CHAPTER 2

Musth factors analysis

2.1 Introduction

Musth in adult bull elephants is an annually occurring period of physiological, anatomical and behavioral changes, and occurs in both species (*Loxodonta* and *Elephas*) (Eisenberg et al., 1971; Hall-Martin and Walt, 1984; Jainudeen et al., 1972b; Lincoln and Ratnasooriya, 1996; Poole, 1989; Poole and Moss, 1981; Rajaram, 2006). At least for African elephants, most matings in the wild are performed by musth bulls, and the most dominant ones usually are in musth at the most favorable time of year for mating (Ganswindt et al., 2005a; Hollister-Smith et al., 2007; Sukumar, 2003). Musth therefore plays an important role in elephant society for ensuring that the most healthy, dominant bulls produce more offspring. However, it is important to note that musth is not necessary for breeding in either species (Hollister-Smith et al., 2007; Sukumar, 2003).

Musth is associated with a dramatic elevation in serum testosterone concentrations and is characterized by swelling of the temporal gland (TG), temporal gland secretions (TGS) of sweet-smelling exudates, urine dribbling (UD), an increase in aggressive behavior driven primarily by testosterone (Ganswindt et al., 2005a, 2005b; Rajaram, 2006; Rasmussen et al., 1984; Rasmussen and Schulte, 1998; Yon et al., 2008), and sexual activity including raised libido and increased frequency of spontaneous semen ejaculation. During musth, bulls produce pheromones, such as frontalin, that are important factors in olfactory communication (Goodwin et al., 2012; Lazar et al., 2004). In addition to testosterone, musth is associated with altered serum LH secretion, presumably under GnRH control via the hypothalamo-pituitary-gonadal (HPG) axis. A study in Asian elephants found testosterone increased after LH pulses (~1 pulse/3 hours),

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and although LH pulse amplitude was similar between musth and non-musth bulls, there was a greater testosterone response observed in musth bulls (Niemuller and Liptrap, 1991). In African bulls, the testosterone response to a GnRH challenge African also was significantly greater than that of non-musth bulls (Brown et al., 1993). Together, these studies suggest that the testes of musth bulls are hypersensitive to LH stimulation during musth, perhaps related to increased testicular LH receptors, as was demonstrated in beef bulls (Melson et al., 1986). A longitudinal study of one African elephant observed markedly elevated LH concentrations for approximately 5 weeks about 4 weeks before the musth onset (Kaewmanee et al., 2011). Thus, a protracted LH surge might be important for initiating processes that result in high testosterone production, and could perhaps be used as a biomarker for impending musth. Other factors related to musth include age, nutrition and social status (Cooper et al., 1990; Lincoln and Ratnasooriya, 1996; McKay, 1973; Rajaram, 2006; Sukumar, 2003). Most healthy adult bulls exhibit musth at predictable times of each year within individuals (Lincoln and Ratnasooriya, 1996), but in Asia it often occurs after the rainy season. Because musth is correlated with nutritional status, a common method to control musth is to decrease food intake (Cooper et al., 1990; Lincoln and Ratnasooriya, 1996); elephants drop out of musth in association with a drop in body condition. In terms of social status, high ranking and/or older age elephants enter musth before subordinates, and can suppress musth in younger bulls (Brown et al., 2007; Hall-Martin and Walt, 1984; Niemuller and Liptrap, 1991; Poole, 1994; Sukumar, 2003).

Normally, elephants in Thailand come into musth in the late raining to early winter (November-January) seasons, and the musth duration varies (1– 3 months or more). When they come into musth, mahouts will isolate the bull and shackle him to a tree or post with a stronger chain. Some, but not all, attempt to attenuate musth by reducing food, the conventional musth control method (Cooper et al., 1990; Lincoln and Ratnasooriya, 1996). Although most healthy elephants exhibit musth once annually, some exhibit symptoms several times a year, while others skip one or more years; some may not show musth at all. It is not entirely clear how different elephant management systems affect musth both the first musth occurrence, or subsequent cycles, but certainly could be related to age, body condition and nutrition status as in other populations.

