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Survey of the Reproductive Cyclicity Status of Asian and African Elephants in North America

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The Asian and African elephant populations in North America are not self-sustaining, and reproductive rates remain low. One problem identified from routine progestagen analyses is that some elephant females do not exhibit normal ovarian cycles. To better understand the extent of this problem, the Elephant TAG/SSP conducted a survey to determine the reproductive status of the captive population based on hormone and ultrasound evaluations. The survey response rates for facilities with Asian and African elephants were 81% and 71%, respectively, for the studbook populations, and nearly 100% for the SSP facilities. Of the elephants surveyed, 49% of Asian and 62% of African elephant females were being monitored for ovarian cyclicity via serum or urinary progestagen analyses on a weekly basis. Of these, 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); however, acyclicity was found in all age groups of African elephants. Fewer elephant females (~30%) had been examined by transrectal ultrasound to assess reproductive-tract integrity, and corresponding hormonal data were available for about three-quarters of these females. Within this subset, most (~75%) cycling females had normal reproductive-tract morphologies, whereas at least 70% of noncycling females exhibited some type of ovarian or uterine pathology. In summary, the survey results suggest that ovarian inactivity is a significant reproductive problem for elephants held in zoos, especially African elephants. To increase the fecundity of captive elephants, females should be bred at a young age, before reproductive pathologies occur. However, a significant number of older

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Asian elephants are still not being reproductively monitored. More significantly, many prime reproductive-age (10–30 years) African females are not being monitored. This lack of information makes it difficult to determine what factors affect the reproductive health of elephants, and to develop mitigating treatments to reinitiate reproductive cyclicity. Zoo Biol 23:309–321, 2004.

Key words: ultrasound; ovarian cyclicity; reproductive dysfunction; hormones; progestagens

INTRODUCTION

The Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephant populations in North America are not self-sustaining, and it has been predicted that demographic extinction will occur within three to five decades unless reproductive rates are increased severalfold [Wiese, 2000; Olson and Wiese, 2000]. Historically, captive populations have been supplemented by elephants imported from range countries, but this is not a preferred long-term, conservation-oriented strategy, and it generates financial, logistical, and ethical concerns. To address these management issues, the Elephant Taxon Advisory Group (TAG)/Species Survival Plan (SSP) works with advisors to identify problems and establish priorities for research and collection planning. The challenges facing elephant managers are significant. The fecundity of elephants in captivity is low, in part because of limited numbers of bulls and breeding facilities. However, even when introductions are made, breeding efforts are not always successful.

The Endocrine Research Laboratory at the Conservation & Research Center (CRC) currently assists the Elephant TAG/SSP by evaluating endocrine activity to assess the fertility status of female elephants throughout North America. This is done by measuring the concentration of progestagens in blood or urine samples collected weekly. One finding from this work is that a number of elephant females are not cycling [Brown, 2000]. In these animals progestagens remain at stable, baseline concentrations, indicating a failure to initiate or sustain luteal activity. The cause of this acyclicity is unknown, and there is concern that if the number of acyclic females is high or growing, a significant population decline is inevitable. Transrectal ultrasound examinations have shown that aging females often have reproductive-tract pathologies, such as uterine or ovarian cysts and tumors, that may prevent conception [Hildebrandt et al., 2000].

In the light of these findings, the Elephant TAG/SSP has endorsed research to determine the extent of reproductive dysfunction in captive elephants, identify the causes, and develop mitigating treatments [Keele and Ediger, 1997–2002]. Toward that end, a reproductive survey was conducted in conjunction with the 2001–2002 Asian and African Elephant SSP Studbook updates to determine 1) how many females in the captive population are being hormonally evaluated for estrous cyclicity, 2) how many females are not cycling normally, 3) what types of reproductive-tract pathologies exist, and 4) whether any pathologies are related to acyclicity. The goal is to conduct periodic surveys to help the TAG/SSP continuously monitor the reproductive health of individual elephants, as well as to assess changes in the overall status of the population. Additionally, the ability to pinpoint the precise time a female stops cycling would enable a better assessment of what factors are associated with the development of reproductive problems (e.g., changes in social status, environment, behavior, disease, nutrition, etc.).

