

Status Survey and Conservation Action Plan

Equids: Zebras, Asses and Horses

Edited by Patricia D. Moehlman



IUCN/SSC Equid Specialist Group

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**IUCN – The World Conservation Union
2002**

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Foreword

Horses, asses, and zebras have captured human hearts with their speed, grace, and beauty from the time our ancestors first drew art on cave walls. Yet most species in the equid family are at risk of extinction today, primarily due to human activities. Moreover, despite our admiration of equids and familiarity with domestic breeds, we know surprisingly little about the basic behavior and ecology of a number of wild species. Because equids tend to live in harsh, dry lands shared by nomadic peoples, the conservation of the animals and the survival of these traditional peoples are intertwined and pose complex questions for conservation practice.

This new Action Plan for the conservation of equids is an urgently needed response to the problem of creating effective conservation strategies in equid habitats. Its value has been greatly enhanced because its authors are grounded in the realities of local socio-economic circumstances as well as cognisant of the scientific basis needed for the protection and management of species. The authors have created a clear and concise document that brings together the full range of what is known about the

conservation status and biology of each of the seven species of horses, asses, and zebras in Asia and Africa. It is a blueprint for further research to fill important gaps in knowledge, and it is also a document wildlife managers can use to create optimum strategies for conservation, given the state of current knowledge of equid biology and ecology and small population management.

Now that the Equid Action Plan has been published, it is up to local conservationists to use it to create local equid preservation strategies and to use equid conservation as a rallying point for protection of the delicate dryland ecosystems that form their habitats. It is now the responsibility of the international conservation and philanthropic communities to ensure that resources are applied to realise recommended actions. In particular, those whose lives have been enriched by a love of equids need to realise that there has never been a more important time to act to prevent the extinction of this magnificent family of wildlife.

Mary Pearl, Executive Director, Wildlife Trust

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Parks, and the Ministry of Environment and Tourism of Namibia, as well as the owners and managers of other reserves and game ranches who over the years have patiently answered our requests for updated information. M. Lindeque thanks the CITES Management Authority of Switzerland, the Namibia Nature Foundation, and Total Namibia for assistance.

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The Wildlife Trust and Pamela Thye and her family have provided critical assistance to the Equid Specialist Group since 1997. Without their support, the Equid Specialist Group would not have been able to form the partnerships that have provided training, research, and conservation action for wild equids in their native habitats.

Executive Summary

The new Equid Action Plan provides summaries of the conservation status, biology, and ecology of wild zebras, asses, and horses. During the Pleistocene, equids were the most abundant, medium-sized grazing animals of the grasslands and steppes of Africa, Asia, and the Americas. Today there remain only seven species and many of these species are at risk.

In Africa, the African wild ass (*Equus africanus*) is Critically Endangered (CR), the Grévy's zebra (*Equus grevyi*) and the mountain zebra (*Equus zebra*) are Endangered (EN), and the plains zebra (*Equus burchellii*) is dependent on conservation support (LRcd). In Asia, the Asiatic wild ass (*Equus hemionus*) is Vulnerable (VU) and half of the extant subspecies are Critically Endangered (CR). The kiang (*Equus kiang*) is considered at Lower Risk (LR), but data are inadequate for the assessment of the status of two of the three subspecies (DD). The Przewalski's horse (*Equus ferus przewalski*), or Takhi, exists in captivity, but is extinct in the wild (EW). Successful reintroduction projects for the Takhi are occurring in Mongolia and China.

The 2002 *Red List of Threatened Species: Equids* can be found in Appendix 1. Assessments were made in 1996 using 1994 Categories and Criteria (version 2.3) and in 2001 using the 2001 Red List Categories and Criteria (version 3.1). Version 3.1 is available in Appendix 2.

The majority of species in this small family are endangered or vulnerable. Most of the endangered equids live in desert ecosystems. These habitats are not rich in species, but do contain unique and endemic animals and plants. Zebras, asses, and horses can serve as 'flagship' species for the conservation of desert ecosystems and their biodiversity. Equids persist in some of the harshest climates and terrains in the world. These arid habitats are also home to human populations that are also at risk from climatic extremes. Conservation of wildlife will be closely linked to local nomadic pastoralists being able to participate in, and benefit from, the conservation management of their areas.

The Action Plan presents the current state of knowledge for all seven species, specifying what information is lacking,

and prioritising conservation action. For all the zebras, asses, and horses better information is needed on 1) national and local population status and trends, 2) genetic definition of subspecies, 3) genetic viability of isolated and reintroduced populations, 4) behavioral ecology, resource requirements, disease epidemiology, and demography, 5) risk assessment of geographically distinct populations, and 6) socio-economics and viability of alternative conservation/utilisation strategies.

The Action Plan also provides chapters on equid taxonomy, genetics, reproductive biology, and population dynamics. These chapters highlight unsolved issues of taxonomy and genetics. They also provide information and insight into the special demographic and genetic challenges of managing small populations. The chapter on disease provides a review of documented equid disease and epidemiology and focuses on priorities for equid conservation health. The final chapter deals with the importance of developing an assessment methodology that explicitly considers the role of equids in ecosystems and the ecological processes that are necessary for ecosystem viability. The chapter describes how a spatial ecosystem model can be used to assess a wild horse population and its habitat, and it demonstrates how such an approach could be used for equid conservation and used to assess the effects of different equid population sizes and climate scenarios on population dynamics and ecosystem health. The approach of combining ecological field studies and ecosystem modelling should prove useful for the scientific management and conservation of wild equids worldwide. These chapters provide research and conservation practitioners with new information and paradigms.

The plan provides recommendations for action that we hope will assist researchers, management authorities, government agencies, donor organisations, and local resource users to prioritise and activate conservation on threatened and endangered equids in their native habitats.

Patricia D. Moehlman,
Chair, IUCN/SSC Equid Specialist Group

PART 1

Species Status and Conservation Action Plans: Africa

Status and Action Plan for the African Wild Ass (*Equus africanus*)

Patricia D. Moehlman

1.1 Nomenclature and conservation status

Scientific name:

Equus africanus Heuglin and Fitzinger 1866

Equus africanus africanus Heuglin and Fitzinger 1866

Equus africanus somaliensis Noack 1884

Important synonyms: *Equus asinus*

Common names:

African wild ass, Somali wild ass, Abyssinian wild ass, Nubian wild ass

Indigenous names:

Dabokali (Afar), Adghi Bareka (Tigrinia), Eritrea
Gumburiga (Issa), Dibakoli (Afar), Ethiopia, Gumburiga,
Gumburi, Somalia

IUCN Red List Category (version 2.3):

Equus africanus **CR A1b** Critically Endangered

E. a. africanus **CR A1b** Critically Endangered

E. a. somaliensis **CR A1b** Critically Endangered

CITES Listing:

Equus africanus Appendix I

E. a. africanus

E. a. somaliensis

1.2 Biological data

1.2.1 Distribution

During the Pleistocene, the African wild ass may have existed in Israel and Syria. Historically, there were three recognised subspecies. The Atlas wild ass, *Equus africanus atlanticus*, was found in the Atlas region of north-western Algeria, and adjacent parts of Morocco and Tunisia. It survived in this area until about 300 AD (Antonius 1938). In recent times, there have been reports of wild asses in northern Chad and the Hoggar Massif of the central Sahara, but it is in doubt as to whether these are true wild asses.

The Nubian wild ass, *Equus africanus africanus*, lived in the Nubian desert of north-eastern Sudan, from east of the Nile River to the shores of the Red Sea, and south to



The African wild ass (*Equus africanus*).

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the Atbara River and into northern Eritrea. During aerial flights in the 1970s, wild asses were seen in the Barka Valley of Eritrea and in the border area between Eritrea and the Sudan (Watson 1982).

The Somali wild ass, *Equus africanus somaliensis*, was found in the Denkelia region of Eritrea, the Danakil Desert and the Awash River Valley in the Afar region of north-eastern Ethiopia, western Djibouti, and into the Ogaden of eastern Ethiopia. In Somalia, they ranged from Meit and Erigavo in the north to the Nugaal Valley, and as far south as the Shebele River (Ansell 1971; Klingel 1980; Moehlman 1989). The most comprehensive review of the historical literature concerning African wild ass distribution is in Yalden *et al.*'s *Catalogue of the Mammals of Ethiopia* (1986). There is disagreement in the scientific literature as to whether the African wild ass is one continuously distributed species or if there are valid subspecies (Ansell 1971; Groves and Willoughby 1981; Ziccardi 1970; Yalden *et al.* 1986). According to Watson (1982), there is a semi-continuous population extending from northern Somalia into Ethiopia and, possibly, through Eritrea and into the Sudan. A matter of perhaps greater concern is the genetic integrity of the wild stock, e.g. determining if wild populations are interbreeding with domestic donkeys (*Equus africanus 'familiaris'*, Gentry *et al.* 1996).

1.2.2 Population estimates and trends

Somalia

Between 1978 and 1980, Watson (1982) conducted aerial surveys in northern Somalia and estimated a population of 4,000–6,000 wild asses in the area from the Nugaal Valley to the Djibouti border. Given the area covered by the survey, this would indicate approximately six wild asses per 100km². Between 1979 and 1982, Simonetta and Simonetta (1983) estimated about 250 wild asses in the north-western Nugaal Valley and about 50 wild asses near Meit, with scattered groups occurring along the coast in the Erigavo region. In 1989, a ground survey with limited aerial reconnaissance in the Nugaal Valley yielded population estimates of roughly 135 to 205 wild asses or approximately 2.7 to 4.1 asses per 100km² (Moehlman 1998). This indicates, perhaps, a 50% reduction in the wild ass population during the decade between those surveys. In 1997, Moehlman returned to the Nugaal Valley, but was not able to survey the entire area. Local pastoralists, however, said that there were less than ten African wild asses left in the Nugaal Valley.

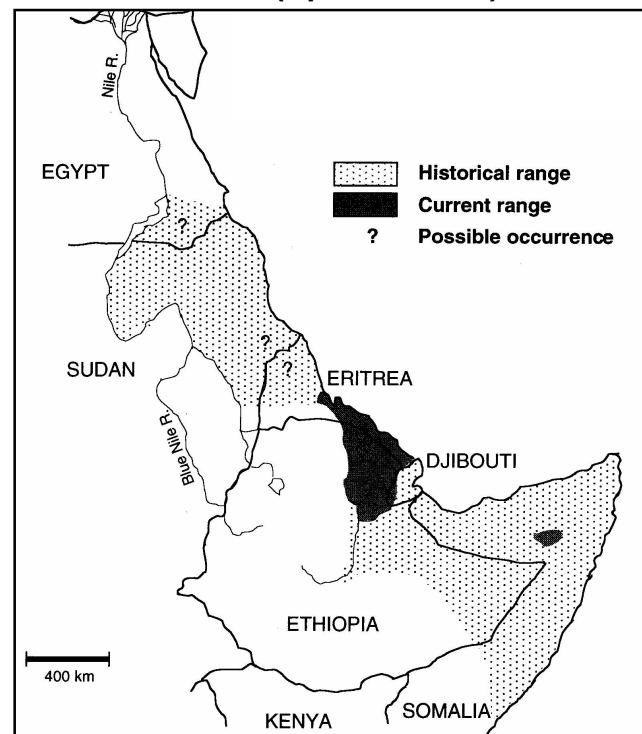
Ethiopia

During 1970 and 1971, Klingel and Watson conducted an aerial survey of the Teo area (5,280km²), the Tendaho-Serdo area (4,270km²), and the Lake Abbe area (6,550km²). Klingel (1972) estimated a total of 3,000 wild asses or 18.6

per 100km². The Teo area, which is now part of the Yangudi-Rassa National Park, had the highest density with 30 wild asses per 100km². In May/June 1972, the Catskill Game Farm captured 12 wild asses in the valleys to the north-west of Serdo. During the eight-day period, a total of four more wild asses were captured and released, and an additional 37 wild asses were observed. This is within an area of approximately 350km². Thus, there were approximately 15 African wild asses per 100km². In 1976, Stephenson (1976) carried out an aerial survey in an area similar to Klingel's Teo area and in an area of 3,990km² had an estimated wild ass density of 21.0 per 100km². In July/August 1995, Thouless (1995) conducted aerial surveys of the Yagudi-Rassa National Park (Teo area) and the adjoining wildlife reserves, and observed no African wild asses.

Starting in January 1994, Moehlman and Kebede conducted surveys of the Yangudi-Rassa National Park and the Mille-Serdo Wild Ass Reserve (Moehlman 1994a, 1994b; Kebede 1994, 1995; Kebede and Ayele 1994). Issa nomads were utilising the Yangudi-Rassa National Park and, in some areas, their herds of sheep and goats were in excess of 50 per km² (Thouless 1995). No wild asses were seen and oral reports from local inhabitants indicated that wild asses were rare and probably existed at a density of well below one per 100km². Thus, in an area where Klingel and Stephenson had observed approximately 20–30 wild asses per km² in the 1970s, 20 years later the population exists at a critically low level.

Figure 1.1. Historic and current distribution of the African wild ass (*Equus africanus*).



In the Mille-Serdo area, Moehlman and Kebede surveyed the area to the north-west and to the south of Serdo (2,000km²). In areas where Klingel and the Catskill Game Farm personnel had observed 15 to 18.6 wild asses per 100km², and Klingel (1977) had observed temporary groups of 43 and 49 individuals, Moehlman and Kebede (1994–1996) could find a total of only ten wild asses. The largest group observed between 1994 and 1996 had six individuals.

Similar to previous observations (Klingel 1977), a solitary male occupied a consistent territory. Small, temporary groups were composed of females and their offspring, and occasionally an adult male. At present, observations indicate that mother and offspring comprise the only stable groups. This is the only area in Ethiopia where it has been possible to consistently see African wild asses, but they are very low in density, and it requires days of walking the volcanic mountains to see these very wild and shy animals. Even if as many as one African wild ass per 100km² exists throughout the species' former range (16,000km²), the population in Ethiopia probably numbers less than 160 individuals. Since most local pastoralists carry automatic rifles, wildlife continues to be at risk of (over) exploitation (Moehlman *et al.* 1998).

Eritrea

Due to Eritrea's 30-year war for independence, there are no long-term data on African wild ass populations. However, recent surveys indicate that viable populations exist in the area between the Buri Peninsula and the Denkelia Depression (Moehlman *et al.* 1998). In 1998, the team of Moehlman, Yohannes, Hagos, Woldu, and local Afar pastoralist, Saleh Mohamed Abdullah, went by foot

and camel to the Messir Plateau. In an area of approximately 50km², they were able to identify individuals and determine a population density of roughly 47 African wild asses per 100km². This is the highest population density found anywhere in the present range of the species and is similar to population densities recorded in Ethiopia in the early 1970s. Currently, the African wild ass density in other locales is less than one individual per 100km². The Messir Plateau is part of the Asaila Mountains, a range that covers approximately 800km². A potentially viable population of approximately 400 African wild asses may extend through the Danakil Depression to Ethiopia. Given the absence of guns among rural people and the conservation ethic among local Afar pastoralists, the African wild ass has good potential for recovery in Eritrea.

1.3 Behavioural ecology

The African wild ass in the deserts of Eritrea and Ethiopia live in temporary groups that are small and typically composed of fewer than five individuals. The only stable groups are composed of a female and her offspring. In temporary groups, the sex and age-group structure varies from single-sex adult groups to mixed groups of males and females of all ages. Adult males are frequently solitary, but also associate with other males. Adult females usually associate with their foal and/or yearling. Some adult males are territorial and only territorial males have been observed copulating with estrous females. Thus, the African wild ass exhibits the social organisation typical of equids that live in arid habitats (Klingel 1977; Moehlman 1998).

Table 1.1. *Equus africanus somaliensis* population estimates.

Location	Year	Year	Year	Comments	Trend
Somalia					
Nugaal Valley	1982 : 250 Simonetta and Simonetta (1983)	1989 : 100 Moehlman (1989)	1997 : 10 Moehlman (1998)	1982: Ground survey 1989: Ground and aerial 1997: Ground survey and interview	Decreasing
Ethiopia					
Yangudi Rasa	1971 : 1,584 5,280km ² Klingel (1972)	1976 : 838 3,990km ² Stephenson (1976) 21/100km ²	1995 : 0 2,800km ² Thouless (1995)	1971: Aerial survey 1976: Aerial survey 1995: Aerial survey	Decreasing
density =	30/100km ²		0/100km ²		
Mille Serdo	1971 : 794 4,270km ² Klingel (1972)	1972 : 53 350km ² Moehlman <i>et al.</i> (1998)	1994–98 : < 20 2,000km ² Moehlman <i>et al.</i> (1998)	1971: Ground survey 1972: Ground survey 1998: Ground survey	Decreasing
density =	18.6/100km ²	15/100km ²	<1/100km ²		
Eritrea			1997–2000 Moehlman and Yohannes	1997–2000 Ground survey	Stable
density =			~40/100km ²	50km ²	

In feral asses, the age of first estrus is about 12 months. With a 330 to 365-day gestation period, a female could potentially have her first foal at two to two and a half years of age (Kenneth 1953). However, in the south-western United States, feral asses typically have their first foal at three and a half to four years of age (Moehlman 1974). Estrous cycles have been described for *Equus ferus* (horse) as being 20 to 21 days, with estrus lasting five and a half days and ovulation occurring 24 to 28 hours before the end of estrus (Hughes *et al.* 1972). Postpartum estrus could occur from seven to nine days after the birth of a foal. Age of first estrus has not been documented in free-living African wild asses, but age of puberty may be similar to that of their domestic descendants. In Eritrea, African wild ass females are polyestrous and natality occurs from October to February.

In Eritrea and Ethiopia, limited observations indicate that African wild asses are primarily grazers (Moehlman *et al.* 1998; Kebede 1999). The only stable groups are composed of a female and her offspring. Females do associate with other females or with males, but even temporary groups are small. Low density and low sociability may be due to low forage quality and availability (Jarman 1974). Ginsberg (1988) found that Grévy's zebra group size correlated with food density and, at biomass levels below 40g/m², there was only food sufficient for a female and her foal. He also documented that during a drought period when the mean biomass levels were just above 40g/m², the normally stable plains zebra harem and bachelor groups became unstable. Such data strongly suggest that the stability and size of groups reflect the distribution and availability of food.

Research on feral asses has documented that they are physiologically well adapted to life in arid habitats. They can sustain a water loss of up to 30% of their body weight and can drink enough water in two to five minutes to restore fluid loss (Maloiy 1970; Maloiy and Boarer 1971). Tomkiewicz (1979), using temperature sensitive implants, determined that feral asses varied their body temperature from 35.0 to 41.5°C, depending on air temperature. In hot summer months, males had lower mean body temperatures (36.5°C) than females (38.2°C). Females maintained higher body temperatures and presumably lost less water due to sweating. A two degree increase in body temperature could provide a two percent daily water savings in a hydrated 150kg feral ass. Tomkiewicz also found that the biological half-life of water for females was one day longer than for males, indicating that their water use was more efficient. Such information indicates that the ancestral species, the African wild ass, is physiologically very well adapted to life in the deserts of Eritrea, Ethiopia, and Somalia. However, the African wild ass still needs access to surface water and the movements of lactating females are constrained by water availability. During aerial surveys in the Danakil Desert of Ethiopia (12,000km, Stephenson

1976), most African wild asses were observed within 30km of known water sources.

Individuals will form groups when benefits exceed costs in terms of feeding, predation, disease, and reproduction (Alexander 1974). The density, continuity of distribution, and biomass of forage are key factors in the stability of association and the spacing of equids (Duncan 1983; Rubenstein 1986, 1994; Ginsberg 1988). However, review of the literature indicates that water distribution and predation pressure are also important factors. When forage and water availability allow females to be gregarious and form stable groups, then a male can attempt to control access to these females. Amongst equids, these female groups form strong bonds and, if a male is removed (Hartmann's mountain zebra: Joubert 1972; horses: Imanishi 1950, Tyler 1972) or displaced (plains zebra: Klingel 1967, 1972), the females often maintain a stable group. Age and fighting ability and the adult sex ratio can also affect a harem male's success in defending his female group against bachelor males. Among equid populations that have a harem mating system (female-defence polygyny), the following have been observed: 1) multi-male harem groups in which all males defend the females and the dominant male achieves the most copulations (feral horses: Keiper 1976, Green and Green 1977, Miller and Denniston 1979, Feist 1971, Nelson 1979; feral asses: Moehlman 1979, McCort 1980), 2) harem males that form alliances and cooperatively defend their harems (plains zebras: Rubenstein 1986), and 3) populations in which adult male sex ratio is significantly low and single-male harems encounter less intrusion/harassment from bachelor males (feral horses: Rubenstein 1986). Harassment involving chases and copulations can negatively affect a female's feeding rate and may even result in abortion (Berger 1986) or involve infanticide (Duncan 1982).

A prerequisite for the 'cost-effective' viability of 'female-defence' polygyny (stable family or harem groups) is a spatial and temporal patterning of resource availability such that it is possible for females to feed in close proximity (Emlen and Oring 1977). In more mesic habitats, forage for ungulates tends to be more abundant with a more continuous distribution. Jarman (1974) reviewed antelope feeding ecology and social organisation and found that group size correlated strongly with food availability and feeding strategy. Large stable groups were more likely to form when one individual's foraging did not adversely affect conspecifics' foraging. Consequently, closer spacing and larger aggregations were possible when food was abundant. Conversely, food shortages would tend to limit group size and stability.

Predation pressure on large mammals, like equids, should increase the tendency to form groups in order to improve detection of and/or defence against predators. The potential for polygyny among equids is further enhanced because 1) females are able to provide nutritional

care for their young, and 2) females do not come into estrus synchronously, which enables a male to mate with several females. Thus, in a mesic habitat, a male can control access to multiple females by virtue of their gregariousness and their non-synchronous estrus. From the female point of view, abundant food allows closer spacing with other females and gregariousness enhances predator detection. In addition, the presence of a dominant male precludes harassment by other males in the population.

By contrast, in more arid environments, limited food availability (both spatially and temporally) usually does not permit females to forage in close proximity and/or to be associated consistently. In dry habitats, equids exhibit the same nutritional and reproductive characteristics (e.g. females provide nutrition and females tend to come into estrus asynchronously), which allow males to attempt multiple matings, but 'indirectly' control access to the females. In most cases, they actually control access to a critical resource, i.e. water. In these territorial mating systems, the only stable social group is a female and her offspring (Klingel 1972, 1974, 1977; Moehlman 1974, 1979; Woodward 1979; Ginsberg 1988, 1989; Becker and Ginsberg 1990; Rowen 1992).

Male feral asses in Death Valley National Monument (Moehlman 1974, 1979) and Grévy's zebra (Ginsberg 1988, 1989) hold territories adjacent to localised water sources. Females must pass through these territories to drink. Furthermore, females with young foals (<1.5 months of age) are water stressed, drink three times as often as other adults in the population, and tend to stay within one kilometre of water (Moehlman 1974). Feral ass females will come into estrus seven to nine days after parturition. If they are not fertilised during their post-partum estrus, then they will come into estrus again in 28 to 30 days. Thus, females with newborn foals will spend the first one and a half months on a territory near water and potentially will come into estrus twice during this time period. On these territories, they will have improved access to water, reduced harassment from bachelor males and interference with feeding, and potentially better anti-predator protection. Territorial males gain access to multiple matings by controlling the resources that females require a 'resource-defence' strategy (Emlen and Oring 1977).

Information is needed on the reproductive biology and population dynamics of the extant populations of African wild ass in the Afar region of Ethiopia, the Denkalia Desert of Eritrea, and the Nugaal Valley of the Somali Democratic Republic. Data are limited, but indicate that female wild asses have their first foal at age three to four years and will typically have a surviving foal every other year. In terms of population dynamics, this means that African wild asses are particularly sensitive to predation. Computer simulations for equids indicate that if all females

four years and older regularly produced foals, the survival rate would have to be 70% for foals and 85% for adults to enable the population to increase at a rate of four percent per year. This would allow the population to double in 18 years (Wolfe 1980). If mortality is high, due either to hunting and/or drought, the population will decline and it may be difficult or impossible for it to recover.

1.4 Actual and potential threats

The major threats to the survival of the African wild ass are 1) hunting for food and medicinal purposes, 2) potential competition with livestock for vegetation and water, and 3) possible interbreeding with the domestic donkey.

Research by Kebede (1999) in Ethiopia revealed that 72% of 65 adult male Afar pastoralists had killed African wild asses for food and/or medicine because they could not afford to buy medicine or they were too far from medical facilities. In Somalia, local pastoralists kill African wild ass for food and/or medicine. In interviews, they said that body parts and soup made from bones were good for curing tuberculosis, constipation, rheumatism, backache, and boneache. They feed the soup to their livestock to alleviate mineral deficiencies. When guns and bullets were rare and expensive it was difficult to shoot the wild ass. Currently, Kalashnikov automatic rifles are easy to obtain and bullets are cheap. Several elders said that the killing of the wild ass was the work of a few people (Moehlman *et al.* 1998). In Eritrea, the Afar pastoralists do not shoot wildlife and guns are strictly controlled.

African wild asses live in arid habitats where grass occurs in widely dispersed patches of low biomass. Competition between females for forage may limit their ability to form long-term associations. The only stable unit is mother and offspring. Access to water is critical and lactating females need to drink every day. The African wild ass has a resource-defence polygyny mating system in which males defend mating territories that contain the resources that females require (Klingel 1972, 1977; Moehlman 1974, 1979, 1998). Typically, these critical resources are water and forage. During aerial surveys in Ethiopia in the 1970s, African wild asses were always observed within 20 to 30km of known water sources (Stephenson 1976). Data on movement patterns and feeding ecology would provide information on how the African wild ass are utilising resources in areas that are also needed by pastoralists and their herds of camel, sheep, and goats.