Thus, mahouts need to know the pattern of musth in their elephants to aid musth control and management. Appropriate musth elephant management is necessary to prevent accidents: to humans, elephants and objects (Eisenberg et al., 1971; Jainudeen et al., 1972a, 1972b; Lincoln and Ratnasooriya, 1996; Rajaram, 2006), especially in the free contact systems generally used in elephant camp facilities.

2.2 Materials and methods

2.2.1 Musth factor survey

A musth factor survey was performed using a questionnaire and interviews with mahouts, elephant keepers, and owners. Questionnaire data were collected from 55 elephant bulls, ranging in age from 14-67 years (34.2 ± 13.9 years). The elephant subjects were from Chiang Mai (n=3), Mae Hong Sorn (n=3), Lampang (n=15), Pair (n=3), Nan (n=1), Tak (n=2), Surin (n=25) and Buriram (n=1). All elephants had a record of annual musth periods (TGS and UD). The musth in questionnaire was considered two aspects of musth: the first musth period an elephant exhibited, and the time and duration of annual musth cycles as adults.

The questionnaire (Appendix A) consisted of elephant general data, e.g. name, age, location, type of work and normal habit or behavior, and musth details that included the first musth time, annual musth time, types of behavior change, musth management and control. Additional information was collected to determine how environment, diet or management factors were related to the occurrence of musth in individual bulls.

2.2.2 Statistical analysis

The first musth was analyzed by time-event Survival analysis, Kaplan-Meier model to evaluate time and age of the first musth observation). Factors potentially involved with musth were assessed by COX Regression

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analysis with a 95 % CI by SPSS 16.0 (SPSS Inc., Chicago, USA), including comparing elephants that exhibited musth every year versus every 2-3 years or more. Data (e.g. musth periods, musth duration, musth behavior, musth control, type of work, working hours) are expressed as mean ($\pm$ SD) and each corresponding percentile.

2.3 Results

2.3.1 First musth

Twenty-five bulls had information about their first musth and were included in the Kaplan-Meier model of survival analysis. The median age of elephants at first musth was 21.01 years (range, 11 - 30 years) (Figure 2.1). Most elephants came into the first musth in November-December (Table 2.1), which is the rainy to winter season in Thailand (Table 2.2), at the median age of 20-22 years old. None of the management factors were associated with first musth occurrence ($P>0.05$).

2.3.2 Annual musth

General information on annual musth was collected on 55 elephants (34.2 $\pm$ 13.9 years old (range 14 - 67 years). The average BCS of these elephants was 7.97 $\pm$ 0.14 based on an 11-point score (Wemmer et al., 2006). As categorized by musth occurrence, 50.9% (n = 28; 34.9 $\pm$ 11.8 years of age) exhibited musth every year, 27.3% (n = 15; 43.9 $\pm$ 14.1 years) exhibited musth every 2-3 years, 10.9% (n = 6; 22.8 $\pm$ 7.6 years) exhibited their first musth during the study, and 10.9% (n = 6; 18.8 $\pm$ 3.1 years) had never exhibited musth.
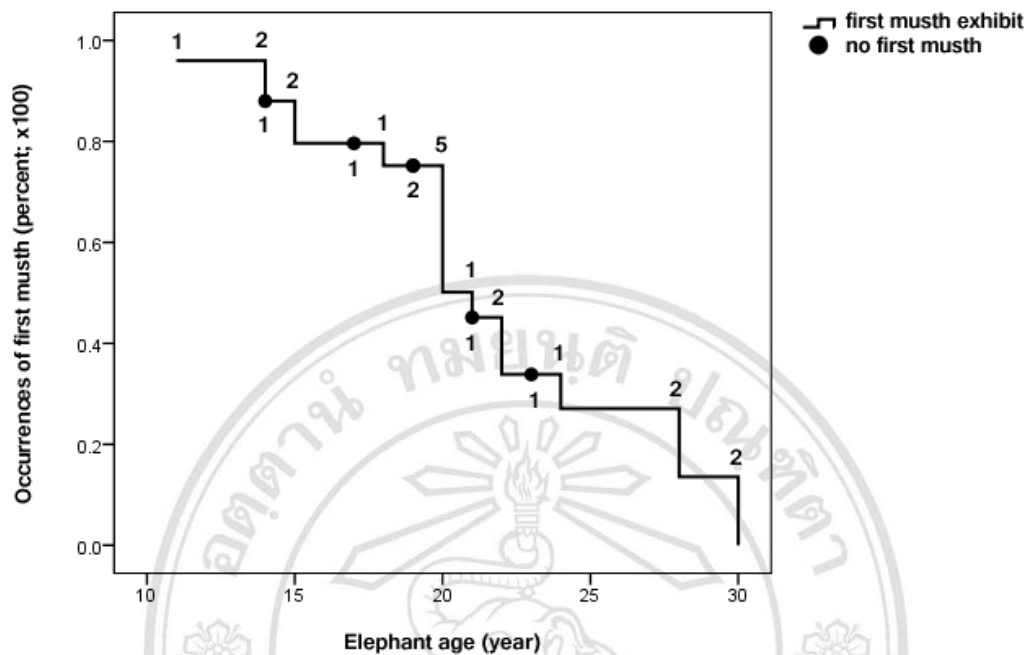
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Figure 2.1 Occurrences of first musth in elephants (n=19) between 11-30 years of age with indicated numbers on above, and elephants were not exhibit the first musth yet (n=6) with indicated numbers at below.

