Symposium: Companion Animals: Exotic Animal Nutrition

631 Zoo nutrition: In the beginning... D. E. Ullrey*, *Michigan State University*, *East Lansing*.

This is not a history of zoo nutrition but a personal retrospective on a career in Comparative Nutrition, beginning with life as a farm boy and a traditional undergraduate education in Animal Husbandry. Wise counsel by R.H. Nelson led to a useful MS degree in Pathology at MSU and a PhD in Animal Nutrition, with minors in Physiology and Biochemistry, at the Univ. of Illinois. Thesis research was conducted with cattle and swine, and my first faculty position in the Dept. of Physiol./Pharmacol. at Oklahoma State Univ. involved research with domestic species, as well. A faculty appointment in Animal Science at MSU in 1956 included responsibility for developing an analytical laboratory, and E.R. Miller and I collaborated on studies of swine for 37 years. Our faculty and graduate students were also interested in beef and dairy cattle, sheep, horses, and poultry, and several collaborative studies of their nutrient needs were published. When the Wildl. Div. of the Mich. Dept. of Natural Resources asked for assistance, research began on nutrition and physiology of white-tailed deer. The diets used in white-tailed deer studies, and concern for the welfare of other captive wild animals, ultimately led to development of diets for a number of wild species. A Comparative Nutrition Group was formed at MSU, and a small group of graduate students began on-site training at the Dallas Zoo. They were asked to gather quantitative data on food offered and consumed in all animal exhibits, to calculate nutrient intakes, and, when appropriate, make recommendations for change. Many decisions were founded on extrapolations from knowledge of needs of domestic animals with similar gastrointestinal physiology. Because specific nutrient guidelines were so limited, studies were initiated to develop research-based diet formulations. Over time, the physiology and nutrient needs of 77 species were investigated. These included marsupials (2), primates, including humans (5), rodents (1), whales (1), mammalian carnivores (10), perissodactyls (7), artiodactyls (19), birds (20), turtles & tortoises (2), snakes (3), frogs & lizards (3), fish (2), and insects (2). Examples and contributions of others are presented.

Key Words: Zoo, Nutrition, Comparative

632 Forty-plus years of exotic animal management - A director's perspective. L. Simmons*, *Omaha's Henry Doorly Zoo*, *Omaha, NE*.

In the beginning, a million years ago, zoo directors and curators formulated diets for exotic animals based on an empirical combination of extrapolations and questions that included:

1. How much was known about the target animal's natural history and diet?
2. What were the diets of the domestic species that the target species was most closely related to?
3. What was the traditional diet fed to the target species in captivity?
4. What did the animal readily eat when given a wide choice of food items?

Sometimes, developing diets based on the answers to these questions worked out well; however, in a substantial percentage of cases, a successful diet was arrived at only after much trial and error. "Successful diets" were passed down from keeper to keeper, from zoo to zoo and even from country to country. Frequently, diets which were coined "successful" for a species were those diets which were fed to multiple species or genera within a single exhibit and therefore, the animals had access to a large number of foodstuffs to choose from. Anecdotally, there were many observations of species that preferred the "other guy's diets." Defining what was meant by a "successful diet" also was problematic. Did it mean that the animal ate the diet and survived? Did the animal grow up to be a healthy adult? Did the animal reproduce and if it did, how long had it been out of the wild when it reproduced and did it reproduce a second time? Diets were also defined "successful" by monitoring the texture and color of an animal's pelage? Over the past forty-plus years, there have been plenty of examples of diets that did work, diets that did not work, and diets that seemed to work but in fact were altogether wrong. Some of these examples include frog eating toucans, yellow brown bears, and drunk hummingbirds. Today, the field of exotic animal nutrition is applying a science based approach to the development and formulation of nutritious diets for captive exotic animals.