If African wild ass are protected (i.e. not killed for meat or medicine), then the major remaining threat is access to water and sufficient forage. Reproductive females and their less than three-month old foals are most at risk. Hence it is important to determine critical water supplies and basic forage requirements, thus allowing management

authorities to determine in consultation with local pastoralists how to conserve the African wild ass. In Eritrea, Ethiopia, and Somalia, all elders were concerned that the African wild ass be protected and conserved. Chapter 13 highlights the information needed for a complete and appropriate ecosystem analysis.

1.5 Current legal protection

Ethiopia: Wildlife laws (Negarit Gazeta No.7 1972) categorise the African wild ass under Schedule 6, Specially Protected Animals and Birds. This legal status means that the African wild ass cannot be hunted and/or killed, and there are no exceptions and/or special permits. The Yangudi-Rassa National Park (4,731km²) and the Mille-Serdo Wild Ass Reserve (8,766km²) were established in 1969 (Hillman 1993). However, the Yangudi-Rassa National Park has never been gazetted, and both areas are utilised by large numbers of pastoralists and their livestock. These areas are remote and extremely arid, and the Ethiopian Wildlife Conservation Organisation (EWCO) has not had sufficient funds or personnel for appropriate management (Kebede 1999). Ethiopia is a signatory to CITES.

Eritrea: Eritrea, as a new nation, is currently writing its environmental laws. The African wild ass has protected status and cannot be hunted and/or killed, but, to date, there is no formal legal protection. In 1995, during their first International Conference on the Environmental Management Plan for Eritrea (NEMP-E), the Government of Eritrea designated the African wild ass area between the Buri Peninsula and the Dalool Depression as a high-priority area for conservation protection as a nature reserve (Government of Eritrea 1995). Eritrea is a signatory to CITES.

Somalia: The African wild ass presently may occur in the Puntland, Somaliland, Sool, and Sanag regions. These areas are individually administered and the African wild ass has no legal protected status.

Sudan: The African wild ass was legally protected in 1963 (Schomber 1963), but its present status is unknown.

1.6 Captive populations

In 1999, the population of captive Somali wild ass (*Equus africanus somaliensis*) reported to the International Species Information System (ISIS) totalled 94 individuals, of which 46 were males and 48 were females (C. Pohle *pers. comm.*, 1999). These captive African wild asses are the descendants of five wild asses (three males and two females) captured in the Nugaal Valley of Somalia and sent to the Basel Zoo in Switzerland in July 1970, and 12 wild asses captured in the Serdo area of the Danakil Desert of

Ethiopia in September 1972 and sent to Hai-Bar in Israel.

Jenny Slunga and Simon Wakefield (*pers. comm.*, 1998) reviewed the status of the captive population as stated in the 1996 International Studbook of African Wild Asses. They used SPARKS 1.4 (Single Population Animal Record Keeping System 1996) to analyse the genetic status of the captive population. The record keeping at Hai Bar did not track parentage, hence, the analyses were restricted to the data in the studbook, which included asses imported from Hai-Bar. Some relationships were uncertain; their best case assumed ten founders and their worst case assumed six founders.

Slunga and Wakefield determined that theoretically, after 25 years in captivity, the 1996 captive population of Somali wild ass had retained 90.3% of their wild genetic variability in the best-case scenario and 85% in the worst-case scenario. Under the best case scenario, they predicted that a captive population of 440 asses would be needed to retain 85% of the wild genetic variation for a 100-year period and that a population of 130 asses would retain 80% of the wild genetic variation. Given the worst case scenario, 140 asses would retain only 74% of the wild genetic variation.

Slunga and Wakefield's analyses of inbreeding in the 1996 captive population indicated that there was no significant difference in survival to the age of three years between inbred and non-inbred asses. However, offspring of full sibling matings had a 17.5% higher risk of dying before the age of 180 days given the best case founder scenario. If the proportion of inbred mating increases in the captive population, then the risk of inbreeding depression will increase. Their analyses of mixed-origin mating (Ethiopia and Somalia) did not indicate any possible outbreeding depression.

At present, the true genetic relationships of the Somali wild ass are unknown. Such information is critical to the sound management of the captive population of Somali wild ass into the future.

1.7 Research activities

In Ethiopia, Kebede, Moehlman, and Tadesse are conducting research on present population size, reproductive biology, habitat requirements, and interactions with local pastoralists and their domestic livestock. Fecal samples are being collected to determine the current level of genetic variation in this population, and to investigate whether hybridisation has occurred between wild asses and domestic donkeys.

In Eritrea, Moehlman and Yohannes are collecting data on African wild ass reproductive biology, population dynamics, social organisation, and feeding ecology on the Messir Plateau. These data on movement patterns and

feeding ecology will provide information on how the African wild ass is utilising resources at its current density levels in areas also needed by pastoralists and their livestock. Data on known individuals will provide information on natality and survivorship and allow a limited projection of population growth and viability. Moehlman and Yohannes will also survey the Yob area of northern Eritrea, which is another potential African wild ass area. Primary research goals for the Messir Plateau and the Yob populations are 1) determine the present distribution and population numbers, and 2) examine the genetic variation in these two isolated populations and determine the validity of their subspecific designation. Genetic analyses would also answer the question of whether hybridisation has occurred with domestic donkeys. DNA would be extracted from dried fecal samples of African wild asses and compared with that of local domestic donkeys.

In Somalia, Moehlman and Hassan Abshir Farah will survey the present status of the African wild ass in the Nugaal Valley.

1.8 Gaps in knowledge

At present better information is needed on:

- national and local population status and trends;
- genetic definition of subspecies;
- genetic viability of isolated and reintroduced populations;
- behavioural ecology, resource requirements, disease epidemiology, and demography;
- risk assessment of geographically distinct populations; and
- socio-economics and viability of alternative conservation/utilisation strategies.

1.9 Recommended actions

Improve the protection and management of existing populations

The African wild ass in the Mille-Serdo Wild Ass Reserve in Ethiopia needs better protection. Given the present lack of resources for EWCO staff and logistics, a small conservation education programme with the local Afar pastoralists may be the most practical option in the near future. However, if this population is to survive into the next two decades, then a management programme that involves Afar regional administrative personnel needs to be developed and implemented. The current African wild ass population cannot sustain the present poaching for meat and medicine.

In Eritrea, the African wild ass population between the Buri Peninsula and the Dalool Depression is 'protected' due to the cultural traditions of the local Afar pastoralists.

In this area, wildlife is not hunted and/or utilised for meat or medicine. However, the Messir Plateau may be a critical breeding area and legally declaring it a wildlife reserve would provide further protection.

In Somalia, a viable population of African wild ass may no longer exist in the Nugaal Valley. A survey and a viability assessment of the remaining population are needed, recognising the political constraints.

New reserves should be established as multiple-use areas with special protection for wildlife and appropriate development and extension support for local nomads. Throughout their range, African wild ass occur in arid habitats where the local human populations are at risk. Conservation of wildlife will not be possible unless local nomadic pastoralists have an opportunity to participate in, and benefit from, the conservation management of their areas. This should involve discussions and education concerning the conservation of natural resources and rare species, the employment of local personnel as rangers, and the provision of medical and veterinary care. In all three countries, further training for wildlife scientists and managers is fundamental to optimising conservation management of natural resources and endangered species.

Clarify the genetic status of the two subspecies of African wild ass

It is important to determine if *Equus africanus somaliensis* and *Equus africanus africanus* are morphologically, genetically, and behaviourally distinct subspecies that require separate conservation management programs. Survey work throughout the species range should determine if any populations are reproductively isolated and thus vulnerable to the demographic and genetic problems characteristic of small populations. In addition, the extent of interbreeding with domestic donkeys needs to be assessed with respect to its potential impact on the genetic integrity of existing African wild ass populations.

Extend surveys and improve monitoring of known populations

Surveys need to be extended to northern Eritrea and into Sudan and Egypt. At the same time, known populations need to be monitored as to age and sex class, and, where possible, natality and survivorship. These data are needed to prioritise conservation action.

Conduct research on basic biology, seasonal movements, and interactions with livestock

Research is needed on the reproductive biology, habitat requirements, seasonal movements, and interactions with local pastoralists and their domestic livestock. It is critical to involve local pastoralists in the development and implementation of a long-term management plan for the conservation of African wild ass and the desert ecosystem it inhabits.

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Status and Action Plan for Grévy's Zebra (*Equus grevyi*)

Stuart D. Williams

2.1 Nomenclature and conservation status

Scientific name:

Equus grevyi Oustalet 1882

Common names:

Kangani or punda milia somali (Swahili), Zèbre de Grévy (French), Grevyzebra (German)

Indigenous names:

Loiborkoram (Samburu), Damer faru (Somali), Loituku kangan (Turkana), Harradida (Gabbra)

IUCN Red List Category (version 2.3):

Equus grevyi EN Ala + 2c Endangered

CITES Listing:

Equus grevyi Appendix I

Legal Status in Range States:

Ethiopia – Legally protected

Kenya – No legal protection, but protected by hunting ban in 1977

Somalia and Djibouti – Extirpated

Sudan – Status unknown and no legal protection

2.2 Distribution, population estimates and trends

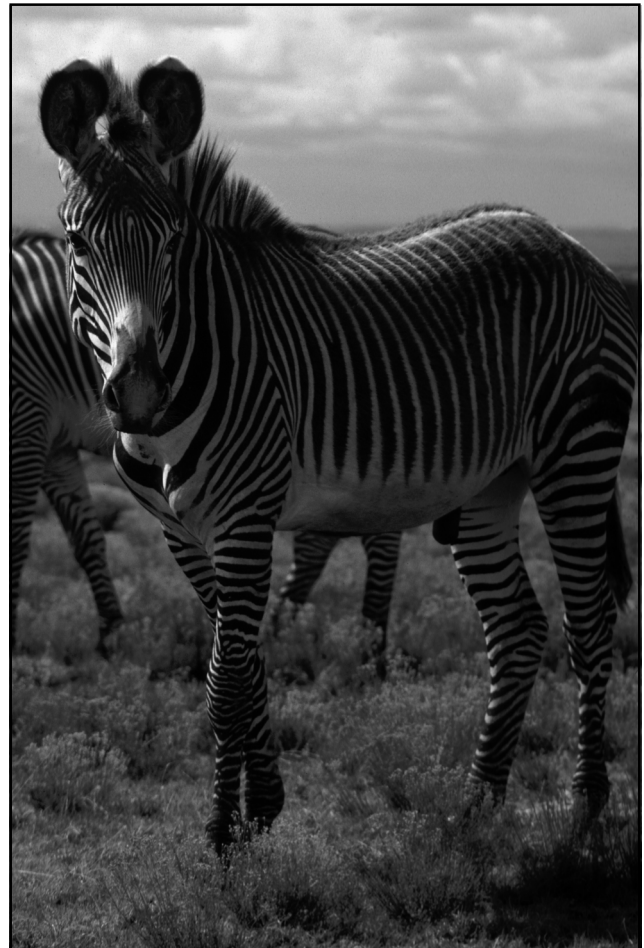
The historical distribution of the Grévy's zebra ranged from the Danakil Desert in Eritrea, through the Awash Valley, the Ogaden region, and north-east of Lake Turkana in Ethiopia. They were found south into Kenya, north of Mt Kenya and the Tana River, east into western Somalia, and east of the Rift Valley (Figure 2.1). There were sightings of Grévy's zebra west of the Rift Valley in Kenya, although these were some time ago (Stigand 1913; Stewart and Stewart 1963). More recently, there have been sightings in southern Sudan (C. Trout pers. comm. to P. D. Moehlman).

In recent history, Grévy's zebra has undergone one of the most substantial reductions of range of any African mammal (Figure 2.1; Kingdon 1997). In addition, there

have been significant declines in the numbers of Grévy's zebra. Towards the end of the 1970s, the total wild population of Grévy's zebra was estimated to be approximately 15,000 animals; present day estimates are between 3,000 and 3,500 animals (Williams and Nelson, in prep.). This represents a 75% decline in numbers.

In contrast, from the 1970s until present, the range of Grévy's zebra in Kenya has extended southwards onto the Laikipia Plateau and the Lewa Wildlife Conservancy. Although this expansion is small relative to the amount of range that has been lost, it is significant because of the sympathetic reception that the zebras have received in these areas. Consequently, it is only within these regions

Grévy's zebra (*Equus grevyi*).



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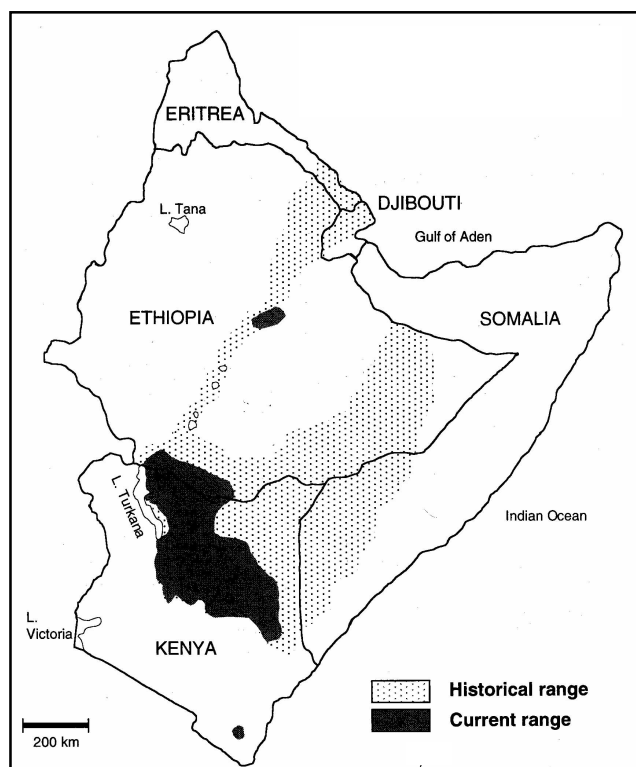


Figure 2.1. The historic and current distribution of Grévy's zebra (*Equus grevyi*).

that there have been increases in Grévy's zebra numbers over the past two decades.

Ethiopia, Djibouti and Eritrea

Grévy's zebra was distributed from the Danakil Desert in Djibouti and Eritrea, through the Awash Valley into the areas north-east of Lake Turkana and into the Ogaden. Its range in Ethiopia, Djibouti, and Eritrea has been much reduced (Figure 2.1), with zebras remaining in Ethiopia alone. The areas where Grévy's zebra was known to exist in Ethiopia were recently surveyed for wildlife, including Grévy's zebra (Thouless 1995a, 1995b):

Alledoghi plains, within the Alledoghi Wildlife Reserve.

This population is important since not only is it the northernmost point of the species' present day distribution, but it is also isolated. However, there has been a steady decline in numbers in this area since the 1970s, from about 600 in 1970, to less than 300 in 1978 (Stephenson 1978). Since 1992 there has been no apparent change in the numbers of zebra. The estimate in 1992 was about 175 individuals (Rowen and Ginsberg 1992); a total count in 1995 recorded 177 individuals (Thouless 1995a). The animals during this most recent survey were predominantly found in the north of the wildlife reserve, away from those areas where there are high densities of domestic livestock.

Table 2.1. Grévy's zebra (*Equus grevyi*) population trends (1977–1994) in Kenya.

The estimates (with standard errors) of the Grévy's zebra populations by the Department of Resources Surveys and Remote Sensing (DRSRS) by district for the years that a given district was surveyed. Data in italics indicate incomplete surveys of the given district. Data taken from Grunblatt *et al.* (1996).

Year	Garissa Estimate	Isiolo Estimate	Laikipia Estimate	Marsabit Estimate	Samburu Estimate	Tana River Estimate
1977	905 (411)	2,969 (1,555)		4,922 (1,607)	2,619 (875)	136 (135)
1978	752 (324)	2,131 (726)		4,437 (1,059)		
1981				2,838 (654)		
1983	484 (176)					
1985	1,664 (1,384)	291 (156)	416 (247)	1,586 (741)	1,001 (738)	333 (204)
1987			298 (272)	2,055 (804)	638 (308)	
1988	371 (145)	610 (310)				
	221 (159)					
1989						1,602 (909)
1990		1,021 (628)	17 (17)	2,232 (552)	760 (395)	
1991				691 (285)		
1992				678 (277)	1,239 (724)	
1993		2,198 (837)		1,561 (674)	1,182 (498)	34 (34)
1994		985 (424)	181 (125)	1,969 (531)	995 (713)	

Notes:

1. When the standard error of an estimate approximates to the estimate itself, it indicates that few groups of Grévy's zebra were sighted during the survey of the given district.
2. Not all districts were surveyed each year; the blank rows indicate no survey was conducted for the given district in the given year. Not all districts were surveyed in any one year; therefore, it is difficult to have a single overall estimate for the total number of animals in Kenya.
3. A survey of Grévy's zebra was conducted throughout its range in Kenya in 2000. A total of 1997 individuals were observed and the preliminary estimate of Grévy's zebra in Kenya was 2,300–2,600 (Williams and Nelson, in prep.).

Yabello Sanctuary and surrounding areas including the Borana Controlled Hunting Area. Rowen and Ginsberg (1992) reported this as being an area where Grévy's zebra was 'more abundant', with numbers being in the 'tens or hundreds'. The recent aerial survey did not find this to be the case. Only one individual was sighted, leading to a low population estimate with high error limits (Thouless 1995b).

Chew Bahir (Chalbi Wildlife Reserve). Grévy's zebra in this area was reported to be abundant in the late 1970s (estimated at about 1,500). The recent aerial survey of the area found that Grévy's densities were higher than elsewhere in Ethiopia but still represent a dramatic decline in numbers (population estimate of 370 individuals, Thouless 1995a). As on the Alledeghi plains, the animals were found in an area where no humans or domestic livestock were recorded – this was to the south of the salt flats. The persistence of this population was confirmed during the ground survey of Grévy's zebra conducted between January and April 2000. Although population estimates were difficult to derive, a minimum of 130 different individuals were sighted (Williams and Nelson, in prep.).

The estimate for the total number of Grévy's zebra in Ethiopia in 1980 was approximately 1,500 (Klingel 1980; Rowen and Ginsberg 1992). The recent aerial survey suggests a total between 500 and 600 animals (Thouless 1995a, 1995b). This indicates that there has been a serious decline in the number of Grévy's zebra since 1980, which appears to be in the same order of magnitude of the decline recorded in Kenya over the same period (see below; Rowen and Ginsberg 1992).

Kenya

In Kenya, the range of Grévy's zebra is also much reduced (Figure 2.1). In addition, between 1977 and 1988, a 70% decline in the number of Grévy's zebra was recorded in Kenya (13,700 to 4,300 animals, Dirschl and Wetmore 1978; Grunblatt *et al.* 1989; Rowen and Ginsberg 1992; Grunblatt *et al.* 1996). Since 1988, data collected by the Department of Resource Surveys and Remote Sensing (DRSRS) in Kenya suggest that the decline in numbers is continuing although at a slower rate (Table 2.1). This is confirmed by the preliminary results of the most recent ground survey of the Kenyan populations. These results indicate a further 30% decline from the mid-1990s estimate of 4,000 for northern Kenya (Williams and Nelson, in prep.).

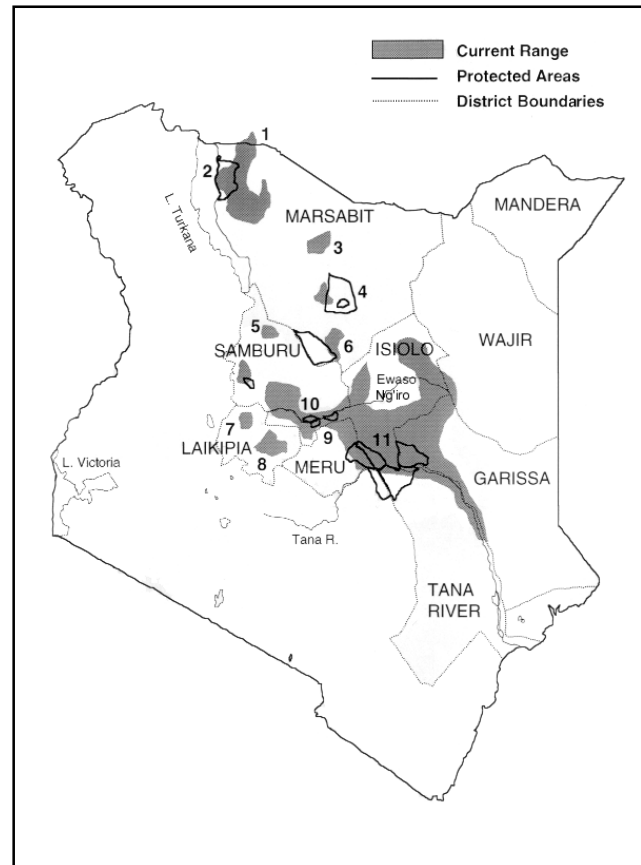
The largest and most stable population of Grévy's zebra (approximately 1,000 animals) is found at the southern end of their historic range (Figure 2.2). This population uses the Buffalo Springs, Samburu, and Shaba National Reserves. It has been the focus of studies since 1980 and many of the animals are known as individuals by researchers.

However, even in this population, the decline in numbers has been predicted to continue. Low juvenile survival results in a depressed rate of recruitment, particularly among those foals born in areas used by pastoral people (Williams 1998). The gravity of this situation may be better appreciated when considering that protected areas form less than 0.5% of the range of Grévy's zebra.

Two recent surveys of the northern Kenyan populations revealed that they were small and potentially isolated (Wisbey 1995; Williams and Nelson, in prep.). These populations include those around Laisamis, Karole, Kalacha, and Sibiloi National Park (Figure 2.2). Of particular significance, the number of animals sighted in Sibiloi National Park was very low. Only 15 individuals were sighted during the 1995 survey and 22 individuals in

Figure 2.2. The distribution of Grévy's zebra in Kenya as indicated by sightings during the surveys by the Kenyan DRSRS between 1990 and 1994.

The populations are in the following areas, as indicated on the map: 1) Chew Bahir (Ethiopia); 2) Sibiloi National Park; 3) Kalacha; 4) Karole; 5) El Barta plains; 6) Laisamis; 7) North Laikipia (Mugie/Kirimon/Loisaba/Kisima); 8) Central Laikipia (Ol Jogi/Mpala/El Karama); 9) Lewa Wildlife Conservancy; 10) the southern population that uses Buffalo Springs, Samburu, and Shaba National Reserves; and 11) the sparsely populated eastern area surrounding Garba Tula. The map shows the district boundaries that are used for the DRSRS surveys and the protected areas. The critical lower part of the Ewaso Ng'iro River is also shown.



the 2000 survey. This differs to the moderate density estimated by Rowen and Ginsberg (1992).

In contrast, Grévy's zebra has expanded its range onto the Lewa Wildlife Conservancy and the Laikipia Plateau. These were, historically, marginal areas for Grévy's zebra (Figure 2.2). It has been speculated that movement of Grévy's zebra from the lowland areas dominated by pastoral people and their domestic livestock was a direct result of loss of habitat through the reduced flow of perennial water sources (see section 2.4.1; Gichuki *et al.* 1998b), and through vegetation changes and erosion that have resulted from sustained, heavy grazing pressures by relatively high densities of domestic livestock (see 2.4.2). As these changes were occurring in the lowland areas of their range, on Lewa and the Laikipia Plateau, there was reduced competition with domestic livestock, increased artificial water sources, and reduced bush cover as a result of increased numbers of browsers – especially elephants and giraffe. Since moving into these areas, the numbers of Grévy's zebra have increased. On the Lewa Wildlife Conservancy, the increase in numbers (present population estimate of about 500; Table 2.2) appears predominantly to be a result of births. This is important as the Lewa population is contiguous with the Buffalo Springs, Samburu and Shaba population. Consequently, like the National Reserves, Lewa is a critical birthing area for Grévy's zebra and is probably also an important dry

season refuge. In contrast, the increase in numbers on the Laikipia Plateau may be primarily due to immigration although there is recent evidence that the zebras are also breeding in this area.

The status of the population of Grévy's zebra that was translocated in the 1960s and 1970s to Tsavo East National Park remains unknown, although sightings are occasionally reported and rough estimates indicate a population of approximately 200 animals (A. Seth-Smith pers. comm.). It is apparent that the animals use a large area mainly on the eastern boundary of the Park, and further east and south-east outside the Park. These areas include large ranches. The ranchers tend to be sympathetic to the presence of Grévy's zebra. The Kenya Wildlife Service (KWS) researchers working on the hirola that were recently translocated into this area of Tsavo could potentially monitor the numbers.

Somalia

There have been recent though unsubstantiated reports of Grévy's zebra sightings in southern Somalia (J. Bauer pers. comm.). However, until confirmed, Grévy's zebra must continue to be considered extirpated in Somalia. The last confirmed sightings of Grévy's zebra in Somalia were in 1973. Grévy's zebras were probably extirpated in Somalia due to hunting for food, trophies, and, although unconfirmed, for medicinal use.

Sudan

There has been a recent sighting of Grévy's zebra in southern Sudan (C. Trout pers. comm. to P.D. Moehlman). Although this region was well within the range of ancestral or proto-Grévy's forms, this is the only sighting of Grévy's zebra in this area to date. However, it is unclear at present whether this sighting was one of a few widely dispersing individuals on the edge of their range, such as those zebra sighted west of the Rift Valley in Kenya (Stigand 1913; Stewart and Stewart 1963), or part of a larger population.

2.3 Ecology, environment and habitat

Before their decline in numbers, Grévy's zebras potentially played an important role in the biodiversity of the region. As the most abundant grazing herbivores in the ecosystems in which they live (Grunblatt *et al.* 1989). Their impact on the structure and composition of the rangelands was likely to have been significant. However, since their decline in numbers, their influence on the environment cannot be assessed, primarily because this would have been overshadowed by the long-term impact of domestic livestock.

