he cycled through the park on a public road and into a family group of elephants whilst delivering produce to a fishing village. There were also no records of elephants destroying structures or food stores.

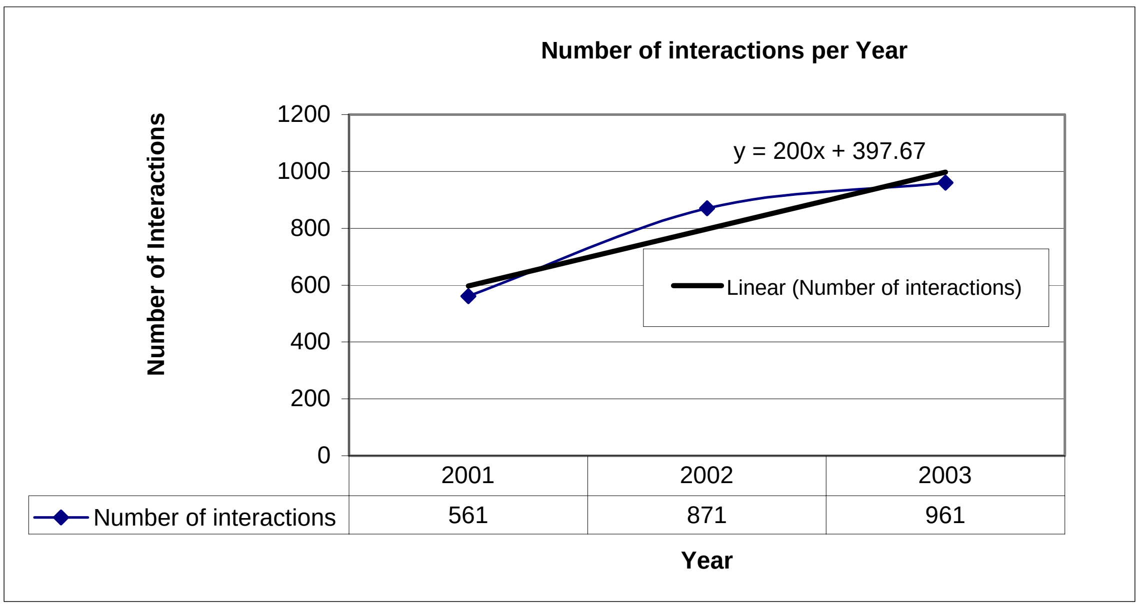
Overall Trend of Elephant – Human Interactions

- Method:

The objective of the encounter rate is to provide an indication as to the trend for positive and negative interactions with humans in the future. The collated records for elephant encounters comes from the transmigration, direct observations and crop raiding files. This rate reflects the number of times elephants were encountered, not the number of elephants encountered. However, it should also be noted that more elephants were also encountered.

RESULTS

A graph showing the number of elephant – human interactions with ECP between 2001 & 2003.



The interactions increased at a rate of 55% (871-561/561x100) between the year 2001 and 2002 and at a rate of 10% (961-871/871x100) between 2002 and 2003.

On fitting a linear trend in the above data of interactions, we get

Year	x	y	Yc (Trend value)
2001	1	561	598
2002	2	871	798
2003	3	961	998
Total interactions		*2,393*	

Yc = a + b x is given by Yc = 397.67 + 200x. This equation is then used to determine the trend values in table above; they are obtained by substituting Xs into the equation.

Trend line increase between 2001 and 2003 was (TL end value – TL start value) / TL start value x 100 = (998 – 598) / 598x100 = 67%

This implies that over the three-year period interactions increased at a rate of 67%. We would expect this increase to be an over estimate as ECP's activities were restricted within SQECA in late 2001.

DISCUSSION

ECP has found that the elephant population is viable and recovering and has ample food and water resources. However FOUR key threats were identified:

1. Transmigration of elephants to the DRC
2. Management and protection in the Ugandan Protected Area estate, outside of UWA's current areas (National Forestry Authority estate).
3. Indirect killings of elephants (snares set for other animals, poisoning in revenge to crop raiding and vehicles such as lorries and coaches colliding with elephants)
4. Negative Elephant – Human Interaction: Crop Raiding

There is currently little or no pressure on the elephants with regards to the amount of food and water available. We have noticed that all of the threats are resolvable, should there be the will and commitment by the relevant Governments and their departments. Most of the threats are human related and ECP has shown that the elephant – human interactions, both positive and negative are increasing rapidly. Along with the increasing elephant population and what is likely to be a gradual increase in habituation, there will be a sharp increase 'over and above' the interaction rate and trend suggested.

