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Isotopic shift in an introduced population of gemsbok (*Oryx gazella*)

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ABSTRACT

We use isotope ratio mass spectrometry to examine the foraging ecology of an introduced population of gemsbok, *Oryx gazella,* in New Mexico, USA. Gemsbok in New Mexico exhibit an isotopic shift in carbon when compared to African gemsbok, suggesting that the introduced gemsbok include more shrubs (C_3 plants) in their diets than do native African gemsbok. New Mexican gemsbok did not differ significantly in isotopic signatures according to gender, maturity, or reproductive status; they did exhibit significant patterns of fractionation in carbon and nitrogen isotopes between-tissue types (bone, muscle, and hair). Stable isotope analysis indicated that C_3 plants (shrubs and forbs) may comprise up to 44% of the diets of gemsbok in New Mexico and that gemsbok diets may vary seasonally. These results are consistent with previously published fecal analyses. Stable isotope analysis appears to be a useful tool for rapid dietary analysis and may help wildlife managers to quickly evaluate the role of diet limitation or expanded diet breadth on the population dynamics of introduced species, and to examine the role of resource competition between native and introduced populations.

1. Introduction

There is much interest in the direct and indirect impacts of introduced species on community composition and stability (Elton, 1958; Simberloff, 1991; Thompson, 1997), on ecosystem structure and function (Ramakrishnan and Vitousek, 1989; Simberloff, 2005), and on endangered native species (Fitzpatrick and Shaffer, 2007; Mack et al., 2000; Pimentel et al., 2005). Much of this interest has focused on introduced mammalian herbivores (Smit et al., 2001; de Vos et al., 1956) and their potential to alter habitats and ecosystems directly through browsing or trampling (Vasquez, 2002), or indirectly by changing plant species diversity (Wardle, 2001), patterns of species interactions (Vasquez and Simberloff, 2003), and nutrient dynamics (Wardle, 2001).

There are two major challenges facing invasion biologists: 1) identifying characteristics of ecosystems that make them susceptible to invasion and characteristics of species that make them successful invaders (Denslow, 2003; Jeschke and Strayer, 2005; Kolar and Lodge, 2001); and 2) the development of predictive models of invasion dynamics that lead to effective management strategies (Davis et al., 2001; Simberloff et al., 2005). Both efforts can be handicapped by a lack of detailed information on basic natural history, such as habitat selection, reproductive biology, physiological tolerances, and parasite and predation pressures (Simberloff, 2003; Simberloff et al., 2005). For introduced mammalian herbivores, detailed information on foraging patterns and diet width may be especially important in developing predictive models and effective management strategies.

The gemsbok (*Oryx gazella*) was introduced to the White Sands Missile Range (hereafter, WSMR), New Mexico in 1969 by the New Mexico Game and Fish Department as part of an exotic game animal introduction program (Saiz and Decker, 1975). When first introduced into New Mexico, gemsbok were expected to utilize lower elevation desert scrub and grassland areas within the designated release sites in the Tularosa Basin (Wood et al., 1970). It is now known that gemsbok occupy various terrain and habitat types ranging from elevations of 1091 m to 2638 m (Burkett et al., 2002). The population currently consists of 3000–5000 individuals (Rodden, pers. comm.) and occupies in excess of 15,000 km^2 in southern New Mexico (Bender et al., 2003). Possible mechanisms for the rapid increase in the New Mexican gemsbok population include predator and parasite release, competitive release, and an expanded diet compared to native populations in southern Africa.

Stable isotope analysis has proven to be an effective technique in diet analysis and in understanding trophic interactions within communities (DeNiro and Epstein, 1978; Hobson et al., 1996; Yarnes and Boecklen, 2006; Yarnes et al., 2005). For example, controlled laboratory and field studies have demonstrated that carbon isotopic signatures in herbivores reflect the proportions of C_3 and C_4 plants in their diets (Cerling and Harris, 1999; DeNiro and Epstein, 1978; Hobson et al., 1996). Here, we use stable isotope analysis of nitrogen and carbon in hair, muscle, and bone collagen to examine the diet of

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gemsbok in New Mexico. We then compare the isotopic signatures of New Mexican and African (published data) gemsbok and demonstrate an isotopic shift for carbon in the introduced population. In addition, we test for differences in isotopic signatures between genders, life stages, and reproductive states (females only) within the New Mexican population. Lastly, we test for fraction between-tissues types (see Martinez del Rio and Wolf, 2005; Tieszen et al., 1983).

2. Materials and methods

2.1. Study area

The White Sands Missile Range encompasses approximately 8800 km^2 and is bounded on the east by the foothills of the Sacramento Mountains and includes parts of the San Andres Mountains, Oscura Mountains, Tularosa Basin and Jornada del Muerto Plain. This research was conducted in Rhodes Canyon in the Tularosa Basin of the WSMR. Physical features include dry lakebeds, canyons, grasslands, sand dunes, lava flows and mountain peaks. The average annual precipitation is 31.3 cm, temperatures range between −23 °C and 44.4 °C, and elevation ranges from 1189 to 2743 m. Vegetation on the WSMR is typical of southwestern semi-desert shrub land and grassland. The northern Chihuahuan Desert ecosystem is characterized by nearly equal annual aboveground net primary productivity in grasslands and shrublands (Muldavin et al., 2008). Aboveground net primary productivity in grasslands tends to peak in summer and fall, while the shrublands tend to peak in spring (Muldavin et al., 2008). Glasslands are composed almost exclusively of C_4 grasses (Cornelius et al., 1991; Muldavin et al., 2008) including various threeawn (*Aristida* spp.), grama (*Bouteloua* spp.), muhly (*Muhlenbergia* spp.), plains bristlegrass (*Setaria macrstachya*), dropseeds (*Sporobulus* spp.), tridens and fluffgrass (*Tridens* spp.), vine mesquite (*Panicum* spp.) and *Hilaria* spp. Forbs are represented by C_3 species, including sunflower (*Conyza coulteri*), pepperweed (*Lepidium* spp.), globemallow (*Sphaeralcea* spp.), and buffalogourd (*Cucurbita foetidissima*); and by C_4 species, including russianthistle (*Salsola kali*) and seepweed (*Suaeda* spp.). Shrublands are dominated by C_3 species, including creosotebush (*Larrea tridentata*), mesquite (*Prosopis* spp.), yucca (*Yucca* spp.), and tamarisk (*Tamarix gallica*). Shrublands also contain C_4 species, including saltbush (*Atriplex* spp.), and CAM species, including pricklypear (*Opuntia engelmannii*) and cholla (*Cylindropuntia* spp.). A list of plants on the WSMR can be found in Saiz and Decker (1975), Fletcher (2000) and Dick-Peddie (1993).