Table 2.1 Number of elephant that became to first musth related in a months.

Months	Elephant number	Age of first musth (year); median	Individual age (year)
January – February	1	21	21
March - April	3	22	15/22/24
May - June	1	20	20
July – August	3	20	11/20/28
September – October	3	20	14/20/22
November - December	8	20	14/15/18/20/20/28/3/30
Total	19	20	

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Table 2.2 Number of elephant that became to first musth in three seasons.

Seasons[a]	Elephant number	Age of first musth (year); median	Individual age (year)
Summer	3	22	15/22/24
Rainy	7	20	11/14/20/20/20/22/28
Winter	9	20	14/15/18/20/20/21/28/30/30
Total	19	20	

[a]Summer; March-May, Rainy; June-October, and Winter; November-February.

2.3.3 Musth factors

Musth factors between 49 elephant bulls that exhibited a musth every year (n = 34) or every few years (n = 15) are shown in Table 2.3. Based on behavior (Appendix 1), 41.8% of non-musth elephants had normal behavior and were not aggressive to strangers (Aggressive Score 1), whereas 72.7% were aggressive to both elephants and human. In terms of workload, more than two thirds were not worked (67.3%); the remaining worked for periods of 4-6 hours per day (late morning to early afternoon). Collectively, all elephants entered musth at the same time each year, with 47.6% coming into musth around November-December, and 59.5% in winter season (November-February). During musth, their behavior became more aggressive; 83.3% had scores of 3 and 4, were aggressive to human strangers, and destroyed objects. Overall, 69.0% of bulls had a musth duration longer than 1 month; however, few bulls were exposed to musth management or control (73.8%).

Statistical COX Regression analysis indicted several factors were significant or approached significance in relation to musth: higher BCS (p=0.058), larger body weight (p=0.004), nonaggressive behavior (p=0.026), not working (p=0.069), entered musth November-February (p=0.027), and

having a long musth duration (*p*=0.060). None of the nutritional factors were related to musth, although because all bulls were housed near the forest, and were supplemented with grass, hay, bananas, vitamins and minerals, there was limited variation.

Table 2.3 Percentage of factors might be most involved to musth in Thai elephant bulls from questionnaire interview.