The current instability being experienced in the PNV is the biggest and most direct threat to the future of the elephants and so the effect of the ecology of the region. ECP has shown this to be a constant and large threat despite the usual behaviour of elephants moving away from poaching pressure as experienced in this region. Records of elephant poaching in the DRC are frequent. Well-armed, facilitated and organised groups are carrying out the majority of the bushmeat and ivory poaching profit for the black and local markets. The PNV Rangers are unable and wise not to confront such groups.

ECP has shown a 28% annual increase in crop raiding. This coupled with the increasing elephant population size, the possibility of them beginning to crop raid during the day time as well, and becoming habituated to people so not fleeing and spending longer in the crops, all bodes for a worsening scenario. Already communities exasperated with the situation are killing elephants in revenge, as well as tending to support those involved in illegal activities within the park. With encroachment now stopped in SQECA, efforts should now be placed on the multi faceted mitigation strategy against crop raiding. This requires close cooperation from UWA, local communities and Government. With QECA a Biosphere Reserve, meaning that people live within and around the park, the people are an integral part of the future of QECA. EHI is a major and growing issue that if left to worsen (and it will), will cause untold damage to the communities 'legal' farming and their relations to the park. As a consequence many elephants, and other animals, will be at greater risk of being poisoned and poached, irrespective of the law.

ECP's EHI research has provided extensive baseline information for UWA's management to clearly and efficiently set out and implement plans for the resolution of much of the negative EHI and community park problems within the region. One such example is that not all areas experience crop raiding to the same levels. Losses in some areas can be considerable whilst other areas experience very little. With over 57% of crop raiding happening in 4 out of the 17 villages, and 82% from 7, UWA and donor support can streamline support to where it is most needed.

ECP has confirmed the continued use of the adjoining areas to QECA by elephants and other wildlife. These areas are vital to the elephants and other animals alike. There are two issues here. Firstly the National Forestry Authority manages the Forest Reserves for forestry activities, and they do not have the mandate for the conservation, preservation and protection of the fauna that use it. However, UWA does, but has no personnel in these areas. Subsequently there is uncontrolled poaching, no Ranger patrolling and no monitoring of the illegal activities affecting the fauna. The second issue is that of the connections between the Forestry Reserves and the better-protected QECA. The main connection between Kyambura WR and Kashoya – Kitomi is severely encroached – but not yet lost and is still used by over 200 elephants on a seasonal basis. This is the only connection between the two areas.

Paradoxically, the success of wildlife management often creates the need for more management activities. However, continued wildlife protection often hinges on the availability of funds to support field activities. One such threat is how UWA will afford the necessary 'on site' actions after the World Bank funding stops in 2007. Has UWA been trying to or can UWA generate income enough through its own estate? How will the authorities be able to afford to extend or sustain their activities in their estate, let alone into the adjoining areas?

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Conserving elephants in a human-dominated landscape in Sri Lanka

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Despite its small size (65,610 km^2), Sri Lanka is home to an estimated 4,200 elephants. The survival of the elephant in such a significant number is due largely to the tolerance of both Buddhists and Hindus. With a human population at 19 million, the human-elephant ratio at present is 4,500:1. As a result, the elephant finds itself with its back against the wall. The conflict between man and elephant is the result of competition for land and its resources. Between 1950 and 1970, a total of 1,163 elephants were lost in the wild in Sri Lanka, of which 639 were killed by farmers in defense of their crops and by poachers for ivory. Between 1990 and 2001, a total of 1,369 elephants died in the wild. During the past five decades, it is feared that up to 4,000 elephants may have perished. The human-elephant conflict in Sri Lanka is leading in just one direction: the destruction and eventual elimination of elephants from agricultural areas, unless innovative measures are adopted. The management of human-elephant conflict has to be integrated into a proper land-use policy and also must recognize the elephant as an economic asset to the community. Unless people value living with elephants, the slaughter will go on. One way that local people can benefit from the elephant in their midst is from the tourist revenues it generates, whether through small-scale ecotourism or through manufacture of paper, production of biogas, or promotion of organic farming using elephant dung.