More recently, the ecology and behaviour of Grévy's zebra have been well studied, particularly in Buffalo Springs

Table 2.2. The number of Grévy's zebra on the Lewa Wildlife Conservancy (1977–2000).

The counts started in 1977 and Lewa Wildlife Conservancy made the total aerial counts. In some years there were no counts (—).

Year	Estimated number of Grévy's zebra
1977	99
1978	122
1979	167
1980	116
1981	—
1982	196
1983	—
1984	—
1985	284
1986	—
1987	230
1988	212
1989	330
1990	—
1991	229
1992	479
1993	343
1994	286
1995	—
1996	387
1997	401
1998	430
1999	632
2000	497

National Reserve in Kenya, where long-term studies have been conducted from 1980 to the present (Klingel 1974; Rubenstein 1986; Ginsberg 1988; Rowen 1992a; Williams 1998).

Grévy's zebra live in arid and semi-arid grass/shrubland where there is permanent water. They are predominantly grazers although in stressed conditions, such as drought, browse can comprise up to 30% of their diet (Rowen and Ginsberg 1992). Like other caecal digestors, they have high intake rates, such that when food is limiting they are constrained to feed in the vegetation communities with the highest biomass of food, regardless of quality (Ginsberg 1988; Williams 1998). They require free-standing water as part of their diet; adults can tolerate between two to five days away from water, while lactating females can only tolerate one to two days (Becker and Ginsberg 1990; Rowen 1992a).

The social organisation of Grévy's zebra has been described by Klingel (1974), Rubenstein (1986), and Ginsberg (1989). Breeding males defend large resource territories. Their behaviour and mating success are dependent on the females that are attracted to their territories. In contrast, a female's reproductive condition determines the priority that she places upon different resources. For example, lactating females are found predictably closer to water than other classes of females and, therefore, mate with only one male whose territory has access to water. Non-lactating females are more promiscuous, mating with males whose territories contain resources that have attracted them. Females with young foals are also predictable in their patterns of association, forming relatively stable groups with other females with whom they are in reproductive synchrony. Females without young foals are less predictable. Their associations are fluid since their movements are determined by the availability and abundance of resources.

Breeding is dependent on conditions that facilitate oestrus among females (Ginsberg 1988; Williams 1998). Females will be induced into anoestrus during times when resource-availability is low, due to poor body condition (Ginsberg 1989). A peak in oestrus among females follows the onset of high resource availability which, in turn, results in a peak in births (Williams 1998). Breeding is, therefore, highly dependent on stochastic patterns of climatic variation, in particular rainfall.

The sources of mortality have not been fully determined. However, juvenile mortality is probably important. Foal survival has been directly related to the extent to which their mothers move. There is low foal survival when mares make large or frequent small-scale movements (Rowen 1992a; Williams 1998). This suggests that foals are energetically constrained (Rubenstein 1986; Williams 1998).

The impact of predation is unknown although it is probably low since in recent times predator densities have been greatly reduced due to poisoning campaigns (using

acaricide) by pastoral people in northern Kenya. Nonetheless, cheetahs are known to take foals, and crocodiles and lions are known to take adults (Rowen and Ginsberg 1992).

2.3.1 Historical perspective and human use

There have been very few studies or documents written regarding the historical importance of Grévy's zebra in human culture. The present day range of Grévy's zebra in northern Kenya overlaps primarily with the following ethnic groups: Boran, Somali, Turkana, Samburu, Aarial, Rendille, and Gabbra. Of these groups of people, the Boran, Somali, and Turkana are known to exploit Grévy's zebra for food. This may have had important consequences on the present distribution of Grévy's zebra. In addition, there have been suggestions that Somali peoples attribute Grévy's zebra with some medicinal uses, but these have not been confirmed. In contrast, it has been suggested that the Samburu (and by probable extension, the Aarial) have a cultural taboo against eating zebras, though again this is unsubstantiated. The situation in Ethiopia is wholly unknown.

During this century, up until the early 1980s, Grévy's zebra skins were sought by hunters either as trophies or for export for use in the fashion markets of Europe and North America. Indeed, there have been suggestions that hunting for skins in the late 1970s may have largely contributed to the 70% decline in Grévy's zebra numbers in Kenya (R. Elliott pers. comm.). Since the CITES listing, the killing of Grévy's zebra for their skins seems to have ceased. Therefore, at present, there is no legal trade in Grévy's zebra parts and the small amount of trade and/or movement in Grévy's zebra skins is probably of old skins of animals killed in the late 1970s.

2.4 Actual and potential threats

2.4.1 Reduction of water sources

Access to water is limited, particularly and critically during the dry season. This is the result of 1) the effect of irrigation schemes in highland areas, and 2) the exclusion of wildlife from water sources. An important effect of the reduction in the number of water sources that are accessible to Grévy's zebra is a significant diminution in the species' range.

Heavy water use of water in populous highland areas, particularly for irrigation schemes, continues to threaten perennial water sources in the historic range of Grévy's zebra. Central and critical to this issue is the Ewaso Ng'iro River basin on which between 60% and 70% of Grévy's zebras in Kenya (including the southern population in Kenya, and the Lewa Wildlife Conservancy and Laikipia

populations) are dependent. The situation is characteristic of a highland-lowland system in which most natural resources are not equally distributed, but are dynamically interrelated (Wiesmann and Kiteme 1998). Indeed, its management is made more difficult by its complexity. The highland-lowland system of the Ewaso Ng'iro basin consists of diverse ecosystems arising from the steep ecological gradient, diverse land uses and management practices, different settlement and population densities, different ethnic communities, and many and complex administrative units (Gichuki *et al.* 1998b). For example, the Ewaso Ng'iro basin falls into seven administrative districts, each with its own development plan (Gichuki *et al.* 1998b). This leads to districts upstream allocating water with little regard to downstream users – including cattle ranchers, pastoral people, domestic livestock and all other water-dependent wildlife (Gichuki *et al.* 1998a).

The basin is primarily fed by water from the Nyandarua Hills (Aberdares), Mt Kenya and the Nyambene Hills. This highland region has witnessed a population growth of up to 7–8% over the past 30 years (Gichuki *et al.* 1998b). This was, in part, due to migration of people as large-scale ranches in the region were sub-divided into smallholdings (Kiteme *et al.* 1998). The migration was primarily from high rainfall areas, and the settlers introduced unsuitable land-use practices resulting in extremely high demands on natural resources, particularly surface water (Gichuki

et al. 1998b; Kiteme *et al.* 1998). The smallholders generally grow rainfed crops, which are increasingly supported by irrigation from perennial rivers (Gichuki *et al.* 1998a), particularly during the dry season. By the end of the dry season, 91% of smallholders are irrigation dependent (Wiesmann and Kiteme 1998). Indeed, the number of water supply systems that are based on perennial water has increased by 60% since the start of sub-division, with 97.5% of the smallholders planning or expressing a need for further development of water supplies for irrigation (Wiesmann and Kiteme 1998). This implies that extractions from perennial rivers will increase in the future. The problem is exacerbated by local politicians, who have suggested that irrigation is the key to solving agricultural problems on marginal land (Kiteme *et al.* 1998).

Although there is an established permit allocation system for the extraction of water, it is subject to flagrant abuse. Over-abstraction by permitted users of the river water for irrigation is common, but up to 80% of extraction is unauthorised (Gathenya 1992; Gichuki *et al.* 1998a). This reflects: 1) the lack of an effective extraction monitoring programme; 2) the high financial returns from irrigated agriculture or horticulture, but low fines for illegal extractions of water; 3) the lack of floodwater storage facilities; and 4) low water-use efficiency in irrigation (Gichuki *et al.* 1998a).

The small-scale farmers are apparently aware that water resources are threatened. However, they do not attribute

Table 2.3. Summary of threats to Grévy's zebra (*Equus grevyi*).

Threat	Cause	Threatened populations
Reduction of water sources	Unsustainable extraction of perennial river water for irrigation in highland areas.	All populations, but particularly the Grévy's zebra dependent on water from the Ewaso Ng'iro River basin. This affects 60–70% of the population in Kenya, including the southern, Laikipia, and Lewa populations.
Reduction of water sources	Exclusion of wildlife from water sources by pastoral people	The small and potentially isolated populations in the more arid parts of their range, including the Laisamis, Karole, Sibilo, El Barta, and Lake Chew Bahir populations.
Habitat degradation and loss	Heavy, sustained grazing by relatively high densities of domestic livestock resulting in vegetation community change and erosion.	All lowland populations in the historic range of Grévy's zebra. Habitat loss has resulted in a large reduction in the range of Grévy's zebra.
Competition for resources	Competition with relatively high densities of domestic livestock for limited resources, particularly in the dry season.	All lowland populations of Grévy's zebra. Grévy's zebra are sympatric with pastoral people and their livestock over 99.5% of their range. Competition results in low juvenile survival.
Tourism	Ineffective management in protected areas.	All lowland populations of Grévy's zebra.
Hunting	Historically, the killing of Grévy's zebra for skins; more recently, killing for meat.	Responsible for the large decline in Grévy's zebra numbers in the 1970s. At present, killing of animals for meat affects the lowland populations.
Trade in live Grévy's zebra	Potential movement of animals that could result in non-viable captive populations.	All resulting introduced populations.

this to inappropriate land use and immigration. Instead, it is simply attributed to climatic conditions coupled with a strong belief in divine responsibility (Kunzi *et al.* 1998).

The long-term consequence of the extraction for irrigation has been a 90% reduction in the flow of the Ewaso Ng'iro River since the 1960s (measured at Archer's Post; mean flow 1960s: 9m³/s; 1970s: 4.5m³/s; 1980s: 1.2m³/s; 1990s to present: 0.9m³/s; (Liniger 1995)), with no corresponding decline in rainfall over the same period (Gichuki *et al.* 1998b). The Ewaso Ng'iro River was previously a perennial river. As a result of the upstream extractions, it has become seasonal in the lowlands, drying up completely for a stretch of up to 60km upstream from Buffalo Springs (S.D. Williams, personal observation; Gichuki *et al.* 1998a; Wiesmann and Kiteme 1998; Gichuki *et al.* 1999). It has been suggested that this is one of the reasons that has led to the movement of pastoral people, domestic livestock, and wildlife upstream, including onto the Laikipia Plateau and the Lewa Wildlife Conservancy (Gichuki *et al.* 1998a; Gichuki *et al.* 1998b).

The exclusion of wildlife from water sources by pastoral people has had a similar effect of reducing the range of Grévy's zebra, particularly during the dry season. In order to achieve this, the pastoral people build thorn exclosures around water sources (S.D. Williams, personal observation) because of their conflict with wildlife over the diminishing water sources. Conflict occurs over both permanent and ephemeral water sources. As the ephemeral sources dry up, the range of all animals, including domestic livestock, will be greatly reduced as they become dependent on the permanent water sources. To prolong the period in which the livestock are not constrained just to the permanent water sources, the humans attempt to protect the ephemeral water sources from the wildlife species. Similarly, wildlife is excluded in an attempt to keep other water sources perennial.

Conflict between ethnic groups in northern Kenya and southern Ethiopia has been escalating over the past decade as the people have increased access to automatic weapons. Although much of the conflict is over livestock rustling, there is conflict over grazing. By controlling permanent water sources, particularly if they are patchily distributed (e.g. as springs), people control the access to grazing in the area. Grévy's zebra are caught up in these conflicts and are, therefore, made vulnerable by their dependence on the same permanent water sources.

2.4.2 Habitat degradation and loss

There has been degradation and loss of Grévy's zebra habitat since the 1950s (Mäckel and Walther 1984; Bronner 1990; Herlocker 1992; Herlocker 1993; Toubert 1993; Mäckel and Walther 1994). The primary cause of degradation in northern Kenya is thought to be overgrazing

(Bronner 1990; Herlocker 1992). Overgrazing, which may be defined as taking place when grazing pressures are greater than the regenerative capacity of the plant species, is a problem because 1) stocking rates of domestic livestock species have been too high; 2) the selection of domestic livestock species has been inappropriate for the environment; and 3) grazing pressures have been sustained for too long a period (Bronner 1990; Herlocker 1992; Herlocker 1993). The situation is exacerbated by inappropriate distributions of livestock. For example, livestock have become concentrated as pastoral people become increasingly sedentary in the vicinity of permanent water sources (Herlocker 1992). Overgrazing directly affects the composition of the vegetation communities. The principal vegetation changes that have occurred in the range of Grévy's zebra, in order of importance, are 1) increases in woody cover (tree, shrub, and dwarf shrub); 2) quantitative decreases in herbaceous and particularly grass cover; and 3) a qualitative decrease in the herbaceous composition (e.g. change from large to small perennials and from perennials to annuals) (Naylor and Herlocker 1987; Bronner 1990; Herlocker 1992).

In addition to altering the vegetation communities, overgrazing also reduces overall plant cover, thus increasing the susceptibility of the soil to water and wind erosion. Erosion has the immediate effect of "surface sealing". The soil is blown or washed away, leaving a hard, usually stony surface exposed (Bronner 1990). Compaction and pulverisation of the soil by animals exacerbates this (Sinclair and Fryxell 1985). Water infiltration rates of the soil are also reduced due to the lack of vegetation cover and the sealed surfaces (Synott 1979; Wenner 1981). The resulting conditions are unfavourable for plant establishment (de Vos 1975). However, erosion is not always a consequence of overgrazing. The unpalatable "pasture weeds" and woody vegetation often form adequate protection against erosion, although the range remains as unproductive for grazing herbivores (Bronner 1990).

Existing habitat degradation may, in part, be due to the susceptibility of the region to overgrazing. Pratt and Gwynne (1977) note that susceptibility is dependent on aridity: the greater the aridity, the greater its fragility. The consequence being that a large proportion of the range of Grévy's zebra has undergone rapid and significant degradation. For example, the number of animals using the area that was Hans Klingel's study area during his study of Grévy's zebra in the late 1960s (Klingel 1974) has declined by 90% (Klingel 1980). Although this is probably, in part, due to direct killings, the area had been subjected to sustained, heavy pressures by pastoral people and their domestic livestock. The resulting vegetation changes and erosion, and hence loss of habitat, are probably more important in determining the exclusion of Grévy's zebra from this and other equivalent areas. Herlocker (1992) estimates that over the past four decades 80% of northern Kenya has

undergone similar degradation. The only areas that remain in “good” condition are those that are too far from water to be used by livestock or those that were under-used due to continued security threats (Herlocker 1992).

2.4.3 Competition for resources

A recent study has shown that Grévy’s zebra competes for critical resources with pastoral people and their domestic livestock in northern Kenya (Williams 1998).

The long-term vegetation changes and erosion, as mentioned above, have reduced the availability of forage in the areas used by pastoral people. But, on a seasonal basis, the use of forage by the relatively high densities of domestic livestock species also limits food availability. This means that, while in these areas, Grévy’s zebra must feed in vegetation communities with the highest food abundance – regardless of quality – in order to sustain their intake requirements. These communities are further from water sources than those in protected areas; consequently, the zebra move large distances to and from water. For example, grazing zebra in areas used by pastoral people were recorded at a mean distance of 5.9km (standard error 0.25) from permanent water (Williams 1998). In contrast, those in Buffalo Springs National Reserve were at a mean distance of 2.0km (0.11). Furthermore, as food resources become depleted during the dry season, zebra frequently have to migrate from areas used by pastoral people (Williams 1998). During such occasions, the Buffalo Springs/ Samburu/ Shaba National Reserve complex acts as a refuge (Ginsberg 1988; Williams 1998).

In areas used by pastoral people, Grévy’s zebra are forced to drink at times when water sources are not being monopolised by domestic livestock. In many areas, this means that zebra have to drink at night. This is in direct contrast to those in protected areas, where the zebras drink during a brief time window during the middle of the day, probably as an adaptive response to reduce the risk of predation. This suggests that drinking at night exposes Grévy’s zebra to higher risks of predation at water sources (Williams 1998), thus foals that are left in ‘kindergartens’ while the mares drink at night may also be at risk.

Drought is expected to favour Grévy’s zebra above domestic livestock since the high mortality of livestock during such periods should represent competitive release for the zebra. However, the practice of Non-Governmental Organisations (NGOs) to replace immediately livestock lost in droughts (Drought Monitoring Project Reports 1993–1995) means that the advantage that Grévy’s zebra may have gained through competitive release is quickly negated.

The cost of competition is realised in the low survival of foals in the areas with pastoral people. Foals are thought to be energetically constrained (Rubenstein 1986; Williams 1998). Therefore, the energetic costs of moving

large distances to and from water – particularly for young foals whose mothers are having to drink every one to two days, and of dispersing from an area when the food resources become depleted – results in low survival (Williams 1998).

As long as pastoral people maintain high grazing pressures in the areas used by them, it is likely that Grévy’s zebra will become increasingly mobile, moving from area to area in search of sufficient food resources. They will be forced to drink at night exposing them to higher risks of predation, and juvenile survival will remain low, particularly in areas used by pastoral people (Williams 1998). Given that these areas comprise greater than 99.5% of the historic range of Grévy’s zebra, overall recruitment is likely to remain low and highlights the importance of the protected areas.

2.4.4 Tourism

Managed tourism could enhance the conservation of Grévy’s zebra in their historic range. However, tourism in Buffalo Springs, Samburu, and Shaba National Reserves is a threat due to poor management. Community conservation programmes tend to promote the conservation of Grévy’s zebra in a similar way and as such, are prone to the same issues. Therefore, these threats will be pertinent for their managers as community conservation programmes become more widespread. The following points are critical issues (see also Rowen and Ginsberg 1992):

- *Traffic volume and control.* There has been no change in the management of traffic within the National Reserves since proposals by Rowen and Ginsberg (1992). Off-road driving is widely practiced by tourist guides and continues to threaten habitat, both by reducing vegetation cover and increasing rates of erosion. Road maintenance by the Isiolo and Samburu County Councils (responsible for tourist and road management) is negligible; if the roads were maintained, visitors would be encouraged to use the extant road system, thereby reducing damage to the habitat.
- *Swimming in Buffalo Springs.* Buffalo Springs has been shown to be an important water source for mares with young foals (Becker and Ginsberg 1990; Rowen 1992a). However, there is evidence that the use of Buffalo Springs as a swimming pool excludes the water source from use by animals at a time of day when they prefer to drink (Williams 1998). If the practice is to continue, then it calls for tourist guides to be responsible and to allow the tourists to swim only when there are no animals either at or approaching the Springs.

2.4.5 Hunting

Since Grévy’s zebra was listed on CITES Appendix I in 1979, there has been no evidence of killing for skins.

However, there is a certain amount of killing of Grévy's zebra for meat using guns, non-specific snares, or dogs, primarily by Boran, Somali and Turkana people (S.D. Williams, personal observation). Hunting for meat occurs in the areas where these people are found, including the protected areas where these overlap. Furthermore, unsubstantiated reports maintain that some pastoral people (of Cushitic origin) in Kenya and Somalia use Grévy's zebra for medicinal purposes.

2.4.6 Trade in live Grévy's zebra and translocation of animals

As the number of Grévy's zebra on private ranches on the Laikipia Plateau increases, and as the need grows for ranches with a strong wildlife emphasis to become economically viable, there will be increasing pressure for landowners to benefit financially from wildlife. This would mean trade in live animals, which would directly benefit the landowner. In this context, 'trade' means the translocation of Grévy's zebra for sale and/or exchange of different animals (probably other species) with other landowners or management authorities such as the Kenya Wildlife Service. At present, there is probably only one ranch that could viably trade in Grévy's zebra in such a way. This is the Lewa Wildlife Conservancy, which currently has a population of approximately 500 animals.

Trade in Grévy's zebra is, in theory, legal under certain circumstances, but in all cases requires the prior approval of the relevant Minister within the Government of Kenya (as detailed in the Wildlife (Conservation and Management) Act No 376, 1976). These circumstances include the sale and movement of animals, first, as a Game Animal (the legal status of Grévy's zebra in Kenya) and, second, as part of game ranching. However, trade is not without its dangers and the IUCN/SSC Reintroduction Specialist Group provides a set of criteria that should be fulfilled before movement of animals is considered (IUCN/SSC Reintroduction Specialist Group 1995). For example, thorough research into reintroductions of the same or similar species should be conducted (Section 4a (ii) of the Guidelines). Previous experience has seen that moving equids to establish viable populations (as recommended in Section 4a (iv) of the Guidelines) is far from straight forward. The reintroduction of Asiatic wild ass into the Negev Desert resulted in low recruitment that was probably caused by stress from capture, transport and release procedures, and sex-ratio skews among the offspring (Saltz and Rubenstein 1995). Similar problems would be expected for Grévy's zebra. They are equids with a similar social system living in arid environments. Indeed, the previous translocation of Grévy's zebra out of their range into Tsavo East National Park was problematic and many animals died. As such, benign introductions either to areas

outside the historic range of Grévy's zebra or to isolated areas within their historic range are not recommended (Section 4a (iii) of the Guidelines). Both these actions would effectively create further captive populations, which, as stated below, are not necessary.

Finally, it would be difficult at present to find a site for reintroduction and/or reinforcement that satisfies all the criteria of the Guidelines (Sections 4a (iv) and 4b).

In conclusion, trade should not be permitted without a full study of the implications and dangers, which should include proper analysis of the incentives, markets, and threats posed by trade. Thereafter, each proposal for moving animals should be fully reviewed.

2.5 Current legal protection and effectiveness

2.5.1 Current conservation listings

Using the IUCN categories of threat, Grévy's zebra (*Equus grevyi* Oustalet) is listed as Endangered A1a and 2c in the *IUCN 1996 Red List of Threatened Animals*. They are listed as such because of 1) the 70% decline in numbers in Kenya between 1977 and 1988 determined from aerial counts (Grunblatt *et al.* 1989) and declines of the same order of magnitude reported for Ethiopian populations (Klingel 1980; Thouless 1995a, 1995b); and because 2) not only is there no evidence of any sort of recovery, but a recent study has shown that recruitment rates are depressed due to competition with pastoral people and their domestic livestock, and to the long-term effects of overgrazing (Williams 1998). This second observation suggests that the decline in numbers is continuing.

Grévy's zebra remains on Appendix I of CITES. Hence there is no commercial trade in Grévy's zebra skins.

2.5.2 Current legal protection

Grévy's zebra is legally protected in Ethiopia, though given the population trends there since 1980, such nominal protection has not been effective.

In Kenya, they have been protected by the hunting ban since 1977. However, under the Wildlife Conservation and Management Act No 376 of 1976 (Part II of the First Schedule), Grévy's zebra is listed as a 'Game Animal'; they are not listed under Schedule III. Therefore, they are not a legally 'Protected Animal' in Kenya.

Given that the decline in Grévy's zebra numbers in Kenya occurred after the hunting ban and that the decline may have primarily resulted from killings for their skins (R. Elliott pers. comm.), it is evident that the ban took several years to become effective. However, since the CITES listing of Grévy's zebra and the general reduction of zebra skin use in international fashion markets, there is

no evidence of killings for their skins. Hence, the continued decline in the numbers is likely to be due to the threats described above (e.g. loss of habitat and competition) rather than exploitation for their skins. However, if hunting re-opens in Kenya, including Grévy's zebra in a permit scheme is not recommended.

Protected areas form less than 0.5% of the range of Grévy's zebra. In Ethiopia, Grévy's zebra are found in three nominally protected areas: Alledoghi Wildlife Reserve, Borana Controlled Hunting Area, and Chalbi Wildlife Reserve (Chew Bahir). However, there is no effective protection of wildlife in these areas.

In Kenya, the Buffalo Springs, Samburu, and Shaba National Reserve complex is critical for the southern population of Grévy's zebra. Numbers have declined sharply outside this area and the exceptional Laikipia area. Other protected areas in Kenya appear to be largely ineffective. For example, in Sibiloi National Park, Grévy's zebras are now uncommon, whilst Losai National Reserve is not functional as a protected area.

2.6 Current conservation measures

There is little or no implementation of ongoing conservation action for Grévy's zebra. Many actions proposed by Rowen (1992b) have not been implemented and remain a priority. Notably, the following actions have been introduced:

- A study was carried out to assess evidence of interspecific competition for critical resources between Grévy's zebra, pastoral people, and their domestic livestock (Williams 1998).
- Two surveys were conducted to estimate the numbers of zebra in some of the subpopulations in northern Kenya (Wisbey 1995; Williams and Nelson, in prep). Population numbers were estimated using mark and recapture methods in conjunction with techniques for the identification of individuals from their stripe patterns. The surveys showed that such techniques could provide rapid and accurate estimations of the numbers within subpopulations, and could act as 'ground-truthing' for aerial surveys. Problems encountered during these surveys resulted in refinements that should improve the accuracy of future surveys.
- A poster campaign to increase awareness of the Endangered status of Grévy's zebra has been implemented in Kenya. A poster was produced by Méschina *et al.* (1998), which was then distributed throughout Kenya to conservation organisations, tourist hotels, national reserves, local communities, and schools, particularly where Grévy's zebras are found. Posters were distributed during the recent survey of Grévy's zebra in northern Kenya.

There have been excellent initiatives for the conservation of Grévy's zebra on the Laikipia Plateau, and particularly on the Lewa Wildlife Conservancy. In both these areas, increasing numbers have been witnessed by many ranchers. In addition, and significantly, Grévy's zebra has been proposed as the flagship species for the Lewa Wildlife Conservancy. It also recognises the need for landowners to maintain financial viability. However, until it has been sufficiently assessed, such viability should not be achieved through trade.

In contrast to Rowen and Ginsberg's reports (1992), large parts of the area are not fenced or the fences have been removed, therefore facilitating the movement of animals between ranches. Any future fencing programmes should carefully consider whether the fences will restrict the movement and consequent interchange of animals.