MATERIALS AND METHODS

In 2001–2002, reproductive surveys prepared by the Elephant TAG/SSP were sent to all facilities listed in the Asian and African Elephant North American Regional Studbooks. The survey questions related to this study asked 1) what management system was used (free contact, protected contact, or other); 2) were samples collected for reproductive monitoring (blood, urine, or none); 3) if samples were collected, what was the collection frequency (weekly, biweekly, monthly, elephant in training, or collected but not analyzed); 4) what was the estrous cyclicity status of the elephants (cycling, not cycling, irregular cycles, or undetermined); and 5) was transrectal ultrasound performed, and if so, what were the results (normal, ovarian cysts, uterine cysts/tumors, vaginal cysts, other pathologies, or in training)? Because this was the first survey, "hormone cyclicity status" referred to the results of all hormone evaluations for an elephant at its respective institution. Future reproductive data will be based on changes in cyclicity status that occur between subsequent surveys. The results were summarized with the use of MS Excel. "Animal age" refers to the elephant's age in 2002 (the second year of the survey). Pregnant cows were not included in the survey results or analyses. The mean data were compared by Student's *t*-tests. Differences in survey and ultrasound results between species or cyclicity status within species were determined by Z-tests [SigmaStat v. 2.03, Jandel Scientific, 1997]. Percentage data for age categories within species were tested by chi-square analysis. Data are presented as means $\pm$ SEM.

RESULTS

Of the 66 facilities that maintained Asian elephants, 44 (67%) participated in the Elephant SSP program. Of the 98 facilities that housed African elephants, 45 (46%) were part of the SSP. Twenty-two facilities held both Asian and African elephants, and 14 were in the SSP. Of the 23 facilities that kept multiple Asian females, 15 (65%) had all cycling females, seven (30%) had both cycling and noncycling females, and one (5%) had two elephants that were both noncycling. Of the 27 African elephant facilities, 12 (44%) had all cycling females, 14 (52%) had both cycling and noncycling females, and one (4%) had two noncycling females. In terms of the management systems used, of the 36 facilities with Asian elephants, 21 (58%; 145 elephants) employed a free-contact system, and 15 (42%; 48 elephants) used protected contact. For African elephants, 20 facilities (43%; 74 females) maintained African elephants under free contact, and 26 (57%; 66 females) used protected contact.

The average age of captive female Asian elephants in 2002 was 33.7 ± 0.9 years (range = 2–77 years) for all elephants, and 31.3 ± 1.2 years (2–59 years) for the SSP population. The average age of captive female African elephants was 25.0 ± 0.6 years (2–52 years) for all animals, and 26.6 ± 0.8 years (2–52 years) for those in the SSP. Within species, there were no differences between the studbook and SSP populations in average ages; however, African elephants were younger on average than Asian elephants ($P < 0.05$).

A summary of the reproductive survey results for elephants in the studbook and SSP populations is presented in Table 1. For both Asian and African elephants, ~55% of the studbook population was part of the SSP. Of the remainder, 44% of

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]

[1]Reproductive cyclicity status based on weekly or bi-weekly serum or urinary progestin assessments.
[2]Numbers are based on those monitored hormonally.
[3]Number excludes females $\leq$10 years of age (2 Asian; 1 African).
[4]Unknown = no survey returned; NM = not hormonally monitored.
[5]Does not include 10 females in the SSP that were bled weekly, but hormones were not analyzed.
[a,b]Percentage differences between cyclicity categories with different superscripts are significant ($P<0.05$).

Asian and 29% of African elephants were privately owned (by private individuals, circuses, corporations, etc.). Surveys were returned for over three-quarters of the elephants in North America, and there was a higher ($P<0.05$) response rate for Asian elephants compared to African elephants. For SSP participants, there was a 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, samples collected from 10 females in the SSP 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 the studbook and SSP populations, with higher rates observed for animals managed within the SSP ($P<0.05$). When data were combined for elephants that were not being monitored (NM) and those for which no survey information was available ("unknown," but assumed to be not hormonally monitored), the total number of females with no reproductive hormone data was higher ($P<0.05$) for Asian than for African elephants listed in the studbook, although the percentages were similar ($P>0.05$). However, within the SSP, both the numbers and percentages of females not hormonally monitored were higher ($P<0.05$) for Asian than for African elephants (Table 1).