INTRODUCTION

It would be difficult to imagine Sri Lanka without the elephant, for it is so much a part of the island's history, culture, religion, mythology, folklore and even politics. No other animal has such a close relationship with the people of Sri Lanka. Despite its small size (65,610 km2), Sri Lanka is home to an estimated 4,200 elephants, which represent roughly 10% of the global total of the Asian elephant (Elephas maximus) in the wild (Kemf and Santiapillai 2000). The survival of one of world's last remaining terrestrial megaherbivores in Sri Lanka in such a significant number can be attributed to the tolerance of both Buddhists and Hindus to whom the elephant has a special religious significance. With the increase in human population density and changes in the land-use patterns, elephant habitat is being continuously eroded. As a result, the elephant finds itself with its back against the wall in Sri Lanka.

As Ferrar (1983) points out, except at the lowest density, large wild animals and humans are fundamentally incompatible. This incompatibility increases rapidly as both animal and human densities increase. Given the human population at 19 million, the present human-elephant ratio of 4,500:1 is comparable to that seen in West Africa (4,953:1) as reported by Dublin et al., (1997). The conflict between man and elephant is the result of competition for land and its resources, and it has become one of the most serious conservation problems, for which general solutions remain still elusive. In the recent past, it has escalated to an alarming level. Crop raiding by elephants is a chronic problem in areas where cultivators live in close proximity to elephants (Barnes et al., 1995). In addition to the wanton slaughter of elephants, the conflict also includes crop depredations, destruction of houses and properties by wild elephants, loss of human lives, and the death of elephants from land mines. Elephants also kill and injure livestock and disrupt the social and economic activities of the local communities. The traditional approach towards mitigating the conflict in Sri Lanka has mainly depended on legislative protection of the species and reservation of its habitat.

Conservation Issues

- Deforestation and Habitat Loss

From the point of view of forestry, the island of Sri Lanka, as Szechowycz (1956) describes, is analogous to a crowd of people dancing happily around a floating ice which melts quickly till finally nothing stands under their feet. Much of the ice is gone. Sri Lanka has already lost almost 80% of its original forest cover. The elephant is running out of space among more than 19 million people now living in Sri Lanka. In 1870 when the human population was 2.4 million, the land:man ratio was 2.7 ha. Today, with a human population of 19 million, the land:man ratio is 0.35 ha. The ratio reduces even further to 0.15 if pasture lands are excluded. Over much of the island, there is no longer room for elephants to move about and adjust their densities to changing vegetation patterns. Changes in land-use patterns are resulting in a continuous contraction of habitat available to the elephant. Conservation areas have shrunk as the number of people dependent on the land increases. As Laws (1981) observed in Africa, the situation in Sri Lanka too has reversed from one in which human islands existed in a sea of elephants, to a sea of people with elephant islands. The day is rapidly approaching when the remnants of natural environment will be represented in a patchwork of parks and reserves. When elephants lose their range, they die. The concentration of elephants in limited areas may lead to a buildup in their numbers, even though absolute population size may be decreasing (Laws 1981).

- Protected Areas

Measures to date have mainly depended on legislative protection of the species and reservation of habitat – essentially keeping people and elephants apart. To its credit, Sri Lanka has set aside 8,579 km2 of the land as protected areas for conservation of wildlife. This amounts to 13% of the land area. However, no park is large enough to accommodate the entire annual range of elephants. Of the 14 national parks that cover an area of 4,987 km2, only one – Wilpattu – is more than 1,000 km2 in extent, while 11 are less than 500 km2. Most of the conservation areas are small with low area:perimeter ratios and farmers living along the periphery of such small reserves are vulnerable to elephant depredations. Protected areas alone as viable self-containing oases are poor bets for the long-term survival of the elephant given that almost 70% of the elephant range lies outside the system of protected areas (Figure 1). If the elephant is to survive, there must be healthy populations living both within and outside protected areas. Besides protected areas are also prone to environmental disturbances outside their boundaries.

- Human-Elephant Conflict

In 1870, Sri Lanka's human population was 2.4 million. During the past 130 years the population has increased 8 fold to more than 19 million, and is expected to double in 35-40 years. With a human density of 290 per km^2 Sri Lanka is one of the most densely populated countries in the world, second only to Bangladesh among the less developed countries. There were nearly 12,000 elephants in Sri Lanka at the turn of the 19th century, but today total is estimated to be about 4,200. The decline in number is largely due to the expansion of agriculture brought about by the need to feed a growing human population.