In addition, not only have the numbers of Grévy's zebra increased in the Lewa Wildlife Conservancy and the Laikipia Plateau, but many of the ranchers in the region are willing to manage their wildlife and domestic livestock populations to favour Grévy's zebra. Underlying this is the assumption that competition between Grévy's and the abundant plains zebras may be impeding the population growth of Grévy's zebra. Consequently, large culls of plains zebra have been proposed as a solution to this putative competitive inhibition. The study that took place on Lewa to assess evidence for competition will provide invaluable information for the management of Grévy's zebra relative to plains zebras (see 2.8.2; Hack and Rubenstein, unpubl. data).

2.7 Captive breeding

The captive population held in zoos and sanctuaries throughout the world totals 600 animals (243 males; 357 females; S. Wakefield, the Grévy's zebra studbook keeper, pers. comm., 1997). However, an unknown number is held in wildlife sanctuaries in Kenya (e.g. Ol Jogi Pyramid Game Reserve, Sweetwaters, Mt Kenya Game Ranch). The captive population is, therefore, large and derives from a sufficient number of founders to conserve the genetic diversity of Grévy's zebra (Rowen and Ginsberg 1992). Removing animals from the wild, either into zoos and sanctuaries outside of range states or into sanctuaries or areas in Kenya away from their natural range is not necessary.

All captive populations require specific management. A captive population's genetic and demographic structure will have significant long-term effects on its probability of survival, due to its size and isolation (Lande 1988). Sufficient genetic variation must be maintained to allow for adaptation to changing environments and to reduce the deleterious effects of inbreeding (that is, inbreeding depression) (Lande and Barrowclough 1987). This requires

that a population's genetic structure be adequately managed (Neuhauser 1991). Similarly, the demographic structure of a population will have implications for its survival (Lande 1987; Lande 1993). This is particularly important for equids, which have similar social systems and live in similar environments (Saltz and Rubenstein 1995). There are also social and behavioural considerations that need to be taken into account when dealing with Grévy's zebra in captivity (U. Rademacher pers. comm.).

2.8 Research activities

Many researchers have studied wild populations of Grévy's zebra. Studies have examined ethology (Klingel 1974), social organisation and ecology (Rubenstein 1986; Ginsberg 1988, 1989), mother-infant behaviour (Rowen 1992a), and community ecology and conservation (Williams 1998).

At present, there are five studies (listed below) that are being undertaken or have been recently completed on Grévy's zebra, not including ongoing research on the captive populations in zoos and sanctuaries. In addition, there are other projects that have been proposed and are currently seeking funding, including a ground survey of Ethiopian populations (similar to that of Kenyan populations that was conducted from January to April 2000), which is planned for the year 2003 (see 2.11 below). A study of the small and potentially isolated populations of Grévy's zebra found in northern Kenya is planned. This study would include data collection on the southern population of Grévy's zebra in and around the Buffalo Springs, Samburu, and Shaba National Reserves.

2.8.1 The behavioural ecology and conservation of Grévy's zebra on the Lewa Wildlife Conservancy

This project has three primary research objectives: 1) to describe the size, structure, distribution, and ranging behaviour of this important population; 2) to examine the behaviour and interactions of Grévy's and plains zebra for evidence of competition; and 3) to train local personnel so that data collection continues over the long-term. The demographic, behavioural, and ecological data from this project will shape the management strategy for this population and other populations on the Laikipia Plateau, while considering the need for ranches to balance wildlife conservation with activities such as livestock ranching, ecotourism, and wildlife cropping.

The project is being conducted by Dan Rubenstein and Mace Hack of Princeton University in partnership with the Lewa Wildlife Conservancy and with a grant from St Louis Zoo – Field Research for Conservation Fund.

2.8.2 Long-term monitoring of the Grévy's zebras on the Lewa Wildlife Conservancy

The Lewa Wildlife Conservancy is monitoring the population of Grévy's zebra using their own staff and core funds to cover the costs. One aim of monitoring is to determine survival rates among foals born on Lewa.

2.8.3 Herbivore dynamics in and around Buffalo Springs and Samburu National Reserves

The principal aim of the research is to examine herbivore dynamics in relation to habitat resources and human activities in and around Samburu and Buffalo Springs National Reserves. The specific objectives include an assessment of herbivore abundance, trend, and distribution over space and time (including Grévy's zebra); mapping the seasonal distribution of herbivores in relation to habitat variables; investigation of vegetation cover change in and outside the reserves; and an analysis of the impacts of human activities on herbivore dynamics.

The project is being conducted by Patrick Wargute, a PhD student from University College London and former employee of the Kenyan Department of Resource Surveys and Remote Sensing.

2.8.4 Grévy's zebra survey 2000

The survey sought to quantify the threat of extinction faced by small and potentially isolated subpopulations of Grévy's zebra in northern Kenya. It was carried out between January and April 2000. When going to press, only preliminary results were available. Where appropriate, these have been incorporated into this Action Plan. The outcomes of the survey include the following: 1) an estimate of size and demographic composition of each subpopulation of Grévy's zebra and the total number of Grévy's zebra in Kenya; and 2) an assessment of the resource base on which the subpopulations are dependent.

The survey was carried out by Stuart Williams and a team of volunteers in collaboration with the Kenya Wildlife Service with funding from the St Louis Zoo's Field Research for Conservation Fund, the African Wildlife Foundation, and the Species Action Fund of the World Wildlife Fund (US).

2.8.5 Demography and feeding ecology of Grévy's zebra in the Alledoghi Plains Game Reserve, Ethiopia

This project is researching Grévy's zebra population size and distribution, reproductive biology, habitat

requirements, and interactions with local pastoralists and their domestic livestock. Data are being collected on vegetation biomass, species composition, and the nutrient quality of preferred forage species. Fecal samples, for determining levels of genetic variation within this population and potentially for comparison with populations in Kenya, are also being collected.

Fanuel Kebede, Patricia Moehlman, and Almaz Tadesse are conducting the research under the auspices of the Ethiopian Wildlife Conservation Organisation with funding from the Wildlife Trust.

2.9 Gaps in knowledge

Much of the information available on Grévy's zebra comes from a single population of Grévy's zebra (see above). Much remains unknown about this population (e.g. age-specific fecundity and survival, longevity, inter-birth intervals, large-scale movement patterns). Even less is known about other populations, although a few surveys have been conducted: ground surveys (Wisbey 1995; Williams and Nelson, in prep.) and aerial surveys of the other Kenyan populations (Grunblatt *et al.* 1989), and aerial surveys in Ethiopia in 1995 (Thouless 1995a; Thouless 1995b). Therefore, estimates do exist for these populations, but their ecology and behaviour, use by humans, and threats remain unknown.

2.10 Recommended actions

The number of conservation efforts directed towards Kenyan populations emphasises not only that Kenya is a stronghold for Grévy's zebra, but also that there is a lack of knowledge concerning the Ethiopian (and Sudanese) populations. It is fundamentally important that the information on the Ethiopian (and Sudanese) populations of Grévy's zebra be expanded to determine their importance and the steps necessary for their conservation.

There is a need for range-state management plans for Grévy's zebra, starting with Kenya. Once the information on the populations in other range states has improved, then management plans can be developed for Ethiopia and, potentially, Sudan. This Action Plan should be useful for the formulation of these plans.

It is also recommended that the status of Grévy's zebra in Kenya be amended to that of a Protected Animal. This would, therefore, require that they be moved from Schedule I (in Part II of the Wildlife (Conservation and Management) Act No 376, 1976) – and hence as a Game Animal – to Schedule III, and necessitate a change in the legal status of Grévy's zebra in Kenya.

Other conservation actions for Grévy's zebra are focused on the wild populations and the captive populations, including those on the Laikipia Plateau.

2.10.1 Wild populations

Protection of water supplies

Reductions in the flow of perennial water in northern Kenya, primarily through extractions for irrigation, threaten to reduce significantly the range of water-dependent animals such as Grévy's zebra (see section 2.4.1). It is vital that water supplies from the highland areas of central Kenya be protected so that perennial springs and rivers in the arid, lowland region of northern Kenya remain that way. In the case of the Ewaso Ng'iro River, the flow should be improved to reverse the seasonal state of the river. This can be considered a critical issue because of the number of Grévy's zebra (and pastoral people, domestic livestock, and other wildlife) dependent on water from the Ewaso Ng'iro River basin. Given the number of stakeholders, this issue must also be resolved to prevent conflict over the dwindling water resources (Gichuki *et al.* 1998a).

Actions that ensure flow of water in the Ewaso Ng'iro in the dry season rely on making use of the water sustainable. This is dependent on arresting the trend for increasingly unsustainable use of the water within the basin (Gichuki *et al.* 1998a). One means by which this could be successfully achieved is through the formation of "river-users associations". Because communities using the rivers would be involved in making decisions about offtake and because upstream users become aware of the needs of downstream users, conservation efforts are more likely to be implemented. This method has been tried in the Ewaso Ng'iro basin with great success (e.g. the Ngare Niti Users Association). Nonetheless, other proposals aiming to attain sustainable water management include the following (for details, see Thomas *et al.* 1996; Gichuki *et al.* 1998a):

- Re-evaluation of the allocation of water from present, ambiguous criteria (Thomas *et al.* 1996).
- Ensuring a low flow criterion to protect downstream users. Each person or groups of persons that are licensed to exploit water resources would be limited in the amount they can harvest, such that the aggregated abstractions would not be greater than an adequate dry season flow of the rivers.
- Ensuring water abstraction compliance.
- Improving water use efficiency.
- Increasing the awareness of the impacts of upstream over-abstraction on downstream users.
- Promoting livelihoods that are less dependent on water.
- Increasing water storage.
- Improving baseline information and developing management tools (Gichuki *et al.* 1998a).
- Strengthening the role of administrative authorities.

- Regulating streamflow using reservoirs (Gichuki and Gichuki 1999; Gichuki *et al.* 1999).

The issues surrounding the Ewaso Ng'iro River basin are being addressed, particularly by the Natural Resources Monitoring, Modelling and Management project (the NRM² Project, formerly the Laikipia Research Programme)—a joint programme between the Universities of Nairobi, Kenya and Bern, Switzerland. They should remain key players in future negotiations regarding the management of water resources to attain sustainability.

Management of protected areas

The importance of protected areas has been highlighted above, with particular reference to Grévy's zebra recruitment (Williams 1998) and as dry season refuges (Ginsberg 1988; Williams 1998). In addition, they provide excellent viewing opportunities for tourists. It is therefore imperative that the reserves be managed efficiently. In order to do so, it may be necessary to review periodically the management strategies of the protected areas. These strategies may also be pertinent for 'community conservation' programmes that may have been or may be established (see below). The following points may be considered when reviewing reserve management strategies:

- **Reinvestment of revenue taken** – An important aspect of protected area management is the proportion of revenue taken by reserve authorities that is re-invested into the reserves. Such investment may include: (1) training; (2) maintenance of infrastructure; and (3) acquisition and maintenance of equipment.
- **Security** – In 1998, there were a series of attacks on tourists. The security of tourists is absolutely essential if they are to continue visiting the reserves.
- **Tourist management** – Although tourism is essential for the long-term future of the National Reserves, management of tourism is important to alleviate the potential threat that tourism represents.
- **Road management** – The road networks within protected areas may need rehabilitation and maintenance. Given that some roads provide the optimal wildlife viewing without proving a threat to the habitat and/or altering the behaviour of animals, such rehabilitation will require detailed planning.
- **Killing of wildlife** – To be effective, protected areas should be sanctuaries with no killing of wildlife.

Community conservation

If local human populations outside the protected areas work to conserve wildlife—including Grévy's zebra—then the long-term survival of these species will be secured (Wells and Brandon 1993). This is extremely important because protected areas make up less than 0.5% of the range of Grévy's zebra. Hence, land-use practices outside

protected areas will have the most significant effect on the survival of Grévy's zebra. Therefore, 'community conservation' programmes such as those that have been established with great success (e.g. Il Ngwesi and Namunyak) are strongly endorsed.

In brief, for human populations to work to conserve wildlife resources, they must benefit directly from them (Wells and Brandon 1993). In 'community conservation' programmes, local human communities have ownership—and, therefore, management rights—to wildlife populations in their region. Management or exploitation of wildlife by communities should be sustainable and not constrained except by national and international legislation. This means that local human communities may benefit directly from wildlife, which, in turn, stimulates them to conserve the wildlife. Such land use policies have a higher yield per unit area than all other land use forms—including domestic livestock management—in all but humid ecosystems. Revenue from such programmes may then be re-invested into local human development.

The first step in establishing community conservation programmes is to determine the means through which communities can benefit from the presence of wildlife. In the context of northern Kenya and southern Ethiopia today, unlike many other programmes (e.g. the CAMPFIRE programme in Zimbabwe, or programmes elsewhere in Kenya), tourism may be the only viable and sustainable means of wildlife exploitation, due to large-scale declines in numbers of many wildlife species (Grunblatt *et al.* 1989). Activities such as sport hunting should be fully assessed and wildlife populations accurately censused before such decisions are made. Similarly, harvesting of wildlife may not be viable.

Considerable experience has now accumulated in the establishment of community conservation programmes, and new programmes should draw upon previous experience. The Lewa Wildlife Conservancy, for example, has considerable experience in this field in northern Kenya, particularly in conjunction with the Il Ngwesi and Namunyak programmes. Given that tourism may be the most viable and sustainable means of exploiting wildlife in much of the range of Grévy's zebra, an efficient and economic method of establishing community conservation programmes may mean that local communities search for private investment and offer concessions to individual tourist operators.

Monitoring of numbers in the wild

The populations of Grévy's zebra in Ethiopia and Kenya should be monitored over time to determine changes in numbers. If changes in the numbers are detected then their causes should be examined and, when necessary, conservation strategies developed. The Kenya Wildlife

Service (KWS), the Kenyan Department of Resource Surveys and Remote Sensing (DRSRS), the Ethiopian Wildlife Conservation Organisation, and National Reserve authorities are responsible for monitoring. Aerial surveys for low-density mammals with aggregated distributions have proven unreliable and require ground-truthing. Alternatively, all surveys could be conducted from the ground. Mark and recapture techniques have been successfully tested by Wisbey (1995) and used in the survey of January–April 2000 for those areas where the density of Grévy’s zebra is highest. In low-density areas, estimates and/or densities may be derived by monitoring water sources and/or using point sampling.

The monitoring of populations should be focused in the following regions:

- Buffalo Springs, Samburu, Shaba National Reserves and the surrounding areas used by the southern population in Kenya. Since the population using these areas is the single largest and most stable of Grévy’s zebra in the wild, it is critical that any changes in numbers be detected.
- The Laikipia ranches to determine the degree of recruitment and immigration into the area.
- The small and potentially isolated subpopulations in the far north of Kenya, particularly those in the Laisamis and Karole regions.
- Each of the small and potentially isolated Ethiopian populations—particularly those in the Alledoghi plains and Chew Bahir regions.
- The population, or potential population in south-eastern Sudan to determine its size and importance.

2.10.2 Further research

DRSRS data

The Kenyan Department of Resource Surveys and Remote Sensing (DRSRS) has long-term data derived from aerial counts. Not only do the counts provide information on the number of Grévy’s zebra, but they also include the location of sighted animals, the number and location of domestic livestock, and the number and location of human habitations. These data relative to spatial distribution could be analysed using a Geographic Information System (GIS) to examine evidence of overlap in habitat utilisation between Grévy’s zebra, and pastoral people and their domestic livestock. Other layers of data that would be interesting to add to such analyses would include the distribution of permanent water sources and vegetation communities (from the database compiled by the Kenyan Ministry of Livestock Development and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)). Some analyses of this type have been conducted by the International Livestock Research Institute (ILRI; cf. de Leeuw *et al.* 2001).

Vegetation surveys

It may be informative to survey the vegetation of Buffalo Springs, Shaba, and Samburu National Reserves, using techniques after Barkham and Rainey (1976). Such a study would assess changes in vegetation and consider how these may have affected and will continue to affect Grévy’s zebra. This could include an assessment in the amount of grazing available to the zebra, which may have changed through heavy use by herbivores, or reduced access to grazing with increased cover of woody plants, possibly because of the long-term reduction in the numbers of browsing megaherbivores such as elephants and rhinos. In addition, any changes in the access for Grévy’s zebra, particularly lactating females, to water sources through increases in woody plants surrounding the water (e.g. at Buffalo Springs) could be assessed. Management strategies for vegetation might be suggested on the basis of such a survey. Such an initiative could be conducted by the research division of KWS, in collaboration with the reserve authorities.

Extend research to other populations

As previously discussed (section 2.9), much of the information on wild populations of Grévy’s zebra is limited to one population. Long-term work on this population would give further information on the longevity, inter-birth intervals, and patterns of movement. Research is needed, however, on all other populations of Grévy’s zebra. Proposals are currently being developed for work on the small, isolated populations of Grévy’s zebra in northern Kenya.

Reintroduction and/or reinforcing depleted populations

Range-state management plans should consider actions necessary to reintroduce animals to areas of their former range, and/or to reinforce or supplement depleted populations threatened with extinction. This may be important to develop a continuous distribution, thereby reducing the extinction threat that arises from isolation of populations.

Areas within the historic range that have a high potential to sustain Grévy’s zebra populations (e.g. Meru National Park, Kenya), but whose populations have either become extirpated or diminished, should be identified. All possible steps should be taken to prepare the sites to support viable populations of Grévy’s zebra, including fulfilling the criteria set out in the IUCN/SSC Reintroduction Specialist Group’s Guidelines for Reintroductions (IUCN/SSC Reintroduction Specialist Group 1995). By taking such steps, there will be significant diminution of the threats to Grévy’s zebra.

At present, the Grévy’s zebra in the Lewa Wildlife Conservancy is the only viable source population for such translocations.

Consumptive use of Grévy's zebra

The consumptive use of Grévy's zebra in the form of hunting or culling is not recommended. Such use may be prevented if the status of Grévy's zebra in Kenya is amended to that of a Protected Animal. Until then, the species should remain off any quotas or hunting lists.

Captive populations

- **No removal of animals from the wild to increase the captive population.** It has been stressed in this Action Plan that animals should not be removed from wild populations. This includes the translocation of animals into sanctuaries or other fenced areas in Kenya, particularly on the Laikipia Plateau, or into areas away from the present range of Grévy's zebra. Such actions would effectively increase the size of captive populations, which is not necessary. If, however, the genetic diversity of a captive population should need to be increased, this could be easily achieved by collecting the semen of wild Grévy's stallions that is ejected by females post-copulation (S.D. Williams, personal observation; Ginsberg and Rubenstein 1990). It could then be frozen in liquid nitrogen, and later used to artificially inseminate captive mares. The viability of this method would need to be tested, but in principle this would be more acceptable than removal of animals from the wild.
- **The numbers of animals within the captive population should be monitored.** The studbook for captive Grévy's zebra continues to be maintained by Marwell Zoological Park. The studbook keeper (Tanya Langenhorst at Marwell; e-mail: Tanyal@marwell.org.uk) should ensure that all information on captive Grévy's zebra, including those in Laikipia and other sanctuaries in Kenya, is collected and updated. These data (total numbers; numbers of males, females, and juveniles; year of establishment; years in which captive Grévy's zebra have been held; breeding history of zebras) could be provided to the studbook keeper by the sanctuaries themselves.
- **The captive populations should be managed as a metapopulation.** The Husbandry Guidelines for Equids provides a valuable tool for management.
- **The dangers of artificial selection should be studied.** Among the zoo population of Grévy's zebra, there may be dangers of artificial selection for characteristics that would probably not be advantageous for reintroduced animals. For example, the most docile and aesthetically attractive males are often selected as breeding males (U. Rademacher pers. comm.). However, studies are needed to determine whether such characteristics (e.g. disposition, testosterone levels, stress-induced aggression, etc) are heritable, and, consequently, whether these characteristics are being bred into the captive population.

2.11 Proposed projects

1. Grévy's Zebra Survey: Ethiopia 2003

This is an aerial and ground survey, aimed to complement that undertaken in Kenya (see above), that is planned for January–March 2003. This will update information provided by aerial surveys carried out in 1995 (Thouless 1995a, 1995b). The survey will effectively complete the surveys of all known populations of Grévy's zebra. It will be carried out by Stuart Williams and Fanuel Kebede from the Ethiopian Wildlife Conservation Organisation.

2. Ecology, behaviour, and conservation of northern Kenyan subpopulations

This is a long-term programme that would have four main areas of research: (1) the ecology and behaviour of the small, isolated populations of Grévy's zebra found in the far north of Kenya; (2) a continuation of the long-term study of Grévy's zebra in the southern part of their range in Kenya; (3) the cultural relationship between pastoral people and wildlife and the people's use of wildlife in northern Kenya; and (4) the potential for and eventual implementation of a community conservation programme in northern Kenya. The proposal for this programme is being completed at the time of writing and will be seeking funding shortly. The aim is to commence the programme by January 2004.

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Status and Action Plan for the Mountain Zebra (*Equus zebra*)

Peter Novellie, Malan Lindeque, Pauline Lindeque, Peter Lloyd and Julius Koen

3.1 Nomenclature and conservation status

Scientific name:

Equus zebra L. 1758

Equus zebra zebra L. 1758

Equus zebra hartmannae Matschie 1898

Common names:

Mountain zebra

Indigenous names:

Dauwa (Xhosa) Dou (San), Ngorlo-hambarundu (Herero),
Nu ! khrob, Nu ! go: reb (Nama)

IUCN Red List Category (version 2.3):

Equus zebra EN Endangered A1b

E. z. zebra EN Endangered C2a

E. z. hartmannae EN Endangered A1a

CITES listing:

E. z. zebra Appendix I

E. z. hartmannae Appendix II

3.2 Biological data and distribution

Historically, mountain zebras ranged from the southern parts of South Africa through Namibia into the extreme

south west of Angola. Two subspecies are recognised – Hartmann’s mountain zebra (*Equus zebra hartmannae* Matschie 1898) and Cape mountain zebra (*E. z. zebra* L. 1758) – on the basis of the following differences:

1. Hartmann’s mountain zebras are a little larger than the Cape subspecies,
2. Cape mountain zebra in general have wider black stripes than the Hartmann’s mountain zebra,
3. the Hartmann’s mane comes further forward between the ears than that of the Cape mountain zebra.

Those who are familiar with mountain zebras can distinguish with confidence between the two subspecies on the basis of these external characteristics.

The ecology and behaviour of the species has been well documented, and readers are referred to Penzhorn (1988), Novellie *et al.* (1992), and Novellie *et al.* (1996) for overviews. *E. z. zebra* dwindled to a few relict populations in South Africa as a result of 19th century hunting excesses and loss of habitat to agriculture, and numbers are now being gradually built up through active conservation programmes. In contrast, *E. z. hartmannae* still occurs throughout its historical range, at least in low densities.

Figures 3.1 to 3.3 show the historic and present ranges of the two subspecies. We postulate that in historic times the ranges of the two subspecies were separated by an area devoid of mountainous habitat, which occurs between the northernmost point of the Cedarberg and Bokkevelberg ranges, and the southernmost point of the Kamiesberg



The mountain zebra (*Equus zebra*).

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range in the Northern Cape. This large plain, constituting unsuitable or marginally suitable habitat for mountain zebras, is about 70km wide at its narrowest point. It may have retarded the flow of genes between those of the mountain zebras occurring in present-day Namibia and

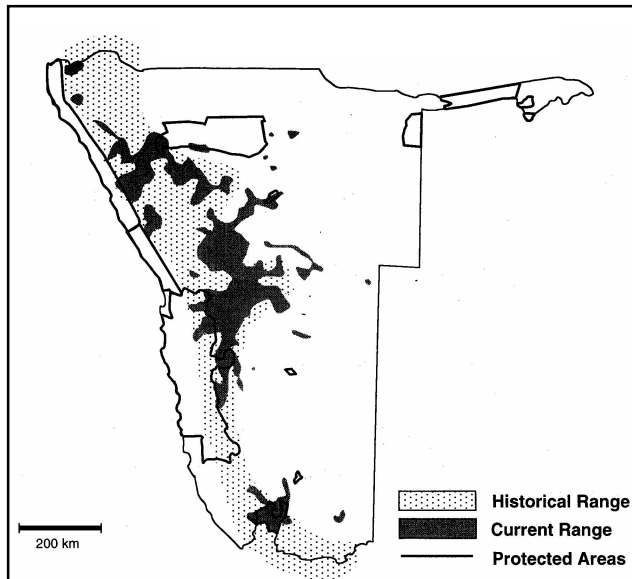


Figure 3.1. Historic and current distribution of Hartmann's mountain zebra (*Equus zebra hartmannae*) in Namibia.

the Namaqualand region of South Africa (Hartmann's subspecies), and those of the south-western parts of South Africa (the Cape subspecies). We refer to this postulated break in distribution as the Kamiesberg Gap.

In Namibia the current range of Hartmann's mountain zebras differs from the historical range, partly because widespread establishment of artificial water points has allowed it to occupy previously unsuitable habitat (Figure 3.1). Today the Cape mountain zebra is restricted to fenced protected areas and game farms (Tables 3.1–3.3), so its distribution is more fragmented than in historical times.

The IUCN Red List of Threatened Animals (Baillie and Groombridge 1996) lists the species *Equus zebra* in the Endangered category. *E. z. zebra* is listed in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix I, while *E. z. hartmannae* is listed in CITES Appendix II.