2.2. Sample collection and tissue preparation

A total of 71 animals were sampled throughout the 2006–2007 hunting season (September 16 to March 4). A total of 65 hair samples, 59 bone samples, and 31 muscle samples were acquired. Whenever possible, gender, age class, and reproductive status were documented.

Lipid extractions were performed on all samples of hair, muscle, and bone using a modified version of the procedure outlined by Blight and Dyer (1959). Hair preparation was as follows: several strands of hair from each animal were cleaned by ultra-sonification twice in a 1:2 v/v methanol: chloroform solution for 20 min to remove surface contaminants and sebum lipids. The strands were then rinsed with deionized-distilled water twice for 20 min after each cleaning. The hairs were then allowed to air dry in a fume hood for 48 h. Next, the samples were ground with a mortar and pestle using liquid N and stored in micro-centrifuge tubes. Each sample was weighed on an electronic microbalance to approximately 0.5 μg.

Muscle was prepared for lipid extraction by first freeze-drying samples in plastic tubes for 48 h. One ml of chloroform and 1 ml of methanol were then added, vortexed for 30 s after which, another 1 ml of chloroform was added. The sample was vortexed again for 10 s and then sonicated for 20 min. One ml of deionized water was then added, vortexed for an additional 10 s and then sonicated for 20 s. This procedure was performed twice to assure the removal of all lipids. The samples were dried under a fume hood for 48 h. The lipid free muscle samples were ground to a fine powder using a mortar and pestle, and approximately 0.5 μg of each sample were placed into foil capsules and stored in a desiccator.

Powdered bone samples were acquired by drilling a portion of the leg bone. The area chosen for sampling was cleaned by first removing all skin and muscle attached to the bone and then "polishing" the area with a diamond-abrasive spear-shaped rotary tool (Gilles St-Jean, pers. comm.). Several layers of bone were removed using a 1.2 mm diamond-tipped rotary tool; approximately 2–3 g of powdered bone was collected. To begin the analysis of bone collagen, it is imperative to remove all traces of lipids in the bone since lipids will interfere with the C/N ratio of the bone collagen (Copley et al., 2004; O'Connel and Hedges, 2001; Post et al., 2007). To begin lipid extraction, approximately 2 g of the bone sample was placed into plastic tubes. The procedure follows the same method as for the muscle samples except that 2 ml of chloroform, methanol and water were used instead of 1 ml and the procedure was only performed once.

Collagen extraction followed the procedure outlined by Copley et al. (2004). Approximately 0.2 g of powdered bone samples was demineralized in plastic tubes, with 10 ml of 0.5 M HCl for 24 h at room temperature. The samples were agitated three times during this period. They were then rinsed twice with 10 ml of deionized water and centrifuged between washes to minimize sample loss. Next, the residues were gelatinized in 10 ml of 0.001 M HCl at 75 °C for 48 h and then freeze dried. After the completion of both lipid and collagen extractions approximately 0.5 μg of sample was loaded into foil capsules and stored in a desiccator.

2.3. Stable isotope analysis

All isotopic analyses of samples were performed in the Laboratory for Ecological Chemistry (LEC) at New Mexico State University. Samples were combusted using a Costech Analytical Elemental Analyzer (Valencia, CA) and introduced to a ThermoFinnigan DeltaPlus XP Isotopic Ratio Mass Spectrometer (Waltham, MA) in continuous-flow through a ConFlo III Interface. Results are described in delta (δ) notation in measures of "per mil" (‰) or per parts per thousand. Results are reported as the difference between the isotopic ratio of the sample and appropriate international standards: "VPDB" (Vienna Pee Dee Belemnite, a carbonate rock) for ^{13}C and "Air" (atmospheric nitrogen) for ^{15}N. The results are then standardized using the following formula:

$$\delta^{13}\mathrm{C} \text{ or } \delta^{15}\mathrm{N} = \left[\left(R_{\mathrm{sample}} - R_{\mathrm{standard}}\right) \Big/ R_{\mathrm{standard}}\right] \times 1000,$$

where $R = {}^{13}\mathrm{C}/{}^{12}\mathrm{C}$ or ${}^{15}\mathrm{N}/{}^{14}\mathrm{N}$. All analyses are traceable to the NIST (National Institute of Standards and Technology, Washington, DC) isotopic standard reference materials IAEA-N1, IAEA-N2, USGS24, USGS32 and NBS-19.

2.4. Statistical analyses

Isotopic differences in carbon and nitrogen between African and New Mexican gemsbok were analyzed using one-sample *t*-tests, where the null hypotheses were constructed using published mean delta values for the African population: −9.5‰ for bone δ^{13}C