Given that for every elephant that exists in the wild, there are 4,500 people, it is inevitable that conflict between man and elephant as a consequence of competition for land would be intense in Sri Lanka. Between 1950 and 1970, a total of 1,163 elephants were lost in the wild in Sri Lanka (Figure 2), of which 639 were killed by farmers in defence of their crops and by poachers for ivory

(Santiapillai 1994). According to Hendavitharana *et al* (2004), between 1990 and 2001, a total of 1,369 elephants died in the wild (Figure 3). In the year 2001 alone, wild elephants were killed at a rate of three per week in the conflict, which also claimed the lives of 44 people. During the past five decades, it is feared that up to 4,000 elephants may have been lost in the island from both natural causes and as a consequence of the human-elephant conflict. Elephants are not being killed in Sri Lanka for ivory, since tuskers are rare (less than 7% of the bulls are tuskers); they are not being killed for meat, since no one eats elephant meat; they are not being killed for leather, since the hide has no commercial value. Thus, elephants are being killed in Sri Lanka mainly because they interfere with agriculture. Most of the elephants killed are young bulls. The biased pattern of mortality in favour of the bulls reflects the high risks they take in comparison to female-led families by foraging on cultivated crops, which have more nutritive value than wild food plants. The bulls seem to take such a risk to enhance their reproductive success (Sukumar and Gadgil 1988).

- Causes of Elephant Mortality

The death of the vast majority of elephants in the wild in Sri Lanka can be attributed to human activities. The causes of elephant mortality are many and they include gunshot injuries, electrocution, poison, untreated wounds, accidents, falling into wells or pits dug and abandoned by those prospecting for gems, landmines etc, but gunshot injuries represent the most common and widespread. Elephants are also electrocuted as they come into contact with live naked wires that the armed forces have set up to tap electricity free from the national grid. These wires are slung so low that they can be touched accidentally by elephants as they move about.

- Agriculture and Elephant Mortality

In Sri Lanka the principal agricultural crop is paddy, which is cultivated twice a year. The major or *Maha* season extends from October to April, during which paddy cultivation depends on the rain associated with the northeast monsoon. The other is the *Yala* season, which coincides with the dry season during which paddy is cultivated using the waters released from the reservoirs in the dry zone. Thus paddy is harvested twice annually in March and September in the *Maha* and *Yala* seasons respectively, and it is during these periods that the impact of wild elephants on paddy is most severe, and it is during these times that elephant mortality too reaches its peak.

CONCLUSION

The long-term future of elephants outside the protected areas in Sri Lanka is inextricably linked to the tolerance of man. Just as Dr Holly Dublin (as quoted in Sugal 1997) has pointed out in the case of the African elephant, the human-elephant conflict has replaced poaching as the biggest conservation issue in Sri Lanka too. While the international conservation organizations are concerned over the trade in ivory, non-tuskers or *makhnas* continue to be killed in large numbers in Sri Lanka.

The human-elephant conflict in Sri Lanka is real, and it is leading in just one direction: the destruction and eventual elimination of elephants from agricultural areas, unless innovative measures are adopted to address the concerns of the farmers (Wickremasinghe and Santiapillai 1999). The management of human-elephant conflict has to be integrated into a proper land-use policy and also must recognize the elephant as an economic asset to the community. Unless people value living with elephants, the slaughter will go on. If the local people could perceive the elephant as an economic asset instead of as an agricultural pest, then they will tolerate it on their land. One way that local people can benefit from the elephant in their midst is from the tourist revenues it generates, whether through small-scale ecotourism or through the manufacture of paper from dung, production of biogas from dung, or the promotion of organic farming using dung (Santiapillai 2003). Although the use of elephant dung for the benefit of the rural poor is unlikely to eradicate the human-elephant conflict, it will certainly help change the perceptions of some people and their hostility towards the elephant. Conservation of the elephant in Sri Lanka is inextricably linked to the welfare of the rural poor and socially disadvantaged who are struggling to survive in areas frequented by potentially dangerous wildlife such as the elephant. The debate over elephants is an emotional one, between the preservationists and the pragmatists. The problem with wildlife is that the people who wish to preserve it, are rarely those who have to bear the cost (Eltringham 1994). Given that the human-elephant conflict is already bad today, it may become worse tomorrow. Even if we cannot eliminate the conflict altogether, we need to reduce it to tolerable levels (Hoare 2002)

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