Representative examples of normal-cycling, irregular-cycling, and noncycling progestagen profiles are shown in Fig. 1. The normal elephant estrous cycle ranges

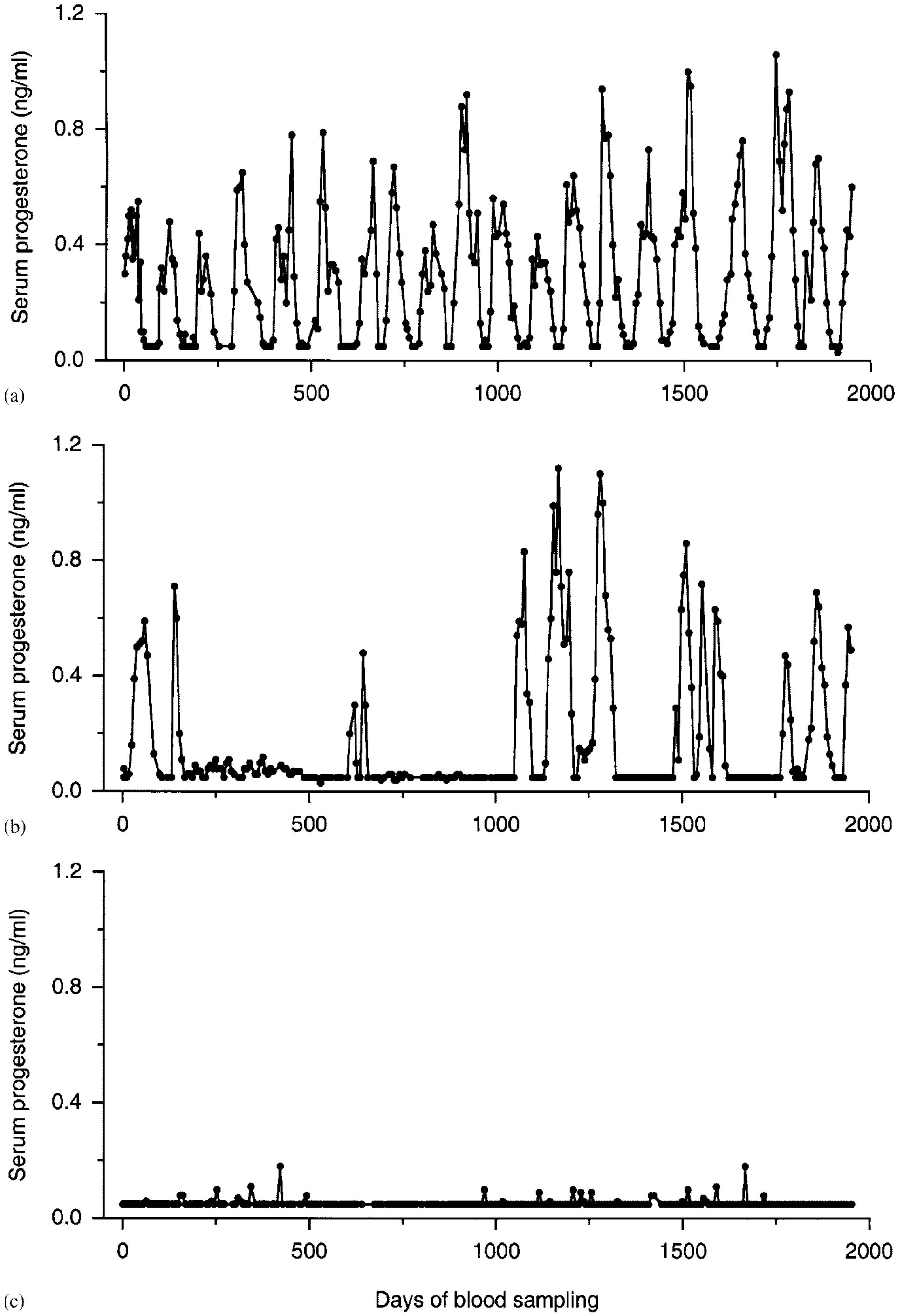

Fig. 1. Representative serum progestagen profiles of normal-cycling (**a**), irregular-cycling (**b**), and noncycling (**c**) African elephant females, from analysis of blood samples collected weekly.

