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Inbreeding depression on reproductive performance and survival in captive gazelles of great conservation value

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Abstract

Here I present a detailed analysis of individual inbreeding coefficient effects on some reproductive parameters and longevity in three species of gazelles under different conservation status: vulnerable dorcas gazelle, endangered Cuvier's gazelle, and extinct in the wild mhorr gazelle. The novelty of this study stems from the inclusion of both males and females in analyses including a large database of information collected during two decades of periodical studbook inventories for these species. Translocations to different zoo locations of the extinct subspecies mhorr gazelle do not apparently affect reproductive performance (population sex ratio) or individual longevity. In agreement with previous works, the average inbreeding coefficients vary inter-specifically, being higher in Cuvier's, followed by mhorr and dorcas gazelles. This reflects the different population size of the founding individuals of each species' captive population. Sexual maturity and age at first birth follow an allometric pattern, occurring at an earlier age in the smallest species (dorcas), followed by Cuvier's and then the mhorr gazelle. Twinning in Cuvier's gazelle depends on maternal experience, as it is less frequent in primiparous females. Inbreeding affects neither twinning nor sex ratio. Mhorr gazelles' studbook shows several causes of death and it emerges that a higher proportion of non-inbred females die due to pathologies than males, although both sexes show similar proportion of mortal pathologies when inbred. Multifactor ANOVA shows that longevity decreases with inbreeding level and that females live longer than males in the three species of gazelles studied, as expected in polygynous mammals. Mhorr and dorcas non-inbred females show higher juvenile survival than males, whereas inbred individuals show a similar declining juvenile survival, particularly in mhorr and Cuvier's gazelles. Finally, it is discussed the apparent inbreeding tolerance in Cuvier's species, and the great value keeping and studying long term data of well-monitored captive populations may prove to the conservation of threatened species.

Keywords: Captive populations; Inbreeding depression; Longevity; Sexual maturity; Ungulates

1. Introduction

Zoological institutions make huge efforts in keeping and breeding endangered species, with a view to preserve them from extinction and, ideally, to reintroduce them back in their natural habitats (Cade, 1988; Rahbeck, 1993; Snyder et al., 1996; Komers and Curman, 2000). One of the main problems that captive breeding programs have to face is the denominated founder effect, i.e., deleterious effects on the captive population derived from few founder individuals and the consequent loss of genetic diversity (see Gompper et al., 1997). Population genetic theory predicts that, in the absence of mutation and migration, small, isolated (captive) populations will lose variation over time as a result of their limited size, loss rate depending on the effective population size (N_e) and the number of generations the population is

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isolated (Frankel and Soulé, 1981; Frankham, 1995a). Therefore, institutions that undergo captive-breeding programs try to maximize population heterozygosity by carefully selecting breeding individuals according to their genetic variability, so that the presence of individuals homozygous for deleterious alleles is minimized (Foose and Ballou, 1988).

Inbreeding depression is the decline in the value of a trait as a consequence of inbreeding (Wright, 1977). Traits more commonly considered are those related to individual fitness, such as reproductive parameters or survival rate. Principally in captivity, there is a fairly large amount of research showing that inbreeding reduces fitness in animal populations (e.g., Ballou and Ralls, 1982; Charlesworth and Charlesworth, 1987; Thornhill, 1993). It has not been until recently, however, that studies carried out in the wild have shown a relationship between inbreeding and fitness (e.g. van Noordwijk and Scharloo, 1981; Keller, 1998; Slate et al., 2000; see revision in Keller and Waller, 2002), and even an increase of extinction risk (Saccheri et al., 1998; Brook et al., 2002; Reed et al., 2003). Now we might put to rest the hot debate on genetic variability and its relationship to wild populations viability (e.g. Mills and Smouse, 1994; Frankham, 1995b,c). Indeed it has been postulated that inbreeding depression may be higher under stressful and harsh conditions in the wild (Crnokrak and Roff, 1999; Reed et al., 2002).

In order to undergo a proper management and detailed analyses on the effects of genetic variability on individual fitness, knowledge of the inbreeding coefficient F (Ballou, 1983) is essential (see Falconer and MacKay, 1996). Empirical evidence has shown that one of the main deleterious effects of high inbreeding coefficients is the reduction of adults fertility and offspring survival (e.g., Ralls et al., 1979; Ballou and Ralls, 1982; Hass, 1989; Stockley et al., 1993), in some ungulate species through the decrease of birth weight (e.g. MacNeil et al., 1989; Alados and Escós, 1991; Cassinello, 1997).

Here long-term data on captive populations of dorcas gazelle (*Gazella dorcas neglecta* Lavauden, 1926), Cuvier's gazelle (*G. cuvieri* Ogilby 1841) and mhorr gazelle (*G. dama mhorr* Bennet 1833) living at the Estación Experimental de Zonas Áridas (EEZA), in Almería (Spain), were analysed from their published studbook files (Cano, 1991; Abaigar, 1993; Escós, 1992, respectively). *G. dorcas* is considered as Vulnerable (A1a), and Cuvier's gazelle Endangered (C2a) (IUCN, 2002). Mhorr gazelles are believed to be extinct in the wild since 1968, and only exists as captive/reintroduced populations (Abaigar et al., 1997; Cassinello and Pieters, 2000), whereas the species, *G. dama*, is categorized as Endangered (A1c, C1) by the IUCN (2002). Unfortunately, to the best of my knowledge, no information is available from wild populations of the study species, nor from other captive ones, that might allow inter-population comparative analyses, as well as, defining life-history traits in the wild.

Even though the three study gazelle populations have already been subject to a series of studies, including, e.g., factors determining reproductive success in females (Alados and Escós, 1991), effects of inbreeding on ejaculate traits (Cassinello et al., 1998; Gomendio et al., 2000) and sex ratio variation in Cuvier's females (Alados and Escós, 1994), because only a small fraction of these populations has been included, to date, the power of the statistical tests carried out is likely to be low. The objective of this study is to analyse in detail the relationship between individual inbreeding coefficient and some key reproductive parameters as well as longevity, using the most complete database available from published sources, which corresponds to the whole captive populations of the study species at the time of publication (see below).

2. Materials and methods

2.1. The study populations

The study population contains all individuals born at the EEZA according to their published studbooks (Cano, 1991; Escós, 1992; Abaigar, 1993) plus others obtained from EEZA staff: 383:369 dorcas, 207:206 Cuvier's and 253:254 mhorr gazelles. The founder population of each species consisted in 11:13 dorcas, 3:9 mhorr and 2:2 Cuvier's gazelles, which has led to quite dissimilar average inbreeding coefficients between them due to differing effective population sizes (see Section 3).

Animals of the three species are kept in four different types of enclosures, mediated by their innate territorial behaviour:

(1) All-male groups: they are single, with no mating experience. Usually made up of no more than five individuals, except dorcas gazelle, which may be kept as relatively large groups due to their small size.
(2) Reproductive groups: made up of females with infants and an adult male.
(3) Isolated males: males who have been kept in reproductive groups are usually placed isolated afterwards, because they tend to be too aggressive if kept with other single males. Also, if a non-experienced male is potentially valuable to be used as a reproductive male, he is usually kept alone, in order to prevent fatal accidents with other males. Two one-male cages of the same species are never placed contiguously, to prevent expected agonistic behaviours.
(4) All-female groups with infants: formerly reproductive groups from which, to control population growth, the adult male has been removed.