3.3 Agencies responsible for the conservation of mountain zebras

The conservation of the mountain zebra is potentially complicated by the fact that it occurs in two countries, Namibia and South Africa, and in each country a number of conservation agencies are involved. It is possible for these two countries to make use of regional

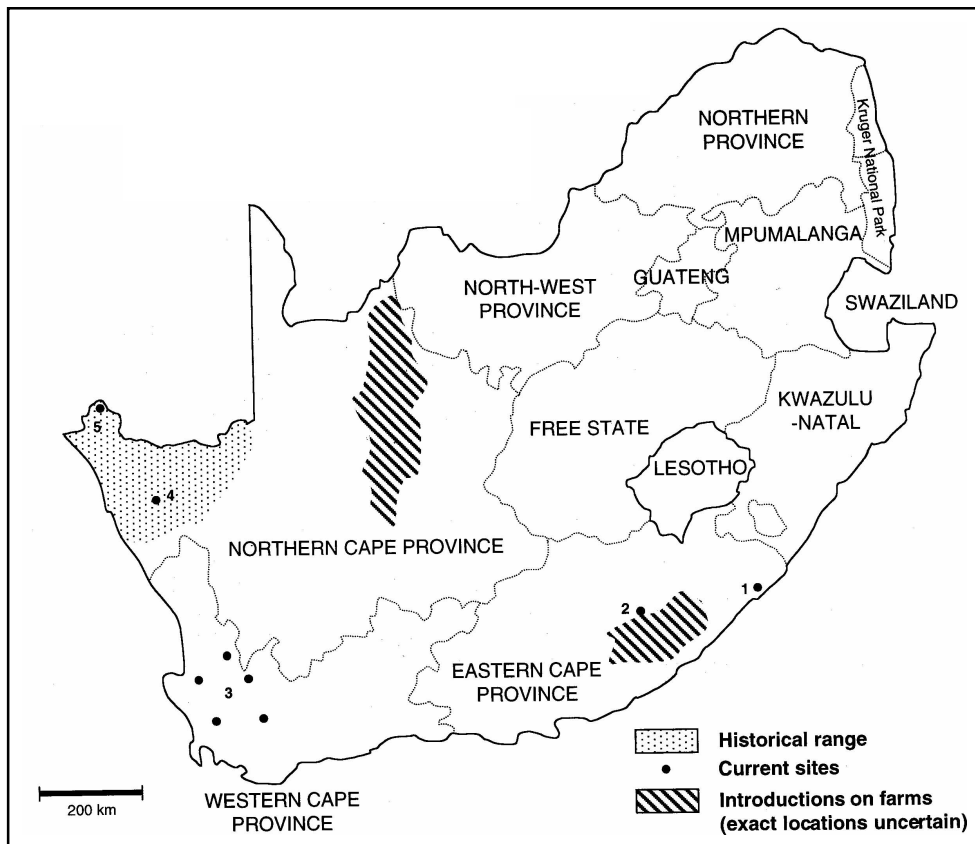


Figure 3.2. Historic and current distribution of Hartmann's mountain zebra (*Equus zebra hartmannae*) in South Africa.

1. Mkambati PNR
 2. Amaqwati TRA
 3. Private owners in Western Cape
 4. Goegap PNR
 5. Richtersveld NP
- PNR = Provincial Nature Reserve
NP = National Park
TRA = Tribal Resource Area

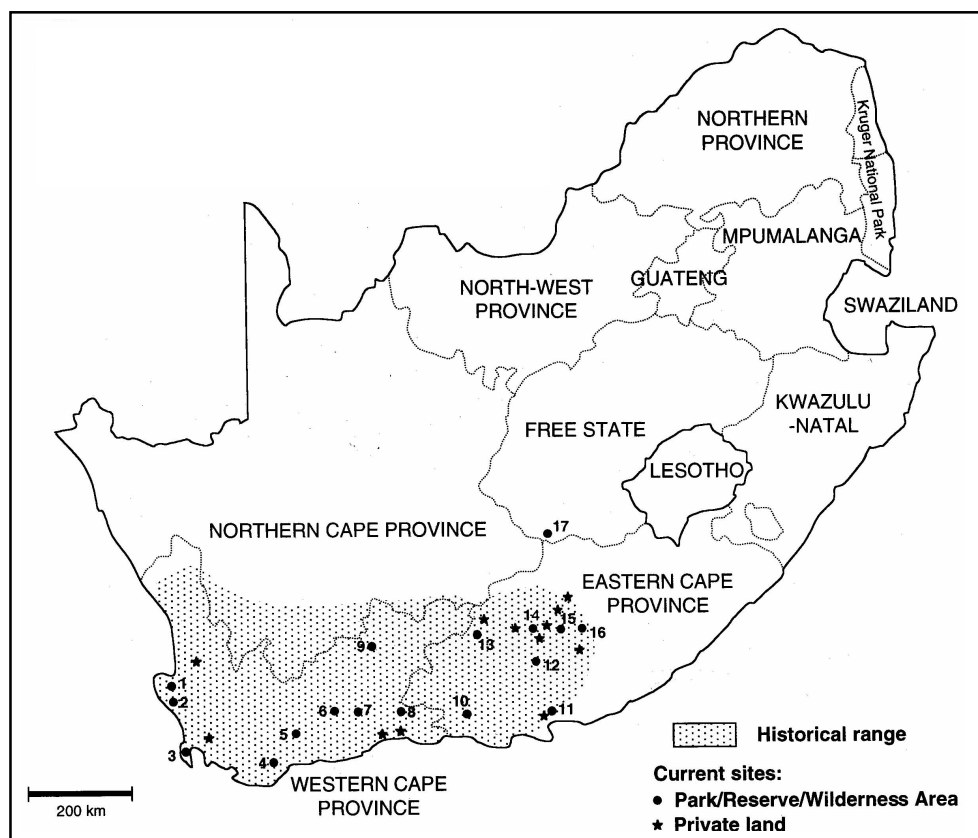


Figure 3.3. Historic and current distribution of the Cape mountain zebra (*Equus zebra zebra*) in South Africa.

1. Saldanha CPNR
 2. West Coast NP
 3. Cape Peninsula NP
 4. De Hoop PNR
 5. Bontebok NP
 6. Ladismith MNR
 7. Gamka Mountain PNR
 8. Kammanassie PNR
 9. Karoo NP
 10. Baviaanskloof WA
 11. Addo Elephant NP
 12. Bosberg MNR
 13. Karoo PNR
 14. Mountain Zebra NP
 15. Commando Drift PNR
 16. Tsalwana PNR
 17. Gariep Dam PNR
- CPNR = Contract Provincial Nature Reserve
PNR = Provincial Nature Reserve
NP = National Park
MNR = Municipal Nature Reserve
WA = Wilderness Area

mechanisms within the Southern African Development Community to coordinate conservation efforts and harmonise conservation strategies concerning this species.

In Namibia, responsibility for conservation of mountain zebras is shared between the central government and a number of registered conservancies on communal land, while a significant proportion of mountain zebras occur on freehold land and are *de facto* owned by the landholder. In South Africa, mountain zebras are found in four provinces, each of which has its own conservation agency, and also in national parks, which fall under the jurisdiction of the central government. Each South African agency has its own policy and legal provisions for conservation. It is therefore helpful to begin by listing the different agencies in Namibia and South Africa.

The situation is further complicated by changes in the South African conservation agencies that came about with the 1994 general election. To place this chapter in relation to previous reports (Novellie *et al.* 1992; Novellie *et al.* 1996) it is necessary to describe these changes.

3.3.1 Cape mountain zebras

Before 1994, the following South African conservation agencies were responsible for the conservation of Cape mountain zebras:

- National Parks Board, a statutory body responsible for South Africa's National Parks;
- Cape Provincial Directorate of Nature and Environmental Conservation (CDNEC), responsible for all categories of protected areas except national parks, and also for conservation on privately owned land;
- Conservation agency of the Ciskei homeland;
- Conservation agency of the Orange Free State (with one population introduced outside the historical range in 1985, Table 3.2).

As a result of the changes in the provincial system introduced with the new South African constitution, CDNEC has been divided into three separate agencies: Cape Nature Conservation (Western Cape Province), Northern Cape Nature Conservation Services, and Eastern Cape Nature Conservation Services. The reserves of the old Ciskei homeland are now run by the Eastern Cape Nature Conservation Services. The Free State remained unchanged as a province, and its conservation agency is now called the Free State Department of Environmental Affairs and Tourism. The reserves administered by each of these agencies are shown in Table 2.

It is also relevant to note some recent changes to the South African national park system. National parks are administered by South African National Parks (the new name for the old National Parks Board). The old Zuurborg

National Park has been linked to the Addo Elephant National Park by means of land purchases. The park is now known by the latter name and the name Zuurberg National Park is no longer used. The Cape of Good Hope Nature Reserve, previously run by a local authority, is now part of the new Cape Peninsula National Park.

3.3.2 Hartmann's mountain zebras

In South Africa, the agency primarily responsible for *E. z. hartmannae* is Northern Cape Nature Conservation Services (NCNCS). Cape Nature Conservation and Eastern Cape Nature Conservation Services are also involved because populations of Hartmann's mountain zebras have been introduced into these provinces, even though they never occurred there in historical times. A small number of Hartmann's mountain zebras (about ten to 15) are present in the Richtersveld National Park (South African National Parks), which borders on Namibia.

In Namibia, the responsible agency is the Ministry of Environment and Tourism (MET). On a less formal basis, extensive management responsibility over *E. z. hartmannae* in Namibia has been transferred from central government to registered conservancies on communal land within the range of the subspecies, that is the Torra and Khoadi/Hoas Conservancies. Several other conservancies in the Kunene and Erongo regions (representing parts of the former Damaraland and Kaokoveld) are in the process of registration and will effectively cover the entire range of Hartmann's mountain zebras in north-western Namibia. Conservancies are registered on the basis of an undertaking that wildlife resources will be sustainably managed and as such, present considerable conservation advantages. Conservancies typically become responsible for short-term or local monitoring of wildlife populations, allocating land and other resources to wildlife populations and participating in or managing community game-guard systems. MET authorises off-takes on the basis of quota submissions from conservancies and on population monitoring conducted by MET.

3.4 Current status, trends and conservation measures

3.4.1 Cape mountain zebras

In the early part of the twentieth century, numbers of Cape mountain zebras were declining, and by the 1930s the subspecies was confined to five localities:

- mountains west of Cradock;
- Kouga-Baviaanskloof mountains;
- Outeniqua mountains;
- Gamka mountains; and
- Kammanassie mountains.

Three of the five surviving populations occurred on areas of government-owned land protected by the Forest Act of that time, and these later became provincial nature reserves, namely the Kammanassie (Provincial) Nature Reserve (established 1923), the Outeniqua (Provincial) Nature Reserve (established 1936), and the Baviaanskloof Wilderness Area (established 1923). In 1937, the Mountain Zebra National Park (MZNP) was proclaimed to protect the Cradock population. Finally, the Gamka Mountain (Provincial) Nature Reserve was established in 1971, thereby affording better protection to the fifth naturally surviving population. The Outeniqua and Baviaanskloof populations went extinct – the former in the early 1970s, and the latter in the early 1980s – probably because excessive numbers were captured for translocation elsewhere and because poaching was not fully controlled. The remaining three populations still exist today. The Baviaanskloof Wilderness Area was later restocked with mountain zebras originating from the Mountain Zebra National Park, and the Outeniqua Nature Reserve is a high priority for restocking in the near future.

The dynamics of the Cape mountain zebra metapopulation since the 1920s have been reasonably well documented (Hornaday and Haagner 1922; Bigalke 1956; Skead 1956; Millar 1970a, 1970b; Lloyd 1984; Novellie *et al.* 1992; and Novellie *et al.* 1996).

Trends in the Cape mountain zebra metapopulation are now monitored jointly by Cape Nature Conservation and South African National Parks. A database of all these populations – which includes contact details of the responsible authorities and owners, number of individuals reintroduced, and date of reintroduction – is being maintained. Since 1984, the database has been updated every two to five years by contacting all responsible authorities and obtaining the latest census results, observations on population performance, as well as details of any animals that were translocated to other areas. Censuses and database updates were conducted in 1984, 1985, 1990, 1993, 1995, and 1998.

Despite the establishment of the protected areas during the 1920s and 1930s, the Cape mountain zebra metapopulation continued to decline until the 1950s (Figure 3.4). Thereafter, numbers began increasing, particularly after the expansion of the Mountain Zebra National Park in 1964, an expansion that permitted the incorporation of a number of mountain zebra groups occurring on neighbouring private farms (Penzhorn 1975). During the 1960s and 1970s the population in the MZNP increased to the point where individuals could be translocated to reserves in other parts of the historical range of the subspecies; first to the De Hoop (Provincial) Nature Reserve and later, during the 1980s and early 1990s, to 25 other protected areas and game ranches (Tables 3.1–3.3). The majority of Cape mountain zebras are in publicly owned protected areas, mostly national parks and

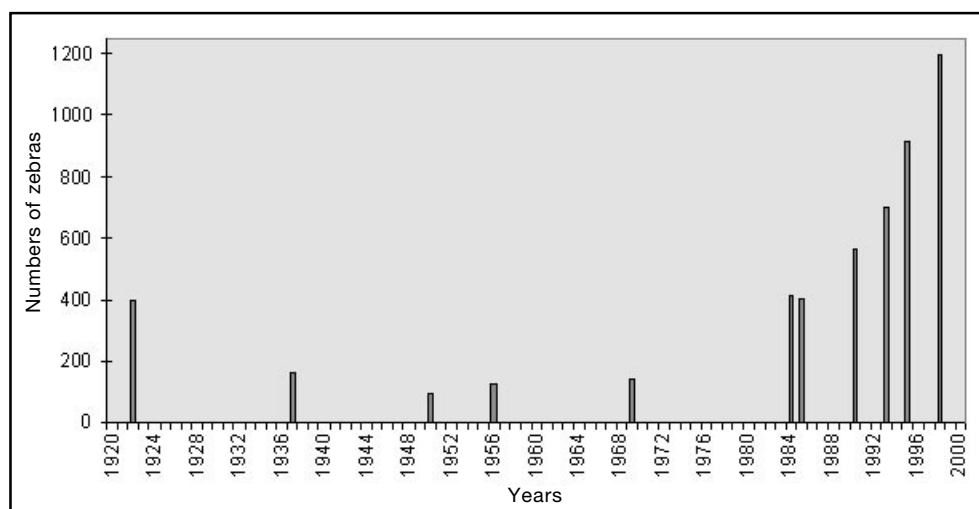


Figure 3.4. The Cape mountain zebra metapopulation: 1922 to 1998.

Data for the period 1922 to 1984 from Lloyd (1984).

provincial nature reserves, but the numbers maintained by private landowners have increased considerably in recent years (Table 3.3).

The average annual rate of increase of the Cape mountain zebra metapopulation from 1985 to 1995,

reported by Novellie *et al.* (1996), was 8.6%. The annual rate in recent years (1995 to 1998) was slightly higher at 9.6% (see also Figure 3.4).

Novellie *et al.* (1996) categorised the performance of the different Cape mountain zebra populations as being

Table 3.1. Numbers of Cape mountain zebra in national parks from 1985–1998.

Reserve/Owner	Reintroductions Year	No.	Source	Pop. 1985	Pop. 1990	Pop. 1993	Pop. 1995	Pop. 1998	Performance
MZNP	o.n.		o.n.	160	178	230	215	210	Good
KRNP	1978	16							
	1979	7							
	1980	13							
	1984	5	MZNP	80	76	85	120 ¹	250	Good
	1995	25							
	1998	10							
	Total	76							
AENP	1985	5							
	1986	5							
	1989	9							
	1993	10	MZNP/KRNP	-	16	9	40	50	Poor
	1994	21							
	Total	50							
BNP Area: 28km²	1986	3							
	1990	7							
	1993	2	MZNP/KRNP	-	9	12	24	17	Poor
	1994	6							
	1997	6							
	Total	24							
WCNP	1995	5							
	1997	7	MZNP	-	-	-	-	8	Poor
	Total	12							
CPNP Area: 78km²	1986	5							
	1990	2	MZNP/KRNP	-	6	5	6	7	Poor
	Total	7							
Total				240	285	341	405	542	

Reintroductions: Year and no: year = year of each reintroduction; no. = the numbers of zebras released. o.n. = population occurred naturally in the area.
Source = reserve/s from which the reintroduced animals were obtained. **Performance:** good if the introduced population increased; poor if it remained stable or decreased. MZNP = Mountain Zebra National Park; KRNP = Karoo National Park; AENP = Addo Elephant National Park (including the old Zuurberg National Park); BNP = Bontebok National Park; WCNP = West Coast National Park; CPNP = Cape Peninsula National Park. Park areas are given in km².
¹ The increase from 1995 to 1998 is abnormally high, and possibly reflects census errors (see text).

“good” if they had increased after establishment, and as “poor” if the numbers remained stable or decreased. At the time of the 1995 census there were 24 reintroduced populations. Of these, the performance of 12 was rated as good, eight were poor, and four were too recently established to be evaluated. One of the main reasons for the poor performance of some of the groups was that insufficient numbers were reintroduced (Novellie *et al.* 1996).

The 1998 census revealed few changes to the 1995 situation (Tables 3.1–3.3). None of the populations that were in the “poor” category in 1995 showed any signs of increasing. One population, in the Bosberg Mountain Municipal Reserve, is now extinct. As noted, most of these poor performers are small populations and this is a probable reason for their lack of success. One exception to this is the population in the Zuurberg section of the Addo Elephant National Park, where a total of 50 animals was brought in over a number of years. Despite this substantial reintroduction, the population has apparently remained around 50. The grassland of the summits of the Zuurberg is nutrient poor, and it is possible that this has limited population growth. The habitat in the Kouga-

Baviaanskloof resembles that of the Zuurberg, and nutrient-poor soils may be a problem there as well. The 12 zebras reintroduced into the Kouga-Baviaanskloof in 1990 had increased to only 16 by 1998, when they were supplemented by 14 zebras from the Gariep Dam Nature Reserve (previously Verwoerd Dam). Game-proof fencing in these mountainous protected areas is a problem, and in both the Zuurberg and the Kouga-Baviaanskloof, a few of the reintroduced animals departed and established themselves on neighbouring private land. More accurate census results are also required. The current estimate of 50 animals in the Zuurberg is based on ground counts by rangers, and may be inaccurate given the very rugged terrain. It is recommended that a systematic air census be undertaken to check on the population total.

For the Karoo National Park, the apparent increase from 120 animals in 1995 to 250 in 1998 (Table 3.1) may be due to census errors. Given the fact that the population was supplemented with ten animals from the Mountain Zebra National Park in 1998, the census figures, if accurate, suggest an annual rate of increase of about 26% per year. This is not impossible – the population at the Commando

Table 3.2. Numbers of Cape mountain zebra in provincial nature reserves from 1985–1998.

Reserve/Owner	Reintroductions Year	No.	Source	Pop. 1985	Pop. 1990	Pop. 1993	Pop. 1995	Pop. 1998	Performance
DHNR (CNC) Area: 550km ²	1963	1	MZNP/KMNR	25	30	35	55	54	Good
	1964	1							
	1966	1							
	1970	3							
	1971	5							
	1972	2							
	1975	1							
	Total	14							
GMNR (CNC) Area: 94km ²	o.n.		o.n.	19	16	17	21	23	Good
KMNR (CNC) Area: 245km ²	o.n.		o.n.	12	19	25	22	31	Good
KNR (ECNS) Area: 165km ²	1981	20	MZNP	33	60	70	94	120	Good
CDNR (ECNS) Area: 51km ²	1984	7	MZNP	7	16	30	46	85	Good
BWA (ECNS) Area: 1,775km ²	1990	12	KRNP/GDNR	-	12	12	16	30	Good
	1998	14							
	Total	26							
TNR (ECNS) Area: 85km ²	1981	20	MZNP	33	49	54	62	90	Good
GDNR (FSDEAT) Area: 60km ²	1985	9	MZNP/KRNP	4	26	47	65	58	Good
	1989	10							
	1997	5							
	Total	24							
Total				133	228	290	381	491	
Reintroductions: Year and no: year = year of each reintroduction; no. = the numbers of zebras released. o.n. = population occurred naturally in the area. Source = reserve/s from which the reintroduced animals were obtained. Performance: good if the introduced population increased; poor if it remained stable or decreased. DHNR = De Hoop Nature Reserve; GMNR = Gamka Mountain Nature Reserve; KMNR = Kammanassie Nature Reserve; KNR = Karoo Nature Reserve; CDNR = Commando Drift Nature Reserve; BWA = Baviaanskloof Wilderness Area; TNR = Tsolwana Nature Reserve; GDNR = Gariep Dam Nature Reserve (previously called Verwoerd Dam). CNC = Cape Nature Conservation (Western Cape Province); ECNS = Eastern Cape Nature Conservation Services; FSDEAT = Free State Department of Environmental Affairs and Tourism; MZNP = Mountain Zebra National Park; KRNP = Karoo National Park. Reserve areas are given in km ² .									

Table 3.3 Numbers of Cape mountain zebra in reserves other than national parks and provincial nature reserves from 1985–1998.

Reserve/Owner	Reintroductions:		Source	Pop.	Pop.	Pop.	Pop.	Pop.	Performance
	Year	No.		1985	1990	1993	1995	1998	
SCPNR	1995	3	MZNP	-	-	-	3	1	Poor
BMNR	1985	4	MZNP	-	3	3	2	0	Poor
	1987	1							
	Total	5							
LMNR	1986	5	MZNP	-	1	1	0	0	Poor
BL ZOO	1985	4	MZNP	3	2	0	0	0	Poor
	1988	1							
	Total	5							
SOMCHEM	1986	7	MZNP	-	12	17	22	25	Good
Cawood	1983	10	MZNP	7	16	19	14	20	Good
	1984	3							
	Total	13							
Halse	1984	3	MZNP	9	7	9	15	20	Good
	1985	6							
	Total	9							
Moorcroft	1983	4	MZNP	7	5	5	5	8	Poor
	1984	4							
	1985	3							
	Total	11							
Murray	1985	1	MZNP	2	3	6	6	7	Poor
	1986	5							
	Total	6							
Scott	1985	4	MZNP	4	3	2	5	6	Poor
	1986	3							
	Total	7							
Lombard	1992	11	MZNP	-	-	11	21	19	Good
Marais/Flack	1993	11	MZNP	-	-	-	13	26	Good
Van Zyl	1993	7	MZNP	-	-	-	16	13	Good
	1994	5							
	Total	12							
Reins Private Reserve	1996	5	VAN ZYL	-	-	-	-	5	-
Macadam	1996	10	LOMBARD	-	-	-	-	13	-
De Waal	1990	2	AENP	-	-	2	2	2	-
Burger	1997	5	GDNR	-	-	-	-	0	Poor
Total				32	52	75	124	165	

Reintroductions: Year and no: year = year of each reintroduction; no. = the numbers of zebras released. o.n. = population occurred naturally in the area. **Source** = reserve/s from which the reintroduced animals were obtained. **Performance:** good if the introduced population increased; poor if it remained stable or decreased. SCPNR = Saldanha Contract Provincial Nature Reserve (South African National Defence Force); BMNR = Bosberg Municipal Nature Reserve (Somerset East); LMNR = Ladismith Municipal Nature Reserve; BI Zoo = Bloemfontein Zoo; SOMCHEM = Kranskop Reserve (Somchem/Denel); Cawood = Mrs. P. Cawood; Halse = Mr R. Halse; Moorcroft = Mr E Moorcroft; Murray = Mr W. Murray; Scott = Mr C. Scott; Lombard = Mr H. Lombard; Marais/Flack = Mr L. Marais and Mr P. Flack; Van Zyl = Mr D. Van Zyl; Reins Private = Reins Private Nature Reserve; Macadam = Mr W. Macadam; De Waal = Mr De Waal; Burger = Mr P.A.B. Burger; MZNP = Mountain Zebra National Park; AENP = Addo Elephant National Park; GDNR = Gariep Dam (Provincial) Nature Reserve.

Drift Nature Reserve increased at a rate close to 25% per year from 1990 to 1995 (Table 3.2) – but it would be abnormally high. The 1995 value of 120 was based on ground counts, which are likely to underestimate the population, whereas the 1998 result was based on an aerial survey, which probably yields a slight overestimate (G. Castley, Scientific Services, South African National Parks, pers. comm.).

The population in the Bontebok National Park has performed poorly in recent years, declining from 24 in 1995 to 17 in 1998, despite the introduction of six more zebras from the Mountain Zebra National Park in 1997. The reason for this decline is unknown. Some animals in the population have large warty skin growths, caused by a sarcoid virus, but since this condition does not normally have fatal consequences and is not highly contagious, it

seems unlikely that this could have caused the population decline (P. Morkel, Veterinary Ecologist, South African National Parks, pers. comm.). The same, or a very similar, infection has been reported in some individuals in the Gariep Dam and the De Hoop (Provincial) Nature Reserves. There were no reports of skin growths from any of the other populations.

The Gariep Dam population has performed very well, with the slight decline in numbers from 1995 to 1998 largely due to removals for reintroduction into other areas. The population in the De Hoop Nature Reserve is also doing well, with 65 animals in 1999, as is the Kammanassie population with more than 30 animals. The population in the Gamka Mountain Nature Reserve suffered losses when a few individuals were killed in a fire, but more than 20 are known to remain.

Of the populations reintroduced between 1993 and 1995 (Tables 3.1 and 3.3), two have performed very well (those of Mr Van Zyl and Mr Marais), while the third (SANDB at Saldanha) declined, with only one animal remaining of the three that were released. It is doubtful whether the habitat in the latter area is suitable, so further introductions are not recommended.

Since 1995, four additional reintroduction attempts have been made, all to private reserves (Table 3.3). In one case, all five introduced animals were found dead soon after reintroduction, possibly because they ate poisonous plants. In the other three cases, the zebras have settled down but have not yet had time to increase significantly. It is noteworthy that two of these new populations resulted from sales of animals by private owners (the sellers were Mr Lombard and Mr van Zyl). These were the first sales by the private sector, the great majority of other populations having originated from the Mountain Zebra and/or Karoo

National Parks. Further sales by private owners are expected to take place during 1999. While it is vital to maintain a substantial proportion of the world population of Cape mountain zebras in publicly owned conservation areas, the role of the private sector is potentially valuable and should be encouraged.

