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Theriogenology 78 (2012) 285–296

Theriogenology

www.theriojournal.com

# Investigation of individual and group variability in estrous cycle characteristics in female Asian elephants (*Elephas maximus*) at the Oregon Zoo

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Received 24 May 2011; received in revised form 18 November 2011; accepted 13 January 2012

**Abstract**

Evaluating ovarian cycle activity through longitudinal progestagen monitoring is important for optimizing breeding management of captive elephants and understanding impact of life events (births, deaths, and transfers) on reproductive function. This study summarized serum progestagen profiles for eight Asian mainland elephants (*Elephas maximus indicus*) and one Bornean elephant (*E. maximus borneensis*) at the Oregon Zoo over a 20-yr interval, and represents the longest longitudinal dataset evaluated to date. Estrous cycle characteristics were more varied than previously reported for this species, with an overall duration of 12 to 19 wk, luteal phase duration of 4 to 15 wk, and follicular phase duration of 2 to 12 wk. In general, there was more cycle variability across than within individual elephants. Compared with other elephants in the group, the Borneo female exhibited consistently longer cycle lengths, higher progestagen concentrations, and greater cycle variability; however, it is not known if this represents a subspecies or an individual difference. Cycle durations did not appear to change over time or with age, and the first pubertal cycle was similar to subsequent cycles. Variability in duration of the follicular phase was greater than that of the luteal phase. In addition, there was a significant negative relationship between luteal and follicular phase durations, suggesting a possible regulatory role of the follicular phase in maintaining a relatively consistent cycle duration within individuals. Overall, we found these elephants to be highly resilient in that major life events (births, deaths, and changes in herd structure) had minimal effect on cycle dynamics over time. In conclusion, the higher range in cycle phase characteristics is likely because of the larger number of elephants studied and longer duration of longitudinal monitoring, and may be more representative of the captive population as a whole. Furthermore, identification of significant interanimal variability suggests that understanding the complexities of herd reproductive characteristics could facilitate development of more effective institution-specific breeding management strategies.


*Keywords:* Elephant; Reproduction; Estrous cycle; Follicular phase; Luteal phase; Progesterone

## 1. Introduction

The Asian elephant (*Elephas maximus*) is listed as endangered, with estimates of only 25 000 to 50 000 remaining in the wild, and approximately 16 000 managed under human care [1–4]. In North America, there are 269 (53 male, 216 female) individuals in the Asian Elephant Regional Studbook [5]. Currently, this population is not self-sustaining and historically has relied on supplemental importations from range countries to sustain numbers, an increasingly unrealistic option as

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doi:10.1016/j.theriogenology.2012.01.014

import restrictions increase. Weise [6] reported that to maintain a captive population of approximately 250 Asian elephant females in North America, seven to nine female calves must be born annually. The actual birth rate has been only 2.6 female calves per year over the past 10 yrs [5], which is considerably lower than the rate needed to maintain the population. Thus, institutions must rely on all available tools to maximize reproductive efficiency, including a combination of assisted reproductive techniques and managed natural breeding introductions. To accomplish this goal, it is critical to understand the range of normal variation in Asian elephant reproductive cycles, as well as how management and social factors might impact those cycles.

Based on behavioral observations, the Asian elephant estrous cycle was originally believed to be 18 to 27 days in length [7,8]. Elephant ovarian cycles were initially difficult to monitor because the CL produces primarily 5$\alpha$-dihydroprogesterone (5$\alpha$-DHP) and little actual progesterone [9–13]. Through improved progestagen monitoring with assays that detected 5$\alpha$-DHP, the elephant estrous cycle was found to be the longest of any mammal published to date, with a 13 to 17 wk duration, consisting of an 8 to 10 wk luteal phase and a 4 to 6 wk follicular phase [14–16]. Another unique aspect of the elephant estrous cycle is the occurrence of two LH surges, approximately 20 days apart during a normal follicular phase, with only the second surge inducing ovulation [16–18].

Because of the long ovarian cycle, elephant females are fertile only three to four times per year, and for only 2 to 3 days per cycle [19]. With so few opportunities to impregnate elephant females, breeding managers must have accurate data on individual elephants to understand subtle variations in estrous cycle patterns. Published estimates of the Asian elephant estrous cycle duration are derived from a surprisingly limited number of individuals studied for variable, and often short, intervals [7,8,13–15,19,20]. With such a long-lived species, it can take decades to compile a dataset large enough to identify subtle variations in estrous cycle patterns. Thus, most studies to date have been of insufficient duration to evaluate cycle characteristics within or among females with respect to age, management, and social (e.g., herdmate introductions and deaths) factors.

The Oregon Zoo has the longest-running dataset of routine weekly blood samples for Asian elephants, including data from males and females, breeding and non-breeding. This study summarizes serum progestagen data for eight Asian mainland elephants (*Elephas maximus indicus*) and one Bornean elephant (*E. maximus borneensis*) housed at the Oregon Zoo, several of which have been monitored for over two decades. Longitudinal serum progestagen data were analyzed to determine: 1) cycle variability across and within individuals; 2) role of luteal and follicular phase durations in maintaining duration of cycle; 3) effect of age on cycle parameters; 4) characteristics of the first pubertal cycle compared to subsequent cycles; 5) impact of management and social changes (transfers in, transfers out, births, deaths) on long-term cycle dynamics; and 6) timing of progestagen peaks relative to the luteal midpoint (as a potential method of predicting the end of the luteal phase). Results of evaluations of more than 3000 weekly data points and over 180 estrous cycles, encompassing puberty through senescence, are presented. This study represents the most thorough investigation published to date on estrous cycle characteristics of Asian elephants, on both a group and an individual basis.

## 2. Materials and methods

### 2.1. Animals and sample collection

This study utilized serum progestagen data collected between 1988 and 2008 for nine female Asian elephants (n = 8 *E. m indicus*; n = 1 *E. m borneensis*) housed at the Oregon Zoo (Table 1). All elephants were conditioned to blood sampling procedures (without anesthesia), as part of the normal management routine. Blood samples (3–9 mL) were collected approximately weekly (interval range 3–11 days) from either an ear or leg vein, generally in the morning. Blood was maintained at ~4 °C, allowed to clot at room temperature, then centrifuged (~1500*g*) and frozen. Serum was stored at −20 °C or colder until analysis.

During the 20-yrs study period, females were housed as a single herd or as two separate herds comprising two to four individuals each. Two to four adult bulls were present at any given time and were housed separately, except when placed with females for breeding or for male/female socialization. Over this time, elephants considered dominant members of the herd(s), based on keeper observations of social interactions, were OZ-F1 (highest ranking in all groups), OZ-F4 (secondary to OZ-F1), and OZ-F7 (after OZ-F1 and OZ-F4 had died). These three females were euthanized during the study. Elephant OZ-F1 was euthanized at age 44, after treatment for osteomyelitis, distal metacarpus of digit four on the left front foot, and tenosyn-