Musth data list		Elephant	Percent (%)	Remark
Musth	exhibit musth	49[a]	89.1	age 36.22 ± 1.93 range; 15-60 years
	non-exhibit musth	6	10.9	age 18.83 ± 1.27 range; 14-23 years
Musth frequency[b]	every year	28	65.1	age 34.96 ± 2.23 range; 15-60 years
	every few year	15	34.9	age 43.93 ± 3.64 range; 25-67 years
Normal behavior[c]	tame	14	25.5	
	aggressive 1	23	41.8	
	aggressive 2	16	29.1	
	fear	2	3.6	
Aggression to	human	39	70.9	
	human+elephant	1	1.8	
	non	15	27.3	
Elephant work	logging	4	7.3	
	riding elephant	11	20.0	tourist camp
	circus/show	2	3.6	
	other	1	1.8	transportation
	non-work	37	67.3	
Work period	morning	2	3.6	2-3 hours
	morning to afternoon	16	29.1	4-6 hours
	non-work	37	67.3	
Musth season[d]	summer	8	19.0	
	rainy	9	21.5	
	winter	25	59.5	

[a]six elephant exhibited the first musth on questionnaire interview (age 22.83±3.10)
[b]excluded the elephant that exhibited the first musth on questionnaire (n=6), and elephants did not become a first musth (n=6)
[c]musth behavior survey (Appendix A)
[d]Summer; March-May, Rainy; June-October, and Winter; November-February.

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Table 2.3 Percentage of factors might be most involved to musth in Thai elephant bulls

	Musth data list	Elephant	Percent (%)	Remark
Musth circle	January-February	5	11.9	
	March-April	5	11.9	
	May-June	3	7.1	
	July-August	4	9.5	
	September-October	5	11.9	
	November-December	20	47.7	
Musth duration	< 7 days	4	9.5	
	1-2 weeks	5	11.9	
	4 weeks	4	9.5	
	> 1 month	29	69.1	maximum ~6 months
Behavior change in musth	normal (no change)	3	7.1	
	difficult to control	4	9.5	
	to be aggressive	35	83.4	
Musth behavior[c]	tame	3	7.1	
	aggressive 1	2	4.8	
	aggressive 2	18	42.9	
	aggressive 3	17	40.5	
	aggressive 4	2	4.8	
Musth control	yes	31	73.8	
	no	11	26.2	food restriction method (50-70 %)

from questionnaire interview (continue).

[a] six elephant exhibited the first musth on questionnaire interview (age 22.83±3.10)
[b] excluded the elephant that exhibited the first musth on questionnaire (n=6), and elephants did not become a first musth (n=6)
[c] musth behavior survey (Appendix A)
[d] Summer; March-May, Rainy; June-October, and Winter; November-February.

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2.4 Discussion

The elephants in this study exhibited their first musth at about 21 years of age (range, 11-30 years old), close to the adult age (22.5 years old) reported by McKay (1973). There is little information on how first musth is related to puberty, however, because it has not been studied in association with initiation of spermatogenesis in either zoo or camp elephants. First musth has been observed in bulls as young as 11 years, particularly in western zoos (Cooper et al., 1990). Most report that Asian elephant bulls begin musth when they are about 15-20 years old (Douglas-Hamilton et al., 2001; Sukumar, 2003), and that it is dependent on health status; bulls in poor condition might not experience musth (Schmidt, 1986). According to other reports, nutrition plays a major role in musth in elephant (Jainudeen et al., 1972b; Lincoln and Ratnasooriya, 1996; Jainudeen et al., 1972b), both first musth and annual musth. The youngest bull in this study was in good condition, with a BCS of 8.5/11 (~3 tons body weight), and larger than average at this age. This bull never had nutritional restriction to control musth; he, therefore, started to show musth signs at a young age. Other bulls did not exhibit first musth until they were 30 years old, although at the time of the study, their BCS also was good (8.5/11 with a body weight of 3.5 tons). It is possible these elephants might have experienced musth control by restriction of food earlier in life; such histories were not available to us. Other studies also report lack of musth in bulls up to the age of 30 years at a time when food restriction as a control for musth was common (Jainudeen et al., 1972a).