633 Amphibians and reptiles - Trials and tribulations. C. Dikeman*, *Omaha's Henry Doorly Zoo*, *Omaha, NE*.

Animal science research during the last century has given the field of exotic animal nutrition a knowledge base for extrapolation to exotic species. Unequivocal comparisons often are made between traditional animal science research and that conducted with exotics. For example, comparisons between the horse and zebra or the cat and leopard, seem obvious. However, when dealing with nutrition of endangered amphibians and reptiles, direct comparisons with animal science becomes ambiguous at best. Animal scientists have been improving the diets of domestic animals for decades to provide nutritious products for human consumption. Likewise, feeding captive amphibians and reptiles requires careful attention to the diet of the intended prey, typically live feeder crickets. Compounded with a lack of solid information regarding nutrient requirements for amphibians and reptiles, the successful rearing of these captive creatures becomes onerous. Metabolic bone disorders, caused by imbalances of calcium and phosphorus, have been the focus of feeder insect research for amphibians and reptiles over the past 4 decades. While it may seem irrelevant to animal scientists to consider the importance of feeding frogs, currently a crisis is affecting these bio-indicators that could result in the extinction of up to one-third of the World's amphibian species over the next 5-10 years. While many species of birds and mammals (approximately 12 and 23%, respectively) are threatened with extinction, nearly 50% of known amphibian species are threatened. As a result, many of these species are being brought into captivity for critical conservation efforts. As new species are brought into captivity, additional nutritional concerns are becoming apparent. Captive Wyoming and Puertorican Crested toads appear to have extraordinary dependency on Vitamin A concentrations that are largely misunderstood. While researchers are currently working on feeding regimes to improve the nutrient profile of feeder insects, gaps exist in the connection those vital nutrients play in the health and longevity of preying amphibians and reptiles. Dedicated nutritional and biochemical research is imperative to the conservation of these animals.

Key Words: Exotic species

634 Carnivores: From mouse to moose. E. S. Dierenfeld*, *Saint Louis Zoo*, *St. Louis, MO*.

Classic metabolic bone disease, diagnosed in the 1800s in lions at the London Zoo fed unsupplemented meat, is perhaps the first published nutritional problem identified in zoo carnivores. Since that time, enzyme studies with cheetahs, other large cats, carnivorous birds, and even crocodilians confirm that domestic felids are an appropriate physiologic model for many obligate carnivores. The unique metabolic adaptations of felids for high rates of protein catabolism and use of the carbon skeletons for gluconeogensis, dietary requirements for specific amino acids, fatty acids, and both water- and fat-soluble vitamins can be applied with a variety of carnivorous/omnivorous zoo species to determine whether felids or canids may be more suitable models for evaluating nutritional status and dietary adequacy. Despite this wealth of comparative information, actual nutrient requirements are unknown, and physiologic data remain obscure for entire groups of mammalian carnivores (i.e. herpestids, mustelids, generalist insectivores as well as specialists like pangolins and anteaters). Information is even more limited when considering non-mammalian carnivores. Although whole vertebrate prey comprise nutritionally-balanced foodstuffs for a variety of carnivores, there are surprisingly few data on nutrient composition of whole prey, particularly vitamin and micronutrient information (fatty acids, amino acids, trace elements, carotenoids) × all of which may have significant impact on reproductive output, immune function, and overall health. Summarized data that do exist suggest important effects of diet on body composition of whole prey. For example, vitamin A concentrations in free-ranging rodents were found to be significantly and consistently lower (10,000 × 30,000 IU/kg DM) than values measured in laboratory-reared mice and rats of the same body size, likely due to captive diets upon which the feeder animals were raised. The use of domestic carnivore nutrient requirements, developed through controlled experimental studies, provide solid guidelines for development of balanced diets for a variety of exotic carnivores, even given the our current scope of knowledge and limitations.

Key Words: Carnivory, Nutrient Composition, Physiology

635 Comparative Avian Nutrition – Lessons learned from domesticated poultry. E. A. Koutsos*, *Mazuri Exotic Animal Nutrition/PMI Nutrition International LLC*.