3.4.2 Hartmann's mountain zebras in Namibia

Protected areas

E. z. hartmannae occurs in four protected areas larger than 1,000km² (Skeleton Coast Park, Etosha National Park, Namib-Naukluft Park, and Ai-Ais-Hunsberg Park complex) (Ministry of Environment and Tourism, Namibia, pers. comm., 2000). The total population in these four protected areas in 1997–1998 has been estimated at 3,639 (Table 3.4). Lesser numbers occur in smaller parks (Hardap Game Park and Daan Viljoen Game Park). The Namib-Naukluft Park, and particularly the approximately 2,000km² Naukluft part, is by far the most important protected area for mountain zebra, with a population of approximately 2,338 in 1998 (Gibson 1998). Other protected areas in Namibia contain limited mountain zebra habitat due to the scarcity of surface water and/or rocky terrain.

Conservancies on communal land

Approximately 6,413 Hartmann's mountain zebras occur on communal lands in the Kunene and Erongo regions of north-western Namibia (Table 3.4). Some 7,000km² of mountain zebra habitat already form part of registered conservancies (Torra c.3,500km², Khoadi/Hoas

Table 3.4 1997/1998 Minimum national estimates of Hartmann's mountain zebra in Namibia.

Area	Estimate	95% CL	Range
Kunene region (communal land) ¹ asks that the size of the area be included	6,413	48.4	3,310–9,516
Commercial farms (north of 22°S west of 17°E and north of 23°S east of 17°E) ¹	8,097	37.2	5,088–11,106
Etosha National Park ¹	317	57.7	134–500
Namib Naukluft Park (excluding Naukluft mountains) ²	599	118.5	27–520
Naukluft ³	2,338	45.6	1,272–3,404
Hunsberg ³	385	64.2	138–632
Bethanie commercial farms ⁴	146	-	146
Gobabis commercial farms ⁴	130	-	130
Karasburg commercial farms ⁴	264	-	264
Lüderitz commercial farms ⁴	188	-	188
Maltahöhe commercial farms ⁴	615	-	615
Mariental commercial farms ⁴	4	-	4
Rehoboth commercial farms ⁴	37	-	37
Windhoek commercial farms ⁴	5,526	-	5,526
Total	25,059		16,879–32,588

¹ Aerial census of northern Namibia – 1998 (Craig 1999).

² 1997 aerial census of the southern Namib (Killian *et al.* 1999).

³ Aerial surveys of Hartmann's mountain zebra and other animals in the Naukluft and Hunsberg (Gibson 1998).

⁴ National wildlife questionnaire survey for the period 1 January–31 December 1997 (Kolberg and Lindeque 1999).

c.3,400km²) with at least a similar area represented in several emerging conservancies in the Ugab, Uniab, Huab, Koichab, Hoanib-Ombonde, and Hoarusib catchments. It is thus highly likely that the entire core mountain zebra habitat in north-western Namibia will become incorporated within conservancies.

Farmland

A minimum of 6,910 Hartmann's mountain zebras occurs on freehold farms in the commercial areas of Namibia (based on the 1997 farm questionnaire survey of MET (Kolberg and Lindeque 1999)). The large majority of farms are managed primarily for domestic livestock production with co-occurring wildlife or with fenced areas of at least 1,000ha or larger set aside as 'game camps'. Mountain zebras are frequently in competition with domestic livestock on farms and are regarded as a nuisance species by many landholders. MET is in the process of conducting a national census of mountain zebras (as part of a CITES project funded partly by the CITES Management Authority of Switzerland and Total Namibia) and has completed the northern half of the country, as well as key habitat in the southern half. Some 300,000km² of farmland in the South still has to be surveyed, 10% of which could represent mountain zebra habitat. The estimate for farmland of 8,097 (5,088–11,106) mountain zebras in Table 3.4 should therefore be considered a minimum figure (Craig 1999). Estimates derived from questionnaire surveys in 1997 suggest a population of approximately 12,636 mountain zebras on farmland (19% questionnaire returns) compared to 19,690 in 1992 for a proportionally larger number of farms (30% questionnaire returns) (see Table 3.5), but such estimates are not directly comparable.

Conservancies have also been established in commercial farming districts, including one in the Khomas region, which holds about 20% of the national Hartmann's mountain zebra population. The Khomas Hochland Conservancy covers approximately 1,700km², representing most of the core mountain zebra range in the Khomas area. Conservancies on commercial farmland can be expected to play an increasingly important role in the protection of mountain zebra habitat.

Other state land

Shortridge (1934) included the southern Namib Desert in the distribution range of Hartmann's mountain zebras, but the scarcity of surface water in the area now known as the Sperrgebiet (or Diamond Area No. 1) must have severely restricted their density and distribution (Lindeque and Lindeque 1995). No mountain zebras were observed in the 1997 aerial survey of Diamond Area No. 1 or the southern part of the Namib-Naukluft Park (Killian *et al.* 1999), but small groups might have been missed.

National and international policy and legal protection

Hartmann's mountain zebra is classified as a Protected Species in Namibia, with all forms of use and trade subject to permit control. Proposed revised policy and legislation will reinforce this classification, place greater emphasis on habitat conservation of endemic forms, and strengthen the management rights and responsibilities applicable to conservancies and game-fenced areas.

Hartmann's mountain zebra is listed in CITES Appendix II. Namibia is the major source of specimens in international trade, either as hunting trophies or personal effects (e.g. tanned skins sold by registered dealers). MET

Table 3.5. The uncorrected number of Hartmann's mountain zebra reported in the commercial farming districts obtained from the 1972, 1982, 1992, and 1997 wildlife questionnaire surveys.

(The values in this table have not been adjusted for the varying numbers of questionnaire returns received back through the years.)

	1972 (61% returns)	1982 (51% returns)	1992 (30% returns)	1997 (19% returns)
Tsumeb	0	10	200	90
Outjo	2,300	2,500	1,800	1,227
Grootfontein	0	90	100	41
Omaruru	1,400	1,700	2,600	1,135
Otjiwarongo	50	200	400	328
Okahandja	300	400	400	600
Karibib	2,200	2,400	5,300	2,305
Windhoek	4,700	4,200	6,500	5,563
Gobabis	0	20	100	130
Maltahöhe	3,200	1,400	1,800	615
Mariental	0	30	100	4
Lüderitz	1,300	-	50	188
Bethanie	800	400	100	146
Keetmanshoop	0	60	200	0
Karasburg	200	10	40	264
Total	16,450	13,420	19,690	12,636

Table 3.6. WCMC CITES trade data on Hartmann's mountain zebras from Namibia. Approximate numbers traded from 1988 to 1997. Namibian Ministry of Environment and Tourism data from 1992–1997.

Year	WCMC	Namibia
1988	454	
1989	605	
1990	462	
1991	1,325	
1992	1,340	1,035
1993	1,553	1,257
1994	1,554	1,060
1995	2,182	1,257
1996	1,821	1,677
1997	3,000	2,667

actively encourages the use of mountain zebra populations on farmland in particular, in view of serious conflicts over grazing and scarce water sources during droughts and in hyper-arid farming areas. The current level of off-take is under review, and off-takes on certain farms may become subject to a quota system or another form of hunting restriction. Trade off-take from 1988 to 1997 is shown in Table 3.6.

Conclusions: population status in Namibia

The current partial national population estimate for Namibia is the first such estimate based primarily on aerial surveys rather than reports from landholders. As such, no trend can be inferred from these estimates. It should nevertheless be evident that the Namibian population of Hartmann's mountain zebras is relatively large, and occurs in a large area and across a variety of land tenure systems. Only about a quarter of the estimated population occurs within formally proclaimed conservation areas, and principally the Naukluft part of the Namib-Naukluft Park. Of particular importance, however, is the occurrence of 25% of the national population on conservancies in communal lands, with the remainder on commercial livestock and game farms.

The subspecies *E. z. hartmannae* is not listed on the IUCN Red List (Baillie and Groombridge 1996), but the species *Equus zebra* is considered Endangered on the basis of a suspected population decline of at least 50% in ten years or three generations (Table 1 in Baillie and Groombridge 1996). Novellie *et al.* (1992) stated that numbers of Hartmann's mountain zebras had seriously declined in Namibia, but there were insufficient data to determine the magnitude of the decline. Although trends cannot reliably be inferred from Table 3.5, the results appear to be at variance with the idea of a 50% decline over the past ten years. The issue will remain in doubt until the overall population trend can be established more reliably. The national census that is currently under way will provide a good basis for this.

3.4.3 Hartmann's mountain zebras in South Africa

Northern Cape Province

Virtually all the South African *E. z. hartmannae* populations were originally reintroduced from Namibian stock. The data on the status of the population in the Northern Cape are from the Certificate of Adequate Enclosure (CAE) database. The certificates from individual farms are renewed every three years. The game numbers on these farms are owner's estimates and may not necessarily be accurate.

Goegap Provincial Nature Reserve	
(Namaqualand):	27
Private properties in the Namaqua Region:	4
Private properties in the Kalahari Region:	96
Private properties in the Kimberley Region:	152
Total	279

The game translocation policy of the Nature Conservation Service prohibits the establishment of Cape mountain zebras in most of the Northern Cape Province, and it is reasonably certain that there are currently none of the Cape subspecies present there.

Hartmann's mountain zebras are also represented in the Richtersveld National Park, which borders on the Ai-Ais Nature Reserve in Namibia. Numbers are estimated at about ten to 15, but vary because the park is unfenced, and the zebras probably cross the international boundary between South Africa and Namibia.

Western Cape Province

According to the records of Cape Nature Conservation there were about 54 Hartmann's mountain zebras extra-liminally located in the Western Cape Province in 1998, all on private land. The different populations were:

Mr Parker (Elandsberg, Wellington area)	20*
Mr Orchard (Bylshoek, Montagu area)	7
Mr Verneaux (Inverdoorn, Touwsrivier area)	7
Mr Melck (Doringfontein, Berggrivier area)	4
Mr Kings (Vuurfontein, Cederberg area)	c. 16
Total	c. 54

* Mr Parker (1999) sold most of these animals and only two currently remain.

Eastern Cape Province

Hartmann's mountain zebras are present in two nature reserves run by Eastern Cape Nature Conservation Services: Amaqwati Tribal Resource Area (29 animals in 1998) and in the Mkambati Nature Reserve (four animals in 1998). They are also present on a number of private properties, but owing to staff changes and reduced

resources it has not been possible to keep the records up-to-date. During the period 1988–1991, at least three properties in the Eastern Cape were issued with Certificates of Adequate Enclosure with respect to Hartmann’s mountain zebras (Vorster and Lloyd 1994).

3.5 Threats

Major threats to both mountain zebra subspecies noted by Duncan (1992) were:

- the risk of crossing between the two subspecies, which would lead to a loss of genetic diversity;
- droughts; and
- the relatively small numbers in the wild, which means that the loss of a single population (e.g. the Mountain Zebra National Park) could reduce the world population by about a third.

The risk of hybridisation is serious in South Africa, especially in the Eastern and Western Cape Provinces, but not in Namibia where only one subspecies occurs. The risk of droughts does not seem to be serious, as mountain zebras are well adapted to arid conditions. There have been no recorded cases of large scale mortality caused by droughts in Cape mountain zebras. Drought mortality in Hartmann’s mountain zebras occurred in north-western Namibia in the 1970s and early 1980s, but this was due to obstruction of access to water (through the settlement of people and livestock around key water points and the construction of fences), rather than to the drought as such.

For Cape mountain zebra, the risk of losing a large proportion of the metapopulation through the catastrophic loss of one important population is not as great now as it was in 1992. The largest population, that of the Karoo National Park, makes up 20% of the metapopulation, and that of the Mountain Zebra National Park, 18%.

The risk of crossing between the two subspecies in South Africa may, however, have increased since 1992. The most important measure to prevent this is the permit system for the transportation of game maintained by the provincial conservation agencies. This system ensures that Hartmann’s mountain zebras cannot legally be introduced into the range of the Cape subspecies and vice versa. The provincial agencies, particularly in the Eastern Cape and to a lesser extent the Northern Cape are operating on much reduced budgets and they have lost a significant proportion of their experienced personnel. If this trend continues these agencies may well be unable to undertake the necessary measures to keep track of the sale and translocation of zebras, thus increasing the risk that hybridisation may occur. We recommend that representatives of the agencies concerned meet and discuss ways of dealing with this risk. Strict adherence to the policy on the importation and transportation of

mammals into and within the Cape Province by all three provinces constituting the former Cape Province will greatly assist in reducing the threat of hybridisation between the subspecies (Lloyd and Lensing 1990).

Namibia has already added the requirement that confirmation be obtained from the relevant province prior to authorising live exports of mountain zebras to South Africa. In Namibia the importation of mountain zebras of either subspecies has never been permitted and will be expressly forbidden in future policies.

Mention has been made of the “small population problem”, which has threatened the success of reintroduction attempts involving Cape mountain zebra. Past attempts to establish new populations with excessively small numbers of founder animals have led to wasted efforts (Novellie *et al.* 1996) and prospective new owners need to be informed of the problem.

The most important threat to Hartmann’s mountain zebras in Namibia is livestock production and farming activities such as fencing. Many individual landholders regard mountain zebras as a nuisance and a competitor for scarce grazing and water. The MET has accordingly encouraged the commercial use of mountain zebras to provide an incentive (or at least to promote tolerance) for their conservation on farmland. This policy has resulted in considerable off-take pressure in some areas and may even have caused localised population declines. The MET had to approve relatively high offtakes of mountain zebra on fenced commercial farms in drought stricken areas of the Khomas (particularly the Rehoboth district and the Khomas Hochland part of the Windhoek district) and Hardap Regions (Maltahoehe district) in the 1980s and early 1990s during a prolonged period of below-average rainfall (source: Ministry of Environment and Tourism, Namibia). This policy was adopted to contribute to the maintenance of pastures, reduce pressure on water resources in many areas, and prevent further negative perceptions of mountain zebra as a pest species. This may well have led to temporary localised declines, based on anecdotal information received from farmers’ associations and individual farmers (source: Ministry of Environment and Tourism, Namibia).

It is of concern that producers are not able to generate significant revenues from mountain zebra skins despite the high value that such items reach in foreign markets. No exhaustive survey has been done of trade values of mountain zebra skins, but it is well known that producers were offered, as recently as 1999, very low prices for raw salted hides in Namibia (as low as N\$100 each, or about US\$17 each). Tanned and mounted skins trade for up to N\$2,500 (about US\$400) in Namibia and South Africa, and for up to US\$1,000 in the USA (based on a few specimens seen for sale in Washington DC). Better marketing and value addition may be required to help change perceptions of the mountain zebra from pest to asset.

Increasingly sophisticated farming could further disrupt movements through fencing (although mountainous areas are notoriously difficult to fence effectively) or by preventing access to surface water.

Although the population of feral horses in the southern Namib is small and prone to periodic die-offs, it should nevertheless be of concern that feral horses or donkeys may come into contact with or displace mountain zebras in some areas. Hybrids of mountain zebras and domestic equids have been recorded sporadically in the Fish River and Orange River areas, and while not currently a major threat. Such evidence indicates a potential future threat from feral populations.

3.6 Recommended actions

3.6.1 Cape mountain zebra in South Africa

At a Population and Habitat Viability Analysis (PHVA) workshop on Cape mountain zebras held in June 1993 (facilitated by Dr U. Seal of the Captive Breeding Specialist Group and Dr P. Duncan, then Chair of the Equid Specialist Group, and attended by representatives of Cape Nature Conservation and South African National Parks), the objective was set to build up numbers to a target of 2,500 as quickly as possible. The following policy for translocation of Cape mountain zebras was based on discussions at the workshop:

- Reinforcement of existing populations will receive priority over the establishment of new populations, at least until a majority of the existing populations are securely established and increasing.
- In cases where new populations are established, the minimum number introduced should be 14 (either composed of a one to one sex ratio, i.e. seven males and seven females, or slightly skewed in favour of females).
- New owners will be made aware of the difficulties associated with the establishment of small populations and should understand that they will need to acquire one or two new animals once every five to ten years to avoid inbreeding depression.
- The choice of new areas for establishment of populations will follow the criteria set out below.

Except in exceptional circumstances, South African National Parks cannot afford to provide zebras for new areas free of charge. In fact, the organisation has decided, as a matter of policy, to use income from sales of rare species to fund the development of new national parks. Applied with due regard for the conditions set out for re-establishment of new populations, and given a well-informed private sector (see below), the sale of a small number (about 15–20 annually) of mountain zebras to generate revenue

should not pose a serious threat to the build-up of the metapopulation.

- The following criteria for allocating priorities to conservation areas for Cape mountain zebras were established at the PHVA workshop of 1993.
- The site must be within the historical distribution of the subspecies, as determined from historical records (Skead 1980, 1987).
- There must be sufficient infrastructure to provide security and allow monitoring (adequate fences and roads).
- Habitat quality for mountain zebras must be high. (A method for assessing and monitoring habitat quality was designed and tested in the Mountain Zebra National Park by Novellie and Winkler (1993) and Novellie (1994), which needs to be tested in other habitats.)
- The amount of good habitat should be sufficient to support at least 100 animals.
- The site should be geographically distant from other currently occupied sites to achieve as wide a dispersal as possible (to avoid the effects of regional catastrophes such as droughts, outbreaks of disease, *etc.*).
- The site should preferably not have a high agricultural potential, which could affect the future land use of the areas to the detriment of the reintroduced population.
- The reintroduction of mountain zebras should enhance ecotourism in the area.
- The status of the current extant population will also influence the decision regarding reinforcement. If the population is performing well but is below capacity, it could be considered for reinforcement, whereas if it is near capacity, reinforcement would not be warranted.

3.6.2 Specific Hartmann's mountain zebra projects required

1. **Status confirmation of the two subspecies.** A project to analyse the differences between *E. z. zebra* and *E. z. hartmannae* using formal statistical and molecular biological techniques was identified as a priority by Duncan (1992). This has yet to be done.
2. **Regulations to prevent hybridisation.** A conservation action that needs to be maintained is the prevention of hybridisation between the two mountain zebra subspecies. This could be achieved by defining geographically separate regions for each subspecies and making it illegal to introduce one subspecies into the region reserved for the other. This policy will obviously be re-examined if the project referred to above shows that there is no basis for differentiating between the subspecies. In the meantime, however, it is important to strictly prevent hybridisation. The policy should also be communicated to the Ministry of

Environment and Tourism, Namibia, as they can help to maintain and enforce the policy.

3. **Information to landowners in the private sector.** The role of private landowners has become more important in recent years. Many of the privately owned populations of Cape mountain zebras have increased to the extent that the owners are making animals available for re-establishment in new areas. The development of the capacity to conserve mountain zebras in the private sector should be encouraged for a number of reasons, not least of which is the diminishing funding available to the public sector conservation agencies. It is also worth remembering that it was thanks to a private landowner, who maintained Cape mountain zebras for no other reason than personal interest and pleasure, that it was possible to restock the Mountain Zebra National Park in 1950 after the park population had died out. However, it would be a pity if the private sector did not manage to avoid the mistakes made during the early phase of translocation and re-establishment of Cape mountain zebras (e.g. founder groups that were too small, the break-up of family groups during capture and translocation, poor judgment of habitat quality). It would also be disastrous if increased private sector translocations led to hybridisation between the two subspecies. To avoid these threats the conservation agencies need to cooperate to provide information on key conservation issues to private owners, for example, in the form of circulars and articles in the popular conservation literature.

4. **Expanding the Mountain Zebra and Karoo National Park populations.** The fact that the Mountain Zebra and Karoo National Parks have been enlarged would allow larger Cape mountain zebra populations to be maintained in these parks than has been possible up to now. From the conservation point of view there are possible advantages to allowing these two important populations to build up, rather than harvesting them to create more new populations. There are always risks associated with capturing animals and establishing them in new habitat. New Cape mountain zebra populations undergo a period of significantly slower reproduction during the first few years after reintroduction, probably because of adaptation to the new habitat and also possibly because family groups are often broken up during the process of capture (Novellie *et al.* 1996). However, two projects are required before a final decision can be made on this:

i. The habitat quality for mountain zebras provided by the new extensions to the two parks needs to be assessed. This is needed to decide whether grazing should be allowed to recover for a period, or whether mountain zebras and other game can be established

there in the near future. In the case of the Mountain Zebra National Park, this project is currently under way.

ii. Plains zebras have been established in the Karoo National Park and in the recently expanded Mountain Zebra National Park as part of the project to recreate an approximation of the extinct quagga phenotype by selective breeding. As a result of competition between the two equid species, the range of habitats available to mountain zebra may be narrower than is the case in areas where plains zebras are absent. A study aimed at comparing the habitat use and forage selection of the two species could yield useful results.

5. **Improved census procedures for Addo.** As noted, better counts are needed of the Cape mountain zebra in the Addo Elephant National Park.

6. **Investigation into the poor performance of the population in the Bontebok National Park.** This population did well initially, but declined in recent years. An investigation is required into the factors that could have played a role, which should include possible deterioration of habitat quality and competition with other grazers for forage (e.g. red hartebeest and bontebok).

7. **Research into the implications of disease.** The only widespread disease so far noted in the Cape mountain zebra is the sarcoid virus. Although this does not seem to be a major threat, it would be desirable to conduct research into means of controlling its spread. African horse sickness and biliary restrict the establishment of captive breeding populations in zoos outside South Africa. The status of these diseases in Cape mountain zebras needs to be investigated if breeding groups are to be established overseas. This is being undertaken by South African National Parks.

Hartmann's mountain zebras in South Africa

1. **Removal of populations that are outside their historical range.** The Hartmann's mountain zebras in the Eastern and Western Cape Provinces, together comprising at least 23% of total numbers of the subspecies in South Africa, are outside their historical range. They should be removed and replaced with the Cape subspecies. External funding is an urgent need, because none of the conservation agencies can afford to cover the costs of capture and translocation.

2. **Reintroducing Hartmann's mountain zebras into publicly owned protected areas in South Africa.** Within their historical range in South Africa, Hartmann's mountain zebras are present in very small numbers in only two publicly owned protected areas: the Goegap (Provincial) Nature Reserve and the Richtersveld National Park. They should be reintroduced into the Augrabies Falls National Park, into the new, as yet

unnamed, national park in Namaqualand, and possibly also into other suitable protected areas within their historic range. This would be the responsibility of South African National Parks and Northern Cape Nature Conservation Services.

3. **Information and assistance to the private sector.** In total, over 80% of the Hartmann's mountain zebras in South Africa are in the hands of private landowners. In the Northern Cape Province the recent establishment of one very large private reserve has greatly benefited the conservation status of Hartmann's mountain zebras. As for the Cape subspecies, it would be of value to provide information and guidance to private landowners.

Hartmann's mountain zebras in Namibia

1. **Improving the protected area system.** While there is not a significant amount of vacant mountain zebra habitat in Namibian protected areas, improved management of the Hunsberg complex and the possible future proclamation of a part of the Sperrgebiet may allow more substantial populations to be established in southern Namibia. There is considerable potential to develop transfrontier conservation areas along Namibia's southern border with South Africa (e.g. the Richtersveld National Park of South Africa and the Ai-Ais Nature Reserve of Namibia are separated only by the Orange River). Mountain zebra may be one of the species that can benefit most from this form of conservation.
2. **Control of poaching.** As in many countries, ongoing investment in monitoring and crime prevention is required in most Namibian protected areas, with actual needs rarely being met. The Ministry of Environment and Tourism is in the process of updating conservation policies and legislation, which will include a significant increase in penalties concerning illegal hunting and trade in wildlife. Hartmann's mountain zebras will continue to be classified as a 'Specially Protected Species' to facilitate law enforcement as well.
3. **Further promotion of conservancies on communal land.** A significant advance has been made with the establishment of conservancies in Namibian communal lands. Conservancies cover large areas of mountain zebra habitat and there is an admirable degree of awareness of conservation management requirements and community involvement in planning, monitoring, and protection of wildlife. The development of such programmes requires time and various communities are in different stages of organisation. There is considerable pressure on, and opportunities for the Ministry of Environment and Tourism to support conservancy development and management.
4. **Promoting the maintenance of mountain zebras on farmland.** With more than 50% of the national

population of mountain zebras occurring on several hundred individually managed farms, conservation action is largely focused at promoting the maintenance of mountain zebra populations on farmland, particularly during drought times when competition between zebras and livestock may become significant. The role of mountain zebras as a source of food for remote rural communities and farm employees is also recognised and, where applicable, sustainable use is encouraged.

5. **Policymaking and legislation.** The Ministry of Environment and Tourism is in the process of revising and updating policies and legislation regarding wildlife conservation, production, and utilisation. Proposed policies emphasise the responsibility towards endemic and commercially valuable forms, such as the mountain zebra, and provide for a broad range of interventions to enhance habitat protection, provide incentives for landholders to maintain wildlife populations, and, in particular, to establish cooperative management of wildlife resources through conservancies.

