The Effects of Changes in Body Condition on Rhinoceros Birth Sex Ratios: Initiation of a Worldwide Zoo Research Study

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Abstract

We are inviting zoos to participate in a collaborative study examining the effects of stress and overfeeding on rhinoceros birth sex ratios. Our hypothesis is that increasing levels of stress and nutrition elevate glucose concentrations in female rhinos leading to early female embryo loss resulting in male-biased birth sex ratios. Using non-invasive techniques to monitor serum glucose and faecal corticoids and a slight diet reduction, we will test whether declining body condition will result in more female calves. The intended outcome is to increase the number of female births to help ensure the long-term sustainability of the captive rhinoceros population.

1. Introduction:

Skewed birth sex ratios (BSRs) have been observed or speculated to exist in a number of species while in captivity [Faust and Thompson, 2000]. Zoo managers have become increasingly concerned about this issue in captive rhinoceros populations. An analysis of rhinoceros births in the North American captive population demonstrates an overall 61% bias towards males, ranging from 53% in Southern White Rhinos (*Ceratotherium simum*) to 71% in Eastern Black Rhinos (*Diceros bicornis michaeli*) [Atkinson, 1997]. In the last five years, 9 male and 4 female rhinos have been born to ARAZPA institutions, a resulting BSR of 69%.

The challenge to captive animal managers is how to manage the populations in order to bring back a balanced or perhaps female-biased birth sex ratio. Recent discoveries at the molecular and cellular level in domestic mammals have given us insight into the mechanism of birth sex ratio modification [Gutierrez-Adan et al., 2000; Perez-Crespo et al., 2005; Roche et al., 2006]. In addition, they point us towards the sorts of experiments we need to perform to develop husbandry regimes that result in more female calves.

As presented at the 2006 ARAZPA conference, a retrospective study of rhino translocations found that stress during different stages of pregnancy was correlated with changes in birth sex ratios [Linklater, 2006]. Linklater compared the timing of translocation stress in rhinos that were moved during pregnancy. There was a clear effect of stress on the survival of the embryos that was biased between the sexes depending on whether the stress occurred during early or mid-gestation. Rhino births were 86% male if stress occurs in first fifth of gestation (<100 days), then reversed to 38% if translocation occurred during mid-gestation (0.2-0.8 of gestation, 95-380 days). We believe that is probably due to greater female and then male embryo deaths, respectively. Linklater proposed that glucose was the probable cause of early female embryo death. The stress of translocation and associated sedation is known to transiently increase circulating glucose in rhinos and other species [i.e. Kock et al, 1990].

Animals will adjust their birth sex ratios in response to environmental stimuli in order to produce the sex of offspring that has greater reproductive potential [Trivers and Willard, 1973]. When resources are rich, a female will be increasing body condition and increasing glucose stores and will produce more male offspring. When resources are poor, a female will be losing condition, have lower glucose stores and tend to produce female offspring. The primary energy source in food is glucose, and body glucose stores change in proportion to available dietary glucose. This phenomenon is documented in a number of species including a related Perissodactyla: the wild horse [Cameron, 2004; Cameron et al., 1999; Flint et al., 1997; Sheldon et al., 2004]. In mammals, change in body condition and concurrent changes in available glucose, and not body condition per se, have been identified as the causes of changes in birth sex ratios [Cameron and Linklater, in press; Roche et al., 2006]. In wild horses, the birth sex ratio can range from 3 to 81% male between mares in decreasing and increasing body conditions, respectively [Cameron and Linklater, in press].

Recent advances in embryo culture have shed light on the physiological processes that drive birth sex ratios as a result of environmental conditions. As discussed earlier, stress also appears to play a role in skewing birth sex ratios. Stress and improving body condition both increase levels of circulating glucose and result in fewer female births. This observation is confirmed by in vitro studies: bovine embryos grown in high glucose concentrations show preferential survivability of male embryos [Agung, 2006; Kimura, 2005]. Thus, glucose does indeed appear to have a role in the death of early female embryos.

Using historical data from Hluhluwe-iMfolozi Preserve in South Africa, we looked at the relationship between seasonal rainfall, as an indicator of nutrient availability, and birth sex ratios in a wild population of rhinos. During the rainy season, a female has more to eat and will gain body condition but will lose condition during the dry season. We predicted that more male calves will survive early gestation and be born as a result of rainy season conceptions. Table 1 shows our results. During the rainy season, rhinos produced almost 3 times as many male offspring. Conversely, during the dry season and fewer available resources, the birth sex ratio skewed towards females.

Table 1: Birth Sex Ratios of Black Rhino Conceptions During Rainy and Dry Seasons, 1995-2002

	Rainy	Dry	Yearly
Male	8	7	15
Female	3	12	15
Total	11	19	30
% Males	73	37	50

Perhaps male biased birth sex ratios in captivity are a consequence of rhinos being fed like it's the rainy season all year round!

In order to test this hypothesis, we are asking zoos to participate in a collaborative study to establish the link between diet, stress, glucose and birth sex ratios. Using hand-held blood glucose meters (a modern technology developed for diabetic patients), we can measure blood glucose with minimal manipulation and stress to the rhinos. We then plan to place rhinos on slightly restrictive diets directly after breeding in order to place them in a glucose deficient state. We will monitor glucose with the glucose meters, do regular body condition assessments, and monitor stress by measuring faecal corticosteroid metabolites. As opportunities arise, and from those rhinos already trained for blood collection, we will occasionally collect blood samples via venipuncture to confirm glucose meter readings and measure circulating cortisol. We will use husbandry records to monitor stress events. Rhinos will be bred as recommended; the treatment group females will have their diets restricted for a brief period of time following breeding. Then we will compare the resulting birth sex ratios between the two groups.

The hypotheses to be tested are:

Hypothesis 1a: Stress induces hyperglycaemia.

Hypothesis 1b: Excess nutrition induces hyperglycaemia.

Hypothesis 2: Elevated nutrition decreases female births.

Hypothesis 3: Reduction of dietary factors will result in more female calves.

2. Experimental Design and Methods

Experiment 1: We will measure blood glucose and faecal corticosteroids during normal husbandry and feeding regimes to establish the relationship between stress, diet and circulating glucose. In addition, we will feed some females high glucose meals, then measure blood glucose with the glucose meter every hour until it returns to baseline levels.

Experiment 2: We will conduct a retrospective assessment of zoo diets and husbandry. Dietary energy will be correlated with calf sex to establish the long-term relationship between diet and birth sex ratios.

Experiment 3: We will conduct a feeding trial before conception and during pregnancy in an attempt to increase the number of female births. We will reduce the amount of high energy food in diet in the critical period prior to conception and implantation.

3. Anticipated Results

Experiments 1a and 1b will provide information on baseline glucose profiles in nonstressed and stressed captive female rhinos. This information will be compared with historical zoo records and published research reports [i.e. Kock et al, 1990]. We will also profile the glucose response to dietary changes.

From the results of Experiment 2, we will be able to identify specific dietary practices that are associated with increased numbers of male offspring. In addition, we may be able to point out stressful husbandry events that are associated with more male calves.

Experiment 3 will provide evidence that the mechanism is early female embryo loss in response to increasing body condition after conception and before implantation of the embryo into the uterine wall.

4. Conclusion

The intended outcome is to provide husbandry and dietary recommendations that will increase the number of female births in rhinos. By demonstrating these principles in rhinos, we aim to set the groundwork for applying these techniques to other species that exhibit skewed birth sex ratios in captivity (e.g. chimpanzees). Increasing the number of female births will aid zoos in establishing sustainable captive populations for long-term propagation of endangered rhinos.

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