Musth is not seasonally obligatory, and can occur at any time of the year (Lincoln and Ratnasooriya, 1996; Niemuller and Liptrap, 1991; Rajaram, 2006; Brown et al., 2007; Yon et al., 2007). However, at least in Asia, once bulls initiate musth cycles, they tend to exhibit them annually at the same time of the year, with individual bulls having a specific annual cycle, and musth intensity often increases with age. For example, younger bulls between 15-25 years old exhibit lower musth intensity, compared to bulls older than 25 years of age (Sukumar, 2003). Older, mature bulls also have a longer period of full musth (Rajaram, 2006; Sukumar, 2003). In this study, bulls in good health and body condition had musth durations of longer than 1 month, and with a higher

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intensity; e.g., TG, TGS, UD and increased aggressive behavior. However, some bulls did not exhibit musth every year, which appeared to be related to poorer body condition and older age as described for other elephants (Douglas-Hamilton et al., 2001; Rajaram, 2006; Sukumar, 2003). Both BCS and body weight were associated with musth in elephant bulls. The elephants with good BCS and larger body size entered a musth every year (i.e. the big body size, youngest bull exhibited a musth when only 11 years old). Those adult bulls that did not have a musth every year, had a poor body condition (BCS less than 6) and were of an older age (45-65 years). Must was also related to season. Similar to other studies (Spinage, 1994; Lincoln and Ratnasooriya, 1996; Sukumar, 2003; Rajapaksa personal communication), Thailand camp elephants mostly entered musth during the rainy season and early winter. Although none of the nutritional factors were statistically significant, the rainy season is associated with the nutritional status in elephants that consume higher quantities and quality of food. By contrast, there are reports of elephant loss of body condition coming out of musth, presumably due to less food consumption or perhaps poorer quality roughage (Jainudeen et al., 1972b; McKay, 1973; Poole, 1989; Schmidt, 1986; Spinage, 1994). As such, one of conventional methods for musth control, and to prevent or decrease intensity, is to withhold or restrict food (Cooper et al., 1990; McKay, 1973; Rajaram, 2006). What has been found in this study seems to imply that an energetic food and supplement might be involved in musth; e.g. grass, hey, banana and supplements. However, in this study only the type of food and supplement was determined, not the actual amount of food consumed or the nutritional quality of various components. Our study found that non-working bulls were more likely to enter musth every year, probably related to being in good condition. In Thailand, harder working bulls (i.e. logging) generally do not enter musth when they are working (Boonyang Boonthiem, personal community). In fact, one conventional method to prevent musth is to work and exercise the bulls more. This method will prevent the elephant from entering the musth, and also shorten the musth period if they come into the musth, presumably by reducing body condition.

Social factors are involved with musth in both species (Hildebrandt et al., 2006; Sukumar, 2003). Elephant social behavior and dominance status can affect the occurrence of musth, with musth in young bulls being suppressed by older, more

dominant bulls, especially in the wild. In captivity, bulls often are housed alone, or are kept separate from other males. This lack of a social hierarchy can result in bulls beginning to exhibit musth at much younger ages (Hildebrandt et al., 2006; Cooper et al., 2009). All bulls in our study were kept in various elephant facilities under safety procedures; they were isolated and not allowed contact with other bulls directly. Therefore, a social hierarchy was not established in these bulls and musth was not affected by social behavior. Behaviorally, it has been reported that some older elephants in musth are not as aggressive and show decreased intensity (Rajaram, 2006), but the musth bulls in this study were always aggressive. Furthermore, the most aggressive bulls in this study came into musth every year, and exhibited a longer musth duration.

2.5 Conclusion

In conclusion, our results confirmed that domesticated male Asian elephants in Thailand exhibit the first musth when they are about 20 years old. Similar to bulls in Asian elephant range countries, most elephant bulls display musth during the rainy season into early winter. Although elephants enter musth at the same time every year, musth duration and intensity varied in individual bulls. The older elephants had a longer musth duration than the younger ones, with typical signs of musth; i.e. TG, TGS, UD, and more aggressive behavior. Musth in these Thai elephant bulls were related to factors, such as body condition, weight and season. Nutrition might be a major factor, involved in increasing HPG axis activity; however those factors were not significant. However, the number of elephants in this study was small, and some factors bordered on statistical significance and might be with a larger sample size. Therefore, musth factors evaluation should be performed in a larger number of bulls to determine major factors associated with musth in Thai elephant bulls