3.7 References

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Status and Action Plan for the Plains Zebra (*Equus burchellii*)

Mace A. Hack, Rod East and Dan I. Rubenstein

4.1 Nomenclature and conservation status

Scientific name:

Equus burchellii Gray
Equus burchellii boehmi
Equus burchellii zambesiansis
Equus burchellii crawshayi
Equus burchellii chapmani
Equus burchellii antiquorum
Equus burchellii burchellii

Important synonyms:

Asinus burchellii Gray 1825
Equus burchellii Smuts 1832
Hippotigris burchelli Smith 1841
Equus quagga burchelli Pocock 1904

Common names:

Plains zebra, common zebra, Burchell's zebra, painted quagga

Indigenous names:

Punda milia (Kiswahili), itiko (Kichagga), eutulege (Luganda, Runyoro), etuko (Karamojong), lagwar (Lwo),

entorege (Runyankore), injiga (Ishinyika), hares (Kiliangulu), eloidigo (Maasai), iqwaha (Xhosa), idube (Zulu, Ndebele), mangwa (Tsonga), pitsi (Sotho, Tswana), mbidi (Venda), mbizi (Karanga), bontsebra or bontkwagga (Afrikaans)

IUCN Red List Category (*E. burchellii*, *E.b. antiquorum*, and *E.b. boehmi* were assessed using version 3.1; all others with version 2.3):

Equus burchellii **LC** Least Concern
E. b. boehmi **LR** Lower Risk
E. b. zambesiansis **DD** Data Deficient (? extinct in wild)
E. b. crawshayi **DD** Data Deficient (? endangered)
E. b. chapmani **DD** Data Deficient
E. b. antiquorum **LR** Lower Risk
E. b. burchellii **EX** Extinct (1930)

As recently as 15 years ago, the plains zebra could be found in nearly all the countries of eastern, southern, and south-western Africa. It has since been extirpated from several parts of this range, although it remains the most widespread and abundant equid in the world today. Where the plains zebra still occurs, it is usually a numerically dominant member of the ungulate community and therefore plays an important role in the overall dynamics and welfare of its



The plains zebra (*Equus burchellii*).

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grassland habitat. The primary threats to this species include overhunting and loss of habitat to human development and livestock ranching. Overall, those populations constituting a major proportion of the species' total global population have remained stable over the past ten years, or have only recently begun to decline. However, because nearly 70% of the global population resides in only two countries – Kenya and Tanzania – the long-term preservation of the species in a wild, free-ranging state depends critically on their fate in this region of East Africa.

4.2 Taxonomy

A genetics-based taxonomy of the plains zebra has not been fully resolved and there is a troubling lack of consensus among the many traditional taxonomies put forward for this species (Cabrera 1936; Roberts 1951; Sidney 1965; Groves 1974; Kingdon 1979; Skinner and Smithers 1990; Groves' chapter in this document). For the purposes of this report, we follow Duncan's lead in the preceding Action Plan (1992a) and consider the species to consist of six subspecies: Grant's (*Equus b. boehmi*), Crawshay's (*E. b. crawshayi*), Upper Zambezi (*E. b. zambeziensis*), Chapman's (*E. b. chapmani*), Damara (*E. b. antiquorum*), and the nominate Burchell's (*E. b. burchellii*). Whether ultimately judged to be accurate or not, we use these historical subspecies designations because (i) they are convenient for summarising regional differences in population trends and their causes, (ii) they correspond with consistent morphological differences, and (iii) they may yet be important to plains zebra conservation if the genetic distinctions among them are sizeable enough to merit preservation.

Current plains zebra taxonomies divide the species' range into contiguous units, each home to a morphologically distinct subspecies (Figure 4.1). The most conspicuous morphological differences include body size and the width, intensity, and coverage of dark stripes on the adult pelage. In general, the extent of stripe coverage decreases as one moves from north to south, although variation in stripe patterns within any particular population can be large and even include variants more characteristic of other subspecies (see Kingdon 1979). Body size follows a similar north-south cline, with *E. b. antiquorum* in the south averaging 28–40% larger than *E. b. grantii* in the north (Smuts 1975). Small differences in tooth and cranial characters also separate some subspecies (Groves 1974; Groves and Willoughby 1981).

Genetic differences presumably account for these morphological distinctions among subspecies yet it is under debate as to whether subspecific boundaries delineate genetically unique breeding populations or, alternatively, divide a continuum of genetic variation into somewhat arbitrary segments. Evidence derived from analysis of

mitochondrial DNA favors the latter hypothesis since it suggests that genetic differentiation across the species' range is simply clinal and changes smoothly as a function of distance (N. Georgiadis unpublished data; A. Oakenfull unpublished data). However, this result appears at odds with one of the few points of consensus among traditional taxonomists, who perceive geographic features that are likely to inhibit dispersal, most notably the Zambezi River (Figure 4.1), as important boundaries between subspecies (Roberts 1951; Sidney 1965; Groves 1974; Kingdon 1979; Skinner and Smithers 1990). These features may impede gene flow sufficiently to maintain morphologically distinct and locally adapted subspecies without generating the complete barriers to reproduction and dispersal that lead to speciation. More thorough sampling of populations throughout the species' range is needed if we are to resolve the taxonomy of the plains zebra from genetic information. Samples from populations in the middle of the species' range (e.g. Zambia, Zimbabwe, Malawi, and Mozambique) and at its margins (e.g. Namibia, Angola, Sudan, and Somalia) would be particularly valuable.

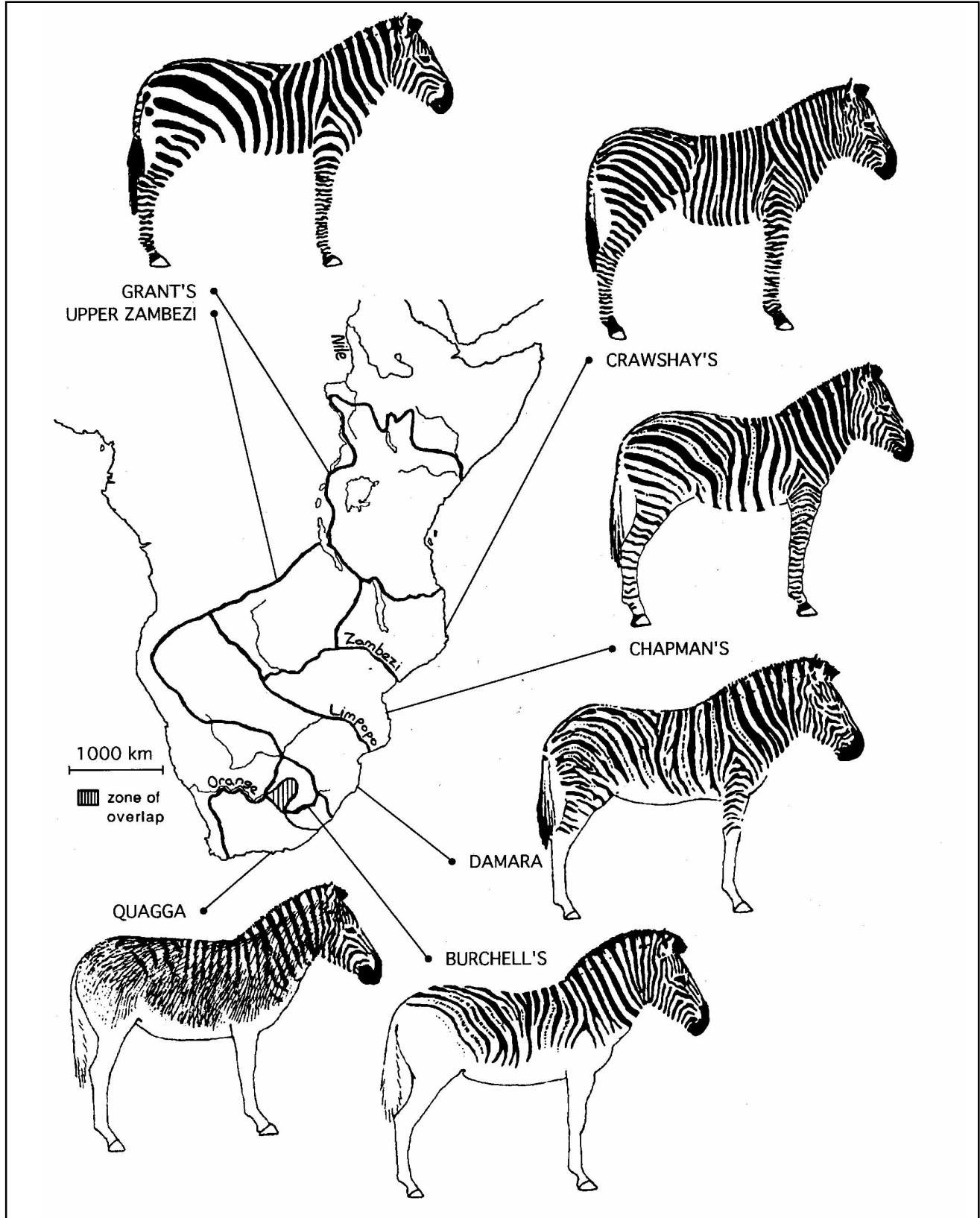
4.3 Quagga: species or subspecies?

The quagga (*E. b. quagga*) represents a possible seventh subspecies of plains zebra if one accepts the results of recent mitochondrial DNA and immunological analyses (Higuchi *et al.* 1984; Lowenstein and Ryder 1985; George and Ryder 1986). These studies have used dried tissue from 19th century museum specimens to demonstrate a greater affinity between the quagga and the plains zebra than that between the quagga and a neighbouring species, the mountain zebra (*E. zebra*). Unfortunately, the genetic analysis, in particular, was based on a very small sample of base pairs, or <2% of that used to resolve analogous differences among the other equid species. Other evidence, including a distinctive stripe pattern (Figure 4.1) and slight tooth and cranial differences on par with those seen between the plains and mountain zebras, suggests a separate species designation should be given for the quagga (Cabrera 1936; Groves 1974; Bennett 1980).

The heart of the quagga's range was the semi-arid and temperate Karroo in southernmost Africa, an area of unique ecology and high floral and faunal endemism. Anecdotal accounts indicate that quaggas and Burchell's zebra encountered each other in a narrow zone of range overlap north of the Orange River (Figure 4.1) – in contrast to the non-overlapping ranges of the other plains zebra subspecies – but they did not appear to interbreed (see citations in Sidney 1965; Groves 1974; Kingdon 1979). Unfortunately, we may never know the quagga's true taxonomic relationship to the other plains zebras because both the quagga and the Burchell's subspecies were driven to extinction in the late 19th and early 20th centuries,

Figure 4.1. Historical range (c. 1800) for each plains zebra subspecies and the quagga (*E. quagga*).

From north to south, note the change in stripe width, presence of shadow striping, and the extent of stripe coverage on the legs, rump, and flanks. Subspecies: Grant's (*Equus b. boehmi*), Crawshay's (*E. b. crawshayi*), Upper Zambezi (*E. b. zambeziensis*), Chapman's (*E. b. chapmanni*), Damara (*E. b. antiquorum*), Burchell's (*E. b. burchellii*). (Adapted from Groves 1974 and Kingdon 1979.)



respectively, by overhunting and competition with livestock, primarily sheep. A recently initiated captive-breeding programme is attempting to 'resurrect' the quagga by breeding individuals with quagga-like stripe patterns from stock of the Damara subspecies (Harley 1988). (N.B. Those who consider the quagga a seventh subspecies prefer to name this plains zebra species *E. quagga* in place of *E. burchellii*.)

4.4 Range

At the beginning of the 19th century, and prior to the extensive European colonisation of sub-Saharan Africa, the plains zebra ranged throughout most of the eastern, southern, and south-western regions of the continent (Figure 4.2). Although this species may have occurred as far north as Algeria during the Neolithic period (Groves 1974), by the 1800s none were found further north than southern Ethiopia and southern Sudan, east of the Nile River (Sidney 1965; Groves 1974; Kingdon 1979). The core of the historical range included what is now Kenya, Tanzania, and Sudan – with peripheral populations in Somalia, Uganda, Burundi, and Rwanda – and continued south through Malawi, Mozambique, Zambia, Zimbabwe, northern and eastern

Botswana, Swaziland, Lesotho, and South Africa as far south as the Orange River. Plains zebra were also historically found in the south-eastern Democratic Republic of Congo (formerly Zaire), and extended westward and south through southern Angola and northern Namibia. As detailed below, this species is now extinct in two countries – Burundi and Lesotho – and may have been extirpated within the last ten years from Angola.

4.5 Ecology: what drives habitat selection and ranging patterns?

Plains zebra graze almost exclusively and are therefore strongly associated with grasslands and savanna woodlands, but they can be found in these habitats in both tropical and temperate climates, and from sea level to over 3,500m in elevation. Only deserts, dense forests, and permanent wetlands are avoided. Adults need to drink at least once per day – lactating females may require two daily trips to water – limiting their range to the close vicinity (five to ten kilometres) of reliable water sources. Many populations are seasonally migratory, travelling hundreds of kilometres annually to track vegetational flushes caused by rainfall (e.g. Serengeti-Masai Mara ecosystem: Maddock 1979).

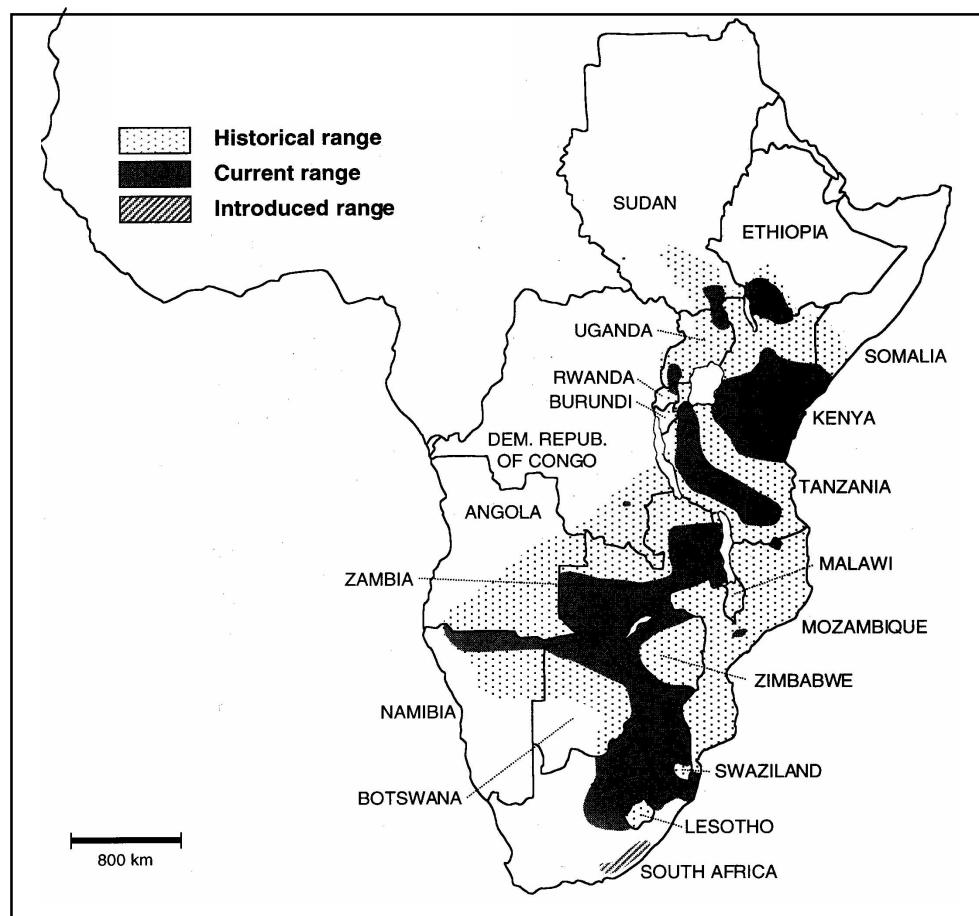


Figure 4.2. The historical and current ranges of the plains zebra. Note the modern introduction of the species in south-eastern South Africa.

(For a breakdown of subspecies population sizes by country, refer to Table 4.3.)

However, even in regions where the majority of individuals migrate, some individuals usually remain as year-round residents. Thus, population density in an area may fluctuate by two or three orders of magnitude (e.g. from 0.01 to 11 per km² on the Simanjoro Plains in Tanzania: Kahurananga 1981). What distinguishes migratory from resident populations is an interesting question for further study, but it is most likely influenced by the frequency-dependent nature of resource availability.

4.6 Ecology: promoter of grassland biodiversity

In contrast to the antelopes and other ruminants that comprise the main consumers of grass on the African savannas, plains zebra utilise a hind-gut digestive system that allows them to process their food at relatively faster rates. Consequently, coarse vegetation of low nutritional value can sustain zebras as long as it is abundant, whereas similarly sized ruminants would starve on the same diet (Duncan 1992b). This critical difference in digestive systems has at least three important implications. First, by being able to exploit a greater range in grass quality, plains zebra occupy a more extensive geographical range, a larger variety of habitats, and reach higher densities in some of the poorest grasslands than most other ruminants of equivalent size. Second, this ability to subsist on low quality forage, when combined with relatively large body size and its concomitant lowering of transport costs, enables plains zebra to undergo large migrations to track changing resources. Thirdly, plains zebra typically move into a grassland ahead of other grazers and, by removing the older growth layer of lignified stems, sheaths, and seed heads, open it up to grazing by the more selective ruminants, such as wildebeest and Thompson's gazelle, which concentrate on the tender and nutritious new growth (Owaga 1975). Thus, on the Serengeti Plains and elsewhere, plains zebra play a key role in initiating the pattern of succession within the grazer community, thereby enriching the variety and numbers of herbivores that these grasslands sustain (Bell 1971).

4.7 Population dynamics: important parameters and ecological consequences

Despite the fact that zebras are the most abundant and most visible of all African grazing mammals, the dynamics of specific populations are poorly documented. Descriptions of population trajectories are often noted and typically compared with those of other sympatric grazing species, but they reveal little about the mechanisms controlling these trends and offer few insights into

predicting what lies ahead. It was observed, for example, that during the 1960s and 1970s zebra numbers in the Serengeti remained relatively constant while those of wildebeest and buffalo increased dramatically, suggesting that the dynamics of zebra populations were being governed differently from those of its competitors. During this period it was also noted that diseases affecting ungulates were absent and that vegetation levels had increased steadily. To explain these differing responses, an intriguing hypothesis was proposed: whereas wildebeest and buffalo numbers were controlled by vegetation abundance and competition for food, zebras numbers were being limited by predators (Sinclair and Norton-Griffiths 1982; Senzota 1988). A similar study of ungulate population trends in Namibia's Etosha National Park reached the same conclusion, citing predation and possibly disease (anthrax) as more important regulators of plains zebra numbers than food abundance (Gasaway *et al.* 1996). Unfortunately, in both studies, the detailed demographic measures that could determine the extent to which population processes are governed by 'bottom-up' or 'top-down' mechanisms are lacking.

As Table 4.1 shows, several populations have been surveyed and censused, but key life-history variables, especially with respect to vital demographic rates, are often not recorded. Overall, plains zebra breeding groups are of moderate size with each male associating with two to three females and their recent offspring. But even as these few studies show, measures of harem size and composition vary among study sites by a factor of two. With respect to demographic characteristics and vital rates, interpopulation variation is even greater. Doubtless this is the result of marked seasonal and yearly fluctuations in environmental conditions, which are known to have major impacts on patterns of foal survival, adult sex ratio, and population density.

As yet, few studies have recorded these trends for long enough to allow us to measure the sensitivity of these variables to changing environmental conditions. As illustrated in Table 4.2, Ngorongoro zebra exhibit yearly variation. The fraction of females giving birth during consecutive years increased from 38% in 1987 to 46% in 1988, while the male:female sex ratio among foals dropped from 1.3 in 1987 to 1.1 in 1988. At this point, however, it is too early to tell whether this level of variation is biologically significant. Moreover, longer term studies will be needed to determine if any systematic correlations can be detected among demographic variables. From studies on Asiatic asses, *E. hemionus*, by Saltz and Rubenstein (1995), we know that identifying these associations is critical to understanding the processes that shape the reproductive potential, and hence recruitment capabilities, of a population. In this closely related species, female age, presumably a good indicator of bodily condition, affects the sex of a female's foal: primiparous

Table 4.1. Summary of demographic variables for plains zebra populations throughout the species' range.

Site	Harem Size (inclu. 1 stallion/)				Recruitment		Mortality Rate		Adult Sex Ratio Males/Females	Source ¹
	Total Harem (mean)	(max.)	Adult Females (mean)	(max.)	%Foals (=1 yr.)	%Juveniles (1<X=3 yrs.)	1st year	Adult		
Kenya										
Samburu NP, Athi-Kapiti Plains	8.2	14	4.7	6	0.20 0.26	0.12 0.28	0.33 0.38	0.17	0.62	1, 2 3
Tanzania										
Ngorongoro Crater	7.7	16	2.8	6		0.20	0.19	0.03–0.09		4, 5
	5.0	10	2.5	6	0.19	0.19	0.19	0.07	0.69–0.88	6
Loliondo area									0.56	7
Serengeti NP	5.1	11	2.2	5	0.11		0.30	0.11		4, 8
Rukwa area	5.4	10	2.5	6						9
Malawi										
Nyika NP					0.10				1.00	10
Zimbabwe										
Wankie NP	4.6	8	2.6	5						4
Namibia										
Etosha NP	4.7	9	2.3	5		0.18				4, 11
South Africa										
Kruger NP	4.5	8	2.4	4		0.09				4, 11
	4.2	11			0.12	0.06	0.47	0.03–0.13	0.75	12, 13

¹ – References cited: (1) Rubenstein 1989; (2) Ohsawa 1982; (3) Petersen and Casebeer 1972; (4) Klingel 1969; (5) Klingel 1975; (6) Hack and Rubenstein, unpublished data; (7) Skoog in Smuts 1976a; (8) Sinclair and Norton-Griffiths 1982; (9) Klingel 1967; (10) Munthali and Banda 1992; (11) Gasaway *et al.* 1996; (12) Smuts 1976a; (13) Smuts 1976b.

¹ – References cited: (1) Rubenstein 1989; (2) Ohsawa 1982; (3) Petersen and Casebeer 1972; (4) Klingel 1969; (5) Klingel 1975; (6) Hack and Rubenstein, unpublished data; (7) Skoog in Smuts 1976a; (8) Sinclair and Norton-Griffiths 1982; (9) Klingel 1967; (10) Munthali and Banda 1992; (11) Gasaway *et al.* 1996; (12) Smuts 1976a; (13) Smuts 1976b.

and old females give birth mostly to daughters, while prime-aged females have mostly sons. The implication of this pattern is clear. If plains zebras behave like their close kin, then knowing that such correlations between variables exist will affect the successful management of any population actively being poached, legally cropped, or being created by the release of translocated animals.

Comprehensive data of the types presented are essential for making reliable assessments of a population's status, as well as for designing and implementing management plans, but by themselves they are not sufficient to do either. In addition, age-specific, or at least stage-specific, vital rates are needed. Unfortunately, few such data exist. Only one life table for the plains zebra has been compiled (Petersen and Casebeer 1972) and cursory analysis by simulation (Senzota 1988) suggested that the Kenyan

population it depicts has a stable age structure. It is unlikely, however, that this age distribution will be representative of all zebra populations given the highly variable nature of the demographic variables listed above (Tables 4.1 and 4.2). Demographic profiles from other studies are even less informative, being derived from age-specific census sightings and samples of serendipitously collected skulls and carcasses (e.g. Smuts 1976). Such data can only provide age-sex distributions that are crude approximations of the actual age structure.

Apart from providing a quantitative description of a population's state, actual age-specific life history measures, especially vital rates, are essential if population projections or viability analyses are to be performed. Clearly, more data are needed before appropriate management or conservation strategies are instituted, but if the Kenyan population's (Petersen and Casebeer 1972) age-specific survival and fecundity patterns are representative, then the patterns that emerge from employing them in population projection simulations can be instructive. When stochastic Leslie matrix population projection models incorporating density-dependence (e.g. Dobson and Lyles 1989; Rubenstein and Dobson 1996) are applied to populations characterised by Athi Plains' vital rates, plains zebra populations facing natural levels of predation and inhabiting stable landscapes that are minimally impacted by people (e.g. East African national parks and other unfenced protected areas) tend to reach equilibrium and remain stable for decades. Even populations inhabiting unprotected areas that are divided into large ranches, such as in the Laikipia region of central Kenya which

Table 4.2. Summary of plains zebra demographic parameters from a free-ranging population of known individuals inhabiting Ngorongoro Crater, Tanzania.

	1987	1988
Females with foals (Jan–Aug)	37.6% (n=210)	46.0% (n=274)
Foal survivorship in 1st year	(n=93)	80.6%
Foal sex ratio (male/female)	1.29	1.11
Yearling sex ratio	-	1.50
Female fecundity:		
No foal either year	-	28.1%
One foal over two years	-	61.0%
Two foals over two years	-	10.9%

covers over 7,000km² and receives nearly 600mm of rainfall per year, are also likely to remain stable as long as no major changes in land use occur.

Results of the model show that the current Laikipia population of approximately 25,000 adults will oscillate around an average of 23,000 adults over the next 30 years. Simulations also reveal that the population will increase slowly if further reductions in predators occur or if global climate change leads to rainfall increases of approximately 20%. But what is perhaps most interesting is that the Laikipia population will remain stable under a variety of moderate cropping regimes. Adult numbers will indeed be lowered by repeated cropping – either by design or by poaching – but they will tend to hover at 20,000 if cropping is limited to removing either 15% of only the young males (aged two to five) or five percent of the entire population, indiscriminately chosen, on a yearly basis. The most successful strategy will depend on other factors and trade-offs that often determine the shape of a multiple land-use scheme. However, only by knowing the life-history details of a population does it become possible to model population processes so that alternative management and conservation strategies can be evaluated and compared. For these scenarios to be accurate, and hence their predictions meaningful, reliable estimates of age-specific demographic vital rates are required. And at the moment, such data are usually absent.