from 14 to 16 weeks in duration [Brown, 2000]. The designation of irregular cycling was subjectively based on observations of extended nonluteal periods (>9 weeks), shortened luteal phases (<6 weeks), and/or the presence of marked, random fluctuations in progestagen concentrations during nonluteal or luteal phases.

In the elephants that were hormonally evaluated, there were species differences ($P<0.05$) in the percentage of cycling vs. noncycling females. A higher rate of normal cyclicity was observed in Asian elephants, whereas the rate of acyclicity was greater in African females ($P<0.05$). Within species, there were no differences ($P>0.05$) in cyclicity status between elephants managed within or outside of the SSP. There also were no differences ($P>0.05$) in cyclicity status between elephants managed under free- or protected-contact systems. Six of 11 (55%) acyclic Asian elephants were managed under free contact, whereas five (45%) were managed under protected contact. For African elephants, 11 (55%) of 20 noncycling females were managed under free contact, and nine (45%) were managed under protected contact.

Tables 2 and 3 summarize the survey results based on age categories. In 2002, the majority of females in the Asian population (67%) were >30 years of age, whereas most African elephants (72%) were <30 years old. Similarly, in the SSP population the majority of Asian elephants (64%) were >30 years old, and most African elephants (67%) were <30 years old. Excluding data for females ≤10 years

Table 2. Numbers and age distribution of Asian elephant females exhibiting normal estrous cycles (cycling), no ovarian activity (noncycling) or irregular estrous cycles (irregular) 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
Responses (Studbook)	20	17	33	72	51
Responses (SSP)	14	12	21	54	28
No. monitored (SB)	7	10	20	42	16
No. monitored (SSP)	6	10	13	31	15
Cycling (SB)	5	10	18	35	12
Cycling (SSP)	4	10	11	25	11
Noncycling (SB)	2	0	1	6	4
Noncycling (SSP)	2	0	1	5	4
Irregular (SB)	0	0	1	1	0
Irregular (SSP)	0	0	1	1	0
% 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 + NM[3] (SB)	14	9	19	51	51
Unknown + NM[3] (SSP)	8	2	8	24	14
% Unknown + NM (SB)	66.7	47.4	48.7	54.8	76.1
% Unknown + NM (SSP)	57.1	16.7	38.1	43.6	48.3

[1]Number of elephants in each population.
[2]Percentage based on elephants being hormonally monitored.
[3]Unknown = no survey returned; NM = not hormonally monitored.
[a,b,c,d]Percentages 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.

Table 3. Numbers and age distribution of African elephant females exhibiting normal estrous cycles (cycling), no ovarian activity (noncycling) or irregular estrous cycles (irregular) 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
Responses (SB)	3	33	58	41	11
Responses (SSP)	3	22	50	25	11
No. monitored (SB)	1	24	42	20	4
No. monitored (SSP)	1	20	37	15	4
Cycling (SB)	0	19	31	12	2
Cycling (SSP)	0	16	29	8	2
Noncycling (SB)	1	2	8	8	2
Noncycling (SSP)	1	2	7	6	2
Irregular (SB)	0	3	3	0	0
Irregular (SSP)	0	3	1	0	0
% 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 + NM[3] (SB)	2	48	32	25	8
Unknown + NM[3] (SSP)	2	2	15	11	7
% Unknown + NM (SB)	66.7	66.7	42.2	55.6	66.7
% Unknown + NM (SSP)	66.7	9.1	28.8	42.3	48.3

[1]Number of elephants in each population.
[2]Percentage of elephants being hormonally monitored.
[3]Unknown = no survey returned; NM = not hormonally monitored.
[a,b]Percentages 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.