There are over 9000 species of birds (more than twice as many as mammals), using virtually every wild type feeding strategy described. Due to limited research in most exotic avian species, captive feeding programs are often designed around the known nutrient requirements of domesticated poultry. Domesticated poultry are generally granivorous, consuming nutrient dense seeds in their native habitats. Their GI anatomy is equipped for such diets (e.g., a well-muscled gizzard), and commercial diets often include similar dietary inputs (e.g., grains from domesticated plant species). Many companion avian species are also granivorous (e.g., many finch species, budgerigar), and domestic poultry requirements may be an excellent starting point for these species. However, many avian species have evolved to eat prey (terrestrial vertebrates, insects, fish and plankton), grasses and other plant components, fruits (from wild rather than domesticated fruit species), nectar and pollen, and other components. For these species, poultry nutrient requirements may not be an adequate starting point for diet development. Further, an understanding of GI and beak morphology is critical to design nutrition programs that meet the requirements of the animal, but also promote consumption, proper GI tract function, ideal excretion properties, and prevents stereotypic behaviors associated with boredom and malnutrition. For example, ratites, which are captively managed in zoos and for production purposes, have significant hindgut fermentation. Thus, these animals have much higher fiber digestion ability than domestic poultry, and as a result, ME values for chickens underestimate the amount of energy that is obtained by growing ratites (Angel, 1993).

Key Words: Avian Nutrition, Comparative

636 Ungulates: Are they cows with long necks? M. S. Edwards*, *California Polytechnic State University*, *San Luis Obispo*.

Ungulates refer to mammal groups that distribute their weight, while moving, over tips of usually hoofed toes. The taxonomic significance of Superorder Ungulata is debatable; however, their shared traits and herbivorous feeding habits allow interesting comparisons. The Orders Perissodactyla (odd-toed ungulates) and Artiodactyla (even-toed ungulates) represent the majority of species with these traits. Although *in situ* work with a species offers insights to its biology, extrapolation to managed environments is often limited. Scientific advances established with domestic ungulates over the past 100 yrs, as well as training professional animal scientists, are a cornerstone of applied nondomestic ungulate management. Comparative nutritionists rely on research of animal scientists and others to support these species programs. A recent example: extrapolation of research on influences of dietary starch fermentation and resulting metabolic changes in dairy cattle. This scientific collaboration led to experimental diets that may address nonclinical, but persistent serum Ca:P below 1:1 ratio in captive giraffe, a physiological measurement inconsistent with observations among free-ranging herds (Koutsos et al., 2007). Opportunities for information transfer are not unidirectional. As modern domestic ungulates demonstrate improved growth and production, the physiological "distance" from their species of origin increases. Nondomestic ungulates, including mouflon, urial, and boar, afford us an opportunity to look back at nutrient requirements and physiology of genetic ancestors and answer questions related to modern breeds. Humans have maintained wildlife species since 2300 B.C., yet significant information gaps exist. Gaps will be filled with experience borne from controlled research and careful documentation of science-based management based on domestic ungulate foundations. Are ungulates cows with long necks? This group's diversity exceeds a simplistic description. Sizes range from a 2.5 kg royal antelope to a 6000 kg African elephant. However, gastrointestinal tract similarities and resulting physiology allow us to compare and contrast species to advance our scientific understanding of all animals.

Key Words: Ungulate, Nondomestic, Nutrition

637 Omnivores – Models of metabolism. J. Williams*, *Indianapolis Zoological Society*, *Indianapolis, IN*.

Plant and animal biomass differs substantially in biochemical composition, with plant material greater in carbon than in nitrogen and phosphorus. Due to the carbon skeleton associated with the structural framework of plant fibers, herbivorous animals typically consume feed resources with greater carbon to nitrogen and carbon to phosphorus ratios than are contained within their own biomass. This makes phos-

phorus and nitrogen the principal growth limiting nutrients associated with herbivorous feeding strategies. Conversely, under a carnivorous feeding strategy animal matter is composed of elemental constituents that are similar to those of the animal that is consuming it. Due to the predator's utilization of organic carbon in physiologic processes such as protein synthesis, energy production and respiration, organic carbon as opposed to other metabolites becomes the limiting nutrient in the diet of the strict carnivore. The term omnivore can best be defined as any animal with the capacity to consume and digest feed resources from more than one ecologic trophic level and this unique ecological niche represents an evolutionary adaptation common to many taxonomic groups. Omnivorous animals are generalists that must possess the ability to not only catch and ingest fellow consumers but also consume and digest primary producers e.g. plant biomass. This feeding strategy enables the omnivore to exploit both the more plentiful but less nutrient dense and less plentiful but more nutrient dense environmental food resources. The factors involved with the development and maintenance of traits enabling omnivorous consumers to exploit food resources from multiple trophic levels will be discussed.

Key Words: Omnivore, Trophic, Feeding