4.8 Social organisation: implications for population dynamics and genetics

Plains zebra are highly social animals. Like the mountain zebra and horse, the basic unit in plains zebra society is the ‘harem’, consisting of a single adult male, one to six adult females, and both sexes of offspring up to the age of two to three years (Klingel 1969; Rubenstein 1986). Females may remain together in the same harem for much of their reproductive lives, and the harem male defends his exclusive right to mate with them. Unlike other mammalian societies based on cohesive, long-lasting female groups, such as those of lions and elephants, the females in an equid harem are not genetically related; both sexes of offspring disperse from their natal group. Males without harems – including young males that have recently dispersed from their natal harems and older males that are unable to compete successfully or have lost their harems to rivals – live as ‘bachelors’ in loose aggregations that may number as many as 50 individuals. Both harems and bachelor groups come together to form larger herds when grazing, sleeping, or moving between areas. This multileveled social organisation is more characteristic of primates, such as baboons, than it is of ungulates, yet why plains zebra form such societies is not fully known and currently under study (Hack and Rubenstein, in prep.).

The plains zebra’s unusual social organisation has several implications for the population dynamics and genetics of this species. Evidence from studies of other harem-forming equids, such as feral horses, suggests that social instability, particularly a high rate of turnover among harem males, adversely affects female reproductive success and patterns of age-specific fecundity (Berger 1983; Rubenstein unpublished data). The increased levels of sexual harassment that result can lower female body condition and disrupt normal endocrine function. A similar linkage between social stability and recruitment probably exists in plains zebra, highlighting an important demographic factor to consider in harvesting strategies since the killing of males is often favoured.

The unusual structure of plains zebra populations also has implications for the conservation of genetic diversity. Polygyny, male tenures as long as ten years (Hack and Rubenstein, unpublished data), together with a high bachelor mortality rate indicate that some males will never have the opportunity to breed. Thus, effective or genetic population sizes will often be substantially less than adult census population sizes. On the other hand, the reduction in effective population size will be less than that for other group-living ungulates because females within each plains zebra breeding group are not genetically related. As a result, founder populations of a few harems will have relatively high genetic diversity. This is particularly relevant for reintroduction efforts since it implies that a normal social structure, and the social stability and reproductive benefits it confers, does not have to be traded off against the selection of individuals to ensure sufficient genetic diversity for the long-term health of a population.

4.9 Current population numbers and trends

Based on information presented in this report, the total global population of plains zebra in the wild is 663,212, or roughly equal to that estimated by Duncan in the last Action Plan (1992a) despite the present survey’s more thorough coverage (Appendix 3). Most of the data used to arrive at this estimate are from censuses conducted within the past seven years. Countries for which no recent data are available probably harbour less than three percent of the total global population. Because much of the data used in this survey derive from aerial sample counts, which inherently miss an unknown proportion of animals, the total population size reported is almost certainly an underestimate of the actual population size. Application of a suitable correction factor, typically between 1.2 and 2.0 for conspicuous savanna ungulates like the plains zebra, places the actual worldwide population between 796,000 and 1,326,000 individuals.

Table 4.3. Summary of plains zebra population sizes per country, and percentages held per country for both the global and subspecific totals.

	Total population per country	% of subspecies' total population	% of species' total population
Grant's total	496,703		
Tanzania	296,508	59.7	44.7
Kenya	152,490	30.7	23.0
Sudan	33,050	6.7	5.0
Ethiopia	7,470	1.5	1.1
Uganda	3,137	0.6	0.5
Somalia	1,000?	0.2	0.2
Burundi	extinct		
Rwanda	3,048		
Upper Zambezi total	19,219		
Zambia	18,219	94.8	2.7
Dem. Rep. Congo (Zaire)	<1000	5.2	0.2
Angola	extinct?		
Crawshaw's total	23,020		
Zambia	21,250	92.3	3.2
Malawi	670	2.9	0.1
Mozambique	1,100	4.8	0.2
Chapman's total	20,294		
Mozambique	65	0.3	0.0
Zimbabwe	20,135	99.2	3.0
Botswana	94	0.5	0.0
Damara total	103,976		
Botswana	34,200	32.9	5.2
Namibia	13,090	12.6	2.0
Swaziland	1,000	1.0	0.2
Lesotho	extinct		
South Africa	55,686	53.6	8.4
Species total	663,212		

The plains zebra is not currently listed in either CITES Appendix I or II. Applying the IUCN Red List of Threatened Animals criteria for threatened species (IUCN 1994) results in a designation of Lower Risk, Conservation Dependent for the species. Although no one subspecies has yet reached the criteria for being deemed Vulnerable, two would certainly become Vulnerable if conservation programmes in Zambia, which protect the plains zebra and other wildlife, were dismantled (Table 4.3).

Over 75% of the world's plains zebra are of the Grant's subspecies and, of these, nearly three-quarters live in just two countries – Tanzania and Kenya (Figure 4.3, Table 4.3). Both countries have extensive national park and reserve systems with well-developed wildlife monitoring programmes, and they derive substantial income from wildlife-based tourism. Global recognition of the importance of this region's wildlife and the countries' commitments to wildlife conservation demonstrated by their governments have attracted significant and vital international support for establishing and sustaining protected areas.

In Tanzania, national parks, game reserves, game-controlled areas and other protected lands cover approximately 25% of the country. Of these, the Serengeti

National Park in the north supports the world's single largest plains zebra population (151,000), as many as a third of which migrate seasonally into south-western Kenya. The Serengeti population has been relatively stable over the past 30 years, but recently appears to be decreasing due to human encroachment and illegal hunting for meat (Campbell and Borner 1995). The estimated annual off-take of 12.9% (Hofer *et al.* 1996) is unlikely to be sustainable given what we currently know about the demography of this species (Tables 4.1 and 4.2). Most other protected populations in Tanzania are stable, although some, such as those of Tarangire National Park in the north and the Burigi-Biharamulo ecosystem in the north-west, depend heavily on unprotected lands for much of their annual migratory cycles. Current agricultural expansion in these unprotected areas is likely to cause future population declines. Improved wildlife protection and management in the southern Selous ecosystem have caused its substantial plains zebra population, the third largest in the country, to increase over the last ten years. Plains zebra numbers in the western Katavi-Rukwa ecosystem have similarly increased.

It is important to note that large tracts of land in Tanzania are not currently censused for wildlife. Many

certainly contain plains zebra populations, though at presumably low densities due to legal and illegal hunting. Consideration of these uncensused populations could significantly increase the estimated total population for the country.

Kenya's plains zebra reside in 13 regularly censused rangeland districts, four of which support over 80% of the country's total population. Several national parks and reserves (e.g. Tsavo, Masai Mara) harbour important resident populations or are vital dry season refuges (e.g. Amboseli, Nairobi). However, in total, protected lands support less than 10% of the country's plains zebra population (Grunblatt *et al.* 1995). Thus, the long-term fate of this species in Kenya depends critically on their success in unprotected areas. Since 1977, most rangeland ungulates have declined in abundance by 40–80% with the apparent exception of one species, the plains zebra (Grunblatt *et al.* 1996). Unfortunately, a country-wide increase of 13% in plains zebra numbers, fuelled by growing populations in just four districts, masks declines averaging 45% everywhere else. Agricultural expansion and competition with livestock constitute the most important pressures on plains zebra populations, particularly in the south. Legal harvesting of plains zebra for meat and skins

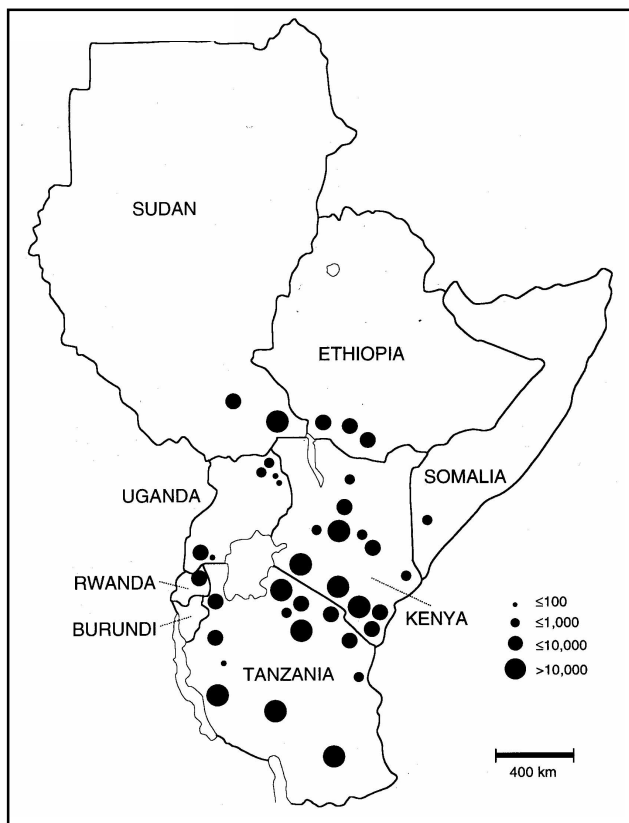
currently occurs in several rangeland areas (e.g. Laikipia), and Kenya may soon join the rest of eastern and southern Africa in allowing trophy hunting of this and other species.

Elsewhere throughout its range the Grant's subspecies has not fared as well (Figures 4.2 and 4.3; Table 4.3). Recent civil wars in Rwanda, Somalia, Sudan, Ethiopia, and Uganda have caused dramatic declines in all wildlife populations, including those of Grant's zebra. In all cases, an abundance of weaponry and the erosion of the wildlife protection infrastructure have led to severe overhunting for meat and intensified encroachment by humans and their livestock. In densely populated Rwanda, plains zebra were already confined to a single national park (Akagera) and neighbouring reserve in the north-east prior to the outbreak of civil war in the early 1990s. Since then, these areas have been intensively hunted and over-run with refugees and their livestock to the extent that much of the park was recently de-gazetted. Ungulate populations in the region have generally suffered 80% declines since 1990, but plains zebra still occur and appear to have only declined by 20% during this same period. Zebra are apparently considered less palatable than other ungulates in Rwanda and may be better at avoiding humans, accounting for their less steep decline (Williams and Ntayombya 1999). Southern Somalia may still have a small, but viable plains zebra population (Estes 1995). Southern Sudan probably retains significant numbers of plains zebra, since it had the third largest population of Grant's in 1983, but we have no current data for this country. Efforts to resurvey the Boma and Southern National Parks are currently underway (R. Olivier *in litt.* 8/97). Ethiopia's plains zebra have rebounded in some areas, primarily the south-western lowlands, from almost catastrophic declines during the 1970s and 1980s. However, levels of wildlife management and protection remain low due to a lack of resources and little public awareness of the value of wildlife. Increasing poaching and human encroachment on protected lands are likely to erase these gains in the near future (C. Schloeder *in litt.* 8/96; Graham *et al.* 1996).

Civil strife in Uganda during the 1970s and 1980s resulted in the devastation of many wildlife populations despite a well-developed system of conservation areas and a committed wildlife protection staff. More recently, government wildlife conservation efforts and the ecotourism industry have been revitalised. Lake Mburo National Park in the south-west and the Kidepo Valley National Park in the north-east retain the largest and most viable plains zebra populations at present, although both continue to suffer from illegal hunting for meat and rapidly increasing livestock populations in the surrounding areas (E. Buhanga *in litt.* 7/97; Lamprey and Michelmores 1996).

Stable populations of Crawshaw's plains zebra currently occur in two countries: Malawi and Zambia (Figure 4.4). Northern Mozambique, despite suffering many years of

Figure 4.3. The locations and current sizes for known populations of Grant's zebra (*E. b. boehmi*) occurring on either governmental or private lands.



civil war and extirpation of its wildlife, has at least one remnant Crawshay's population.

Despite its small size, 11% of Malawi's total area consists of national parks and game reserves, demonstrating this country's strong commitment to wildlife conservation. Of these, two national parks and two game reserves support plains zebra populations, which are confined to these four areas by the surrounding agriculture and development (F. Mkanda *in litt.* 3/97; H. Nsanjama *in litt.* 4/97). Populations in Kasungu National Park and Vwaza Marsh Game Reserve have declined sharply since 1989, probably due to increased levels of poaching (Mkanda 1993). However, plains zebra are not a preferred source of meat in Malawi (Munthali and Banda 1992), so other factors may actually be responsible for these declines. Since plains zebra numbers elsewhere have increased or remained stable since 1989, the country's total population has not changed significantly over this period.

Zambia formerly had one of the best managed networks of protected areas in Africa. Unfortunately, during the last 15–20 years, wildlife protection efforts have diminished, resulting in increased levels of poaching and more frequent incursions of livestock into protected regions. External support has been vital to sustaining the Luangwa Valley national parks, which, together with their neighbouring game management areas, harbour over 90% of the total global population for the Crawshay's subspecies (Table 4.3). Within this complex of protected lands, plains zebra populations have either been stable or have increased slightly where good wildlife protection remains in force

(Jachmann and Kalyocha 1994). Less-protected populations, however, have continued to decline. An upsurge in game ranching over the past five years offers some potential for further increasing Crawshay's numbers in Zambia, as it does for the Upper Zambezi subspecies, provided ranchers consider the origins of their stock. Crawshay's is notable among the subspecies of plains zebra in that its lower incisors lack an infundibulum (Groves 1974). It may therefore be quite genetically distinct from the neighbouring Grant's, Upper Zambezi, and Chapman's subspecies and warrant special conservation focus.

The Niassa Game Reserve, along Mozambique's northern border with Tanzania, currently harbours a small population of Crawshay's zebra. However, zebra also occur still in the surrounding areas and recently proposed plans to expand the Reserve would augment its zebra population considerably (Leo-Smith *et al.* 1997). Encroachment by agriculture during the civil war and poaching remain the biggest threats to these animals. Tourism is also being regenerated though and may help to improve wildlife protection in the region.

Zambia is also the last remaining stronghold for the Upper Zambezi subspecies of the plains zebra (Table 4.3, Figure 4.5). The Kafue, Blue Lagoon, and Lochinvar National Parks, in addition to surrounding game management areas such as Kafue Flats, form a large protected area in west-central Zambia that supports approximately half the global population of the Upper Zambezi subspecies. Although currently stable, the Kafue

Figure 4.4. The locations and current sizes for known populations of Crawshay's zebra (*E. b. crawshayi*) occurring on either governmental or private lands.

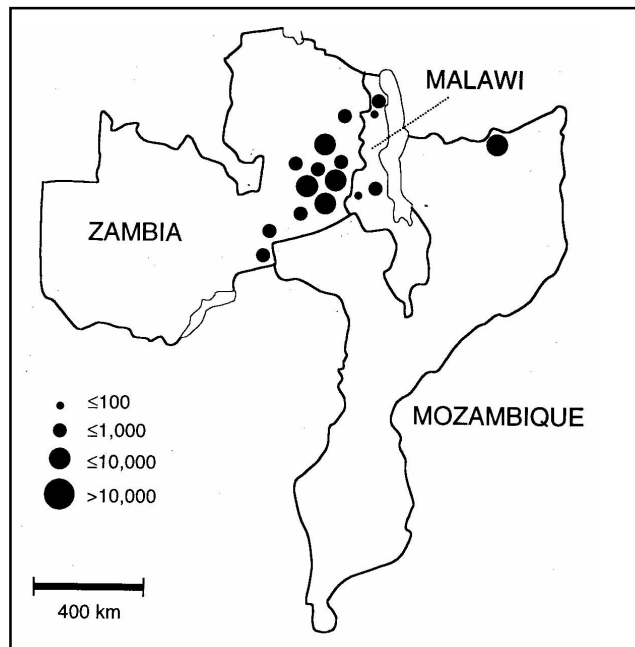
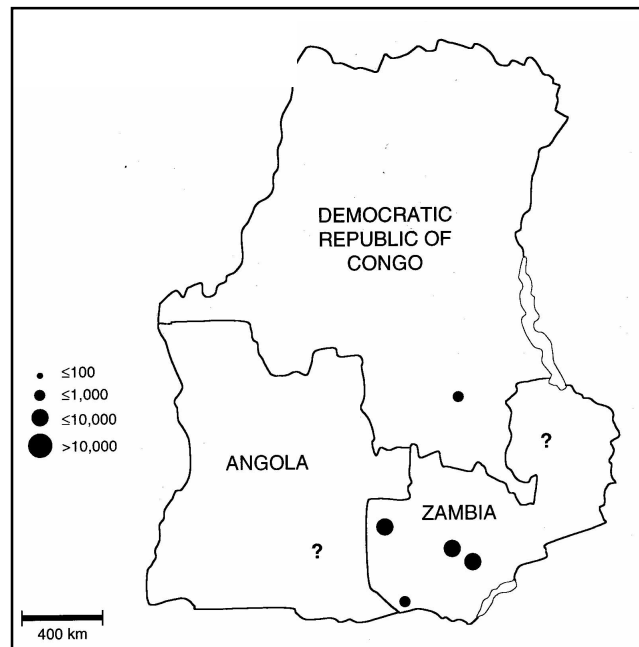


Figure 4.5. The locations and current sizes for known populations of the Upper Zambezi zebra (*E. b. zambeziensis*) occurring on either governmental or private lands.



population will likely increase if anti-poaching efforts improve as expected (Yoneda and Mwima 1995). An important population of Upper Zambezi plains zebra also occurs further west in the remote Liuwa Plain National Park where it is one of the most abundant ungulates. Many parts of Zambia, including game management areas in the Kafue region and the north-west, north-east, and east-central regions of the country, have not been surveyed within the last decade or more. Significant numbers of the Upper Zambezi subspecies may be currently unaccounted for in these areas since habitat generally remains intact and human and livestock densities are low.

The Upper Zambezi subspecies also occurs in eastern Angola and the southern Democratic Republic of Congo (formerly Zaire). Civil war in Angola during much of the past 25 years has devastated its wildlife populations, including its once-abundant plains zebra (see also Damara section), and destroyed the national parks administration and infrastructure (IUCN/ROSA 1992). Consequently, the Upper Zambezi plains zebra is probably extinct or nearly so in Angola, although confirmation will have to wait until future surveys are conducted.

Long-lasting civil strife and the chronic decay of governmental authority in Congo has also led to large losses of its wildlife. Upper Zambezi plains zebra formerly occurred in the southern grasslands and woodlands of the Upemba and Kundelungu National Parks, but had been extirpated from Kundelungu by the 1980s (Duncan 1992a). As of 1991, plains zebra still occurred in Upemba, but this population has almost certainly decreased since 1975, when the animals were estimated to number 1,000 (Verschuren 1975). Continued instability in the region may finally push this remnant population to extinction, if it has not done so already.

The Chapman's subspecies of plains zebra occurs primarily in Zimbabwe, but a small, declining population also resides in north-eastern Botswana (see the Damara section for a discussion of Botswana's plains zebra) and remnant populations may still exist in southern Mozambique (Figure 4.6, Table 4.3). As noted above for Crawshay's zebra, civil war has devastated Mozambique's wildlife populations and wildlife protection infrastructure. Fortunately, much habitat remains intact in formerly protected regions, such as Gorongosa National Park and the Marromeu Game Reserve. Externally funded efforts are currently in progress to protect remaining populations in these areas, and to rebuild the region's wildlife management and ecotourism infrastructures (Dutton 1994; Oglethorpe and Oglethorpe 1996).

In Zimbabwe, a long-established and well-developed system of protected lands maintains a stable or slightly increasing overall population of Chapman's zebra. National parks and safari areas cover over 12% of the country and support a growing ecotourism industry (Child 1995). Plains zebra concentrate in a string of protected

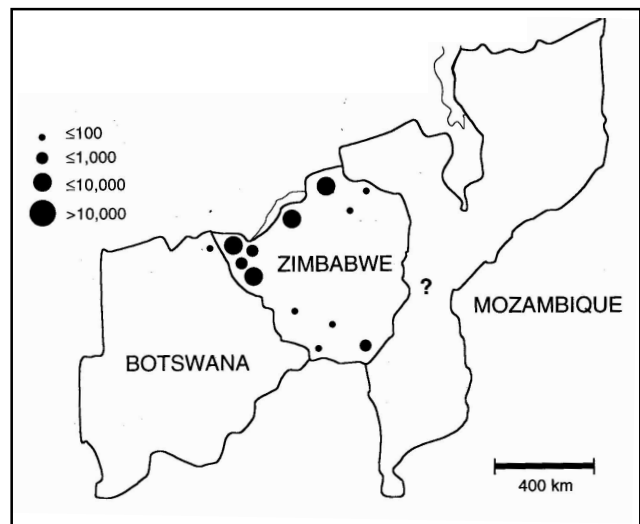


Figure 4.6. The locations and current sizes for known populations of Chapman's zebra (*E. b. chapmanni*) occurring on either governmental or private lands.

areas that begins on the border with Botswana in the west and arcs north along the Zambezi Valley, with nearly a third of the total population on protected lands occurring within the Hwange National Park and the adjacent Deka Safari Area. In recent years, chronic funding shortages have eroded the general infrastructure for wildlife protection and management but, so far, poaching remains at generally low levels (Dublin *et al.* 1994; Meldrum 1996).

In addition to Zimbabwe's parks and safari areas network, private game ranches and communally managed lands support a large number of plains zebra. Indeed, slightly more than half the country's total population resides on these private lands, which together constitute 37% more area devoted to wildlife than protected, government lands (Kock 1996). The transfer of wildlife ownership from the government to landowners has generally benefited conservation by providing economic incentives to manage wildlife as a valuable resource rather than extirpate it as a direct competitor with livestock and agriculture (Child 1995). Levels of protection and management are higher on many game ranches than they are on protected lands and reduced stocking levels of cattle have allowed ranges to recover from overgrazing. Whether this positive trend continues depends critically on the profitability of ecotourism, trophy and sport hunting, and the live animal trade since meat production alone is insufficient to support game ranching (Style 1991). On communal lands in particular, trophy and sport hunting generate 90% of the revenue gained from wildlife (Kock 1996). The sustainability of game ranching also depends on governmental attitudes towards it, which have the potential to shift quickly with domestic political and economic changes or in response to international pressures.

From a taxonomic perspective, Chapman's zebra may be near extinction, or have never existed. The interpretation presented by Duncan (1992a) implies that pure Chapman's zebra only live in southern Mozambique, while those in Zimbabwe and Botswana represent hybrids with either Crawshaw's or Damara zebra. Evidence from stripe patterns suggests that intergradation with Damara zebra does occur in western Zimbabwe (Skinner and Smithers 1990). Some taxonomists recognise an alternative subspecies, *E. b. selousii*, as occupying the eastern half of Zimbabwe and extending to variable degrees into Mozambique (Roberts 1951; Sidney 1965; Kingdon 1979). This is a conflict that is only likely to be resolved through extensive genetic sampling of plains zebra in Zimbabwe and its immediate neighbours. The current expansion of game ranching and trade in live animals in this region will likely add to this taxonomic confusion.

The Damara subspecies historically ranged across southern Africa, from Swaziland, Lesotho and South Africa in the east through northern Botswana to Namibia and Angola in the west (Figure 4.7). As reported above for the Upper Zambezi subspecies, Angola's population of Damara zebra is probably gone, although future surveys may disprove this conclusion. Similarly, no Damara zebra remain in Lesotho at this time (Castley *in litt.* 8/97). Extant populations of this subspecies occur primarily in Botswana and South Africa, but Namibia also supports a significant percentage of this subspecies' total population (Table 4.3).

Namibia retains extensive areas of relatively unmodified natural habitat, has a well-developed system of protected areas, and supports a strong wildlife utilisation industry. A single, large, protected population of plains zebra is confined by fencing to Etosha National Park, while smaller numbers are scattered elsewhere in the north on private ranches and communal lands. Etosha's population declined by more than 75% from 1960 to 1985 due to hunting and the fencing of their range, but numbers have been stable or only slowly declining since then (Gasaway *et al.* 1996). In contrast, between 1972 and 1992 the number of plains zebra on commercial farmlands has increased more than three-fold. The economics of wildlife utilisation in Namibia currently favour the joint ranching of both cattle and game, but as more landowners join together in conservancies to manage their lands as a single unit, economies of scale will favour a greater bias towards wildlife production (Barnes and de Jager 1996). Larger blocks of land also increase the potential for ecotourism, the most profitable form of wildlife utilisation at present.

Botswana retains several large populations of Damara zebra in the north of the country, centred around a few protected areas. This protected region, although extensive in area and now the basis for a substantial ecotourism industry, was established with greater regard for the

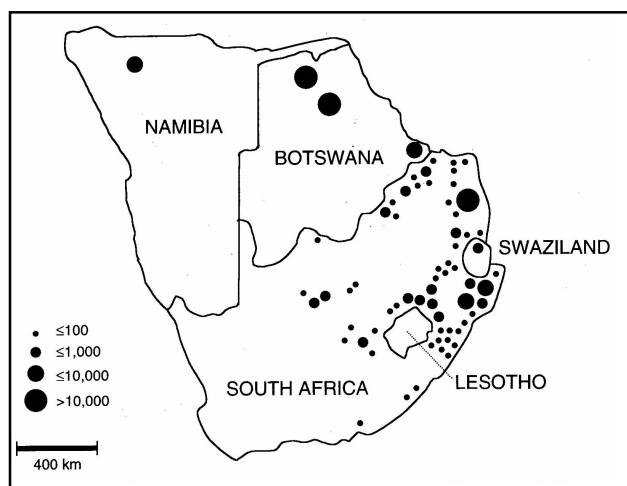


Figure 4.7. The locations and current sizes for known populations of the Damara zebra (*E. b. antiquorum*) occurring on either governmental or private lands.

The numerous game ranch populations on private lands in the Tuli Block, south-eastern Botswana, have been aggregated and considered as a single unit. The locations and sizes of populations on private and communal lands in Namibia are currently unknown, although they are concentrated in the northern half of the country and an overall total figure for these populations is included in Appendix 3. All nationally protected and most provincially protected lands in South Africa have been indicated, but populations on private farms are too small and numerous to plot (see Appendix 3 for estimated totals occurring on these private lands).

avoidance of major areas of human