of age (i.e., potentially prepubertal), the 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 vs. 37.2 ± 1.7 years, range = 27–53 years, respectively) and African (24.4 ± 0.8 years, range = 16–52 years vs. 28.9 ± 1.7 years, range = 14–42 years, respectively) elephants. There were only two irregular-cycling Asian elephants (27 and 32 years old), and these were not were not statistically compared with the cycling and noncycling Asian elephants. The average age of irregular-cycling African elephants (20.8 ± 1.2 years, range = 16–24 years) was less ($P < 0.05$) than that of both cycling and noncycling females. Within age categories, there was also a greater percentage of noncycling females observed in the older age groups ($P < 0.05$) (Tables 2 and 3). However, there were also larger proportions of unmonitored and unsurveyed females in these categories. Overall, the reproductive status of over half of Asian and African elephants >30 years of age, and over two-thirds of elephants >40 years of age was unknown (Tables 2 and 3). For African elephants, a high percentage of unmonitored/unknown elephants (most of which were managed outside of the SSP) was also observed in the 11–20-year-old category (Table 3).

Ultrasound examinations were conducted on 70 Asian and 50 African elephants, and corresponding hormonal data were available for 53 of the Asian and 45 of the African females (Table 4). The average age of females diagnosed with reproductive-tract pathologies was greater ($P < 0.05$) than that of elephants with

Table 4. Numbers of elephants with transrectal reproductive tract ultrasound data from the Elephant TAG/SSP 2001–2002 Reproductive Survey for captive Asian and African elephants in North America

Category[1]	Asian			African		
	Cycling (n = 47)	Noncycling (n = 6)	NM[2] (n = 17)	Cycling (n = 35)	Noncycling (n = 11)	NM[2] (n = 5)
Normal	35[a]	1[b]	13	27[a]	4[b]	3
Ovarian cysts	1	0	0	0	3	0
UT cysts/tumors	5	2	1	2	4	1
UT/VA cysts/tumors	2	2	0	3	0	0
UT cysts/other	1	0	1	0	0	0
Other pathologies[3]	3	1	2	2	0	1

[1]Some females had pathologies in more than one category; thus, some categories include multiple items. A female is represented only once in a category.
[2]NM = not hormonally monitored.
[3]Unspecified pathologies of reproductive origin.
Terms: UT = uterus; VA = vagina.
[a,b]Differences in numbers within species for normal pathology between cycling and noncycling females with different superscripts are significant ($P < 0.05$).

normal tract morphology (Asian: 37.0 ± 1.8 years vs. 27.0 ± 1.5 years, respectively; African: 26.3 ± 1.6 years vs. 21.8 ± 0.7 years, respectively). A comparison of elephants for which both ultrasound and hormonal data were available revealed that a greater proportion ($P < 0.05$) of cycling females had normal reproductive-tract morphology compared to noncycling elephants of both species. Overall, nearly 80% of cycling females had normal reproductive-tract morphologies, whereas ~70% of noncycling females exhibited some type of ovarian or uterine pathology.

DISCUSSION

Based on this first Elephant TAG/SSP reproductive survey, 49% of Asian and 62% of African elephant females in North America were being hormonally monitored for estrous cyclicity. If one assumes that the facilities that did not return surveys were not hormonally monitoring females, the hormonal monitoring rate drops to 40% and 44% for Asian and African elephants, respectively. The total numbers of hormonally assessed females in the different age categories reflected the age distribution of the population: more Asian elephants in the 31–40-year age group were being monitored, and more African females in the 21–30-year age group were being monitored.

These results confirm earlier observations that many females in the captive population are not cycling normally [Brown, 2000]. The problem is particularly significant for African elephants: 29% of hormonally-monitored females exhibited some form of ovarian dysfunction, and many of these (18%) were of reproductive age (i.e., <30 years old). 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 elephant-holding facilities should begin an active program of monitoring through routine hormone and ultrasound assessments of both males and females [Keele and Ediger, 1997–2002]. 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 a female is considered to be postreproductive, the TAG/SSP recognizes that lifelong assessments will be critical to identify the causes of reproductive dysfunction. Until recently, it was believed that elephants exhibited either a cyclic or a 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, evaluations of reproductive data collected through periodic TAG/SSP surveys could serve as valuable tools to help managers identify and understand the factors that impact reproductive health [Keele and Brown, 1998].

