**PhD Dissertation Defense**

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**Title:** Investigating Body Condition and Metabolic Hormones in Relationship to Reproductive Cyclicity in Zoo Female African Elephants, *Africana Loxodonta*

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## ABSTRACT

African elephants (*Loxodonta africana)* in U.S. zoos generally appear heavier than wild counterparts, and there are claims that obesity-related health and reproductive problems may be contributing to population non-sustainability. To determine whether obesity and related metabolic conditions are a problem in zoo-managed African elephants, body condition, insulin, glucose, and leptin levels, and the glucose-to-insulin ratio (G:I) were compared between breeding-aged cycling and non-cycling zoo females. Body condition scoring (BCS) is the assessment of subcutaneous fat stores based on visual or tactile evaluation of muscle tone and key skeletal elements, and provides an immediate appraisal of the degree of fatness of an individual. An objective of this study was to develop a visual BCS index for female African elephants and validate it using ultrasound measures of subcutaneous fat. To develop the index, standardized photographs were collected from zoo and free-ranging female African elephants to identify key body regions and anatomical sites, which were used to visually assess body fat deposition patterns. The visual BCS method consisted of a list of body regions and the physical criteria used for obtaining an overall score on a 5-point scale, with 1 representing the lowest and 5 representing the highest levels of body fat. Significant correlations were found between the visual scores and ultrasound measures of subcutaneous fat thickness at all anatomical sites,

but were highest in the pelvic bone (r = 0.660, $P < 0.01$) and backbone (r = 0.664, $P < 0.01$) regions, indicating that BCS adequately reflects the amount of actual fat reserves.

In comparing photographs of wild vs. captive elephants, the median BCS in the free-ranging individuals (BCS=3, range 1-5) was lower ($P < 0.001$) than that of the zoo population (BCS=4, range 2-5). When comparing, BCS, insulin, glucose, and leptin levels, and the glucose-to-insulin ratio (G:I) between cycling and non-cycling females, the mean BCS of non-cycling elephants was higher than that of cycling elephants [4.39 (SD 0.58) vs. 3.73 (SD 0.93), $P = 0.009$], as were concentrations of serum leptin [4.03 ng/mL (SD 1.63) vs. 3.16 ng/mL (SD 0.88); $P = 0.041$] and insulin [0.65 mg/mL (SD 0.31) vs. 0.48 mg/mL (SD 0.18); $P = 0.032$]. Serum glucose was the only metabolic biomarker that did not differ between cycling and non-cycling elephants ($P = 0.892$); however, the G:I was lower in the non-cycling group [69.82 (SD 53.21) vs. 227.18 (SD 96.23); $P = 0.019$]. Using "non-cycling" as the outcome variable in regression models, we examined BCS, leptin, insulin, and the G:I ratio as predictors, and found that BCS showed the strongest predictive power with an $r^2 = 0.23$ ($P = 0.01$). The odds ratio for the BCS coefficient was 3.15 with a 95% confidence interval of [1.36, 7.26], which suggests that with each 1 point increase in BCS, an elephant is approximately 3 times more likely to be non-cycling. These results demonstrate that ovarian acyclicity is associated with a high BCS and perturbations in markers of metabolic status. The BCS index could serve as a valuable tool for assessing the physical state of individual elephants and monitoring insulin, glucose, and leptin may help identify elephants at risk for developing metabolic health conditions, including fertility problems. This would allow for management interventions to be implemented, improving body condition and metabolic status with the goal of reinitiating ovarian activity and promoting a healthier zoo population.