The urogenital tract pathologies identified in the survey animals included cysts, polyps, and tumors of the uterus, vagina, vestibule, and ovary, and (as reported in previous studies) were more prevalent in older individuals. For example, in nulliparous cows >30 years of age, vaginal cysts can become so extensive that they fill the lumen [Hildebrandt et al., 2000]. Older African elephants are prone to develop endometrial hyperplasia [Hildebrandt et al., 1997, 2000], whereas Asian elephants develop multiple benign uterine tumors (leiomyomas) in the myometrium [Hildebrandt and Göritz, 1995]. Follicular cysts on the ovary tend to occur more frequently in African ($\sim 15\%$) than in Asian ($\sim 5\%$) elephants ex situ, but rarely occur in free-ranging females ($<1\%$) [Hildebrandt and Göritz, 1995; Hildebrandt et al., 2000]. It is not known whether any of these pathologies have a direct impact on fertility or cyclicity status, or whether they are a consequence of other intrinsic or extrinsic factors that inhibit ovarian activity. Based on the age distribution of the females examined to date, the types of pathologies identified, and the historical calving records of elephants in captivity, there appears to be a window of 10–15 years from the onset of estrous cyclicity until a decline in reproductive fitness is observed–particularly in nulliparous cows [Hildebrandt et al., 2000]. This suggests that the continuous cyclicity of nonbred females may have a negative and cumulative effect on reproductive health. In the wild, females are either pregnant or lactating, and therefore they experience comparatively few reproductive cycles in their lifetime.

More noncycling elephants exhibited reproductive-tract pathologies compared to the normal cycling cohorts, and again these tended to be in the older age categories. However, a number of normal-cycling females also presented urogenital tract pathologies. Conversely, a few acyclic females were categorized as having normal ultrasound results. In other species, urogenital cysts and tumors are not always associated with acyclicity, although ovarian follicular cysts often result in infertility [Meirow et al., 1993; Hamilton et al., 1995; Garverick, 1997]. Several noncycling elephants in this survey had ovarian cysts. Treatment options for conditions such as ovarian cysts do exist for other species. For example, previous studies [Seguin et al., 1976; Kesler et al., 1981] have shown that 80% of cystic cows (*Bos taurus*) respond to exogenous gonadotropin-releasing hormone (GnRH) or human chorionic gonadotropin (hCG) treatment, with a resumption of normal cyclic activity. The administration of hCG and GnRH to an African elephant with an ovarian cyst failed to initiate reproductive cyclicity [Brown et al., 1999]; however, more work is needed to determine the potential efficacy of these therapies for elephants.

The difficulty of interpreting current ultrasound results as they relate to fertility is that the data are still limited. Only a third of surveyed females had undergone an ultrasound examination, and corresponding hormone data were not available for all of them. Even fewer females with known reproductive-tract pathologies have been exposed to bulls for breeding, which makes it difficult to assess the impact of these pathologies on conception or gestation. However, a recent finding of multiple endometrial cysts in an Asian elephant that produced a calf after artificial insemination demonstrates that not all pathologies prevent successful pregnancy [Brown et al., in press].

The finding that reproductive problems are at least in part age-related is particularly relevant given current population age structures, especially for Asian elephants. In the wild, elephants can reproduce into their 50s. Reproduction in elephants generally begins soon after puberty and continues throughout most of their life, with an average interbirth interval of 4–6 years [Sukumar, 1989]. However, in captivity few elephants are given the opportunity to breed at regular intervals. Consequently, historical studbook data suggest that animals that are not bred until they are >30 years of age experience reduced fecundity and higher incidences of stillbirths and dystocias [Doyle et al., 1999]. At present, only $\sim 30\%$ of Asian elephant females are <30 years of age [Keele, 2000]. The age structure of African elephants is better, with $\sim 70\%$ between 10 and 30 years of age [Olson, 2001]. However, only about one-third of reproductive-age African females are managed by the SSP and thus likely to be included in any national breeding effort. Given these demographics, the Elephant TAG/SSP has stepped up efforts to breed all reproductively normal females (based on hormone and ultrasound examinations) between 13 and 25 years of age. Future management plans will necessitate the breeding of females regularly beginning at a young age before pathologies develop. It is estimated that about six female offspring will have to be produced annually per species to sustain current levels. Even so, the need to import replacement females from range countries likely cannot be avoided, at least for the near future.

Ultimately, more physiological studies are needed to determine cause-and-effect relationships between reproductive pathologies and fertility. These might include analyses of the nutritional, disease, and health status of individual elephants, in addition to investigations of other potential endocrine abnormalities as they relate to ultrasound and cyclicity results. However, it also is possible that not all reproductive problems have an organic cause–at least directly. Thus, additional research should focus on the extent to which reproductive acyclicity is associated with behavioral or husbandry factors related to captivity. One possibility is that the social structure of captive "herds" leads to reproductive suppression. This is a common strategy used by many social mammalian species (e.g., primates [Abbott, 1984; Epple and Katz, 1984], wolves [Packard et al., 1985], mongooses [Creel et al., 1993], and naked mole-rats [Faulkes et al., 1990; Smith et al., 1997]) to ensure reproduction by specific individuals. Reproductive inhibition may involve the delay or prevention of ovulation or conception by hormonal disruptions of the hypothalamo-pituitary-gonadal axis through behavioral or chemical signals [Abbott, 1984; Epple and Katz, 1984; Faulkes et al., 1990; Creel et al., 1993]. It can also involve behavioral interactions, sometimes aggressive, of dominants over subordinates by either sex to limit breeding opportunities [Abbott, 1984; Creel et al., 1993]. In elephants, there is evidence from wild populations that higher-ranking females can suppress reproduction in less dominant individuals [Dublin, 1983]; however, the mechanism is not clear. Temporary cessation of estrous cyclicity in elephants may be a reproductive strategy to ensure that females in poorer condition have lower fertility rates during periods of limited natural resources. Alternatively, conception may be delayed in order to prevent conflict with dominant individuals or to enable an animal to assist in allomothering [Dublin, 1983; Schulte et al., 2000]. Given how different the captive environment is socially and physically from that in the wild, studies are needed to assess how all aspects of management impact elephant health and, ultimately, reproduction.

To summarize, enough noncycling elephant females have now been identified to warrant concern about the reproductive health of the captive population. The fact that many of these females are of reproductive age adds to this concern. However, it is proving difficult to objectively evaluate the problem because many captive elephant females are not being adequately monitored through routine progestagen and ultrasound analyses. The importance of initiating a continual reproductive monitoring program, preferably throughout an elephant's lifespan, cannot be overemphasized. It is also important to conduct periodic surveys to determine how (or whether) the reproductive status of the captive population is changing. The goal now is to conduct these surveys each time the studbooks are updated (about bi-yearly). Alterations in ovarian cyclicity or reproductive-tract pathologies could then be based on differences in results between subsequent surveys, providing a mechanism by which one could study longitudinal patterns in individual elephants as well as the population as a whole. This effort is absolutely critical if we expect to determine the prevalence of reproductive problems, identify causes, and assess treatment effectiveness. Future studies will attempt to identify causes of reproductive problems in captive elephants by investigating the impact of the captive environment, including social and management factors, on physiology and behavior. It is hoped that we will learn what factors are related to reproductive dysfunction in captive elephant females in time to undertake mitigating actions to prevent the extinction of these animals in captivity.

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 by the use of weekly serum or urinary progestagen analyses.

2. Of the elephants that were 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-tract transrectal ultrasound examinations revealed that pathologies were more prevalent in the noncycling females; however, the impact of these pathologies on fertility is not clear.

4. Reproductive problems were more prevalent in the older age categories, although a number of acyclic African females were in the younger age groups. Consequently, elephant females should be bred at a young age, before pathologies develop.

5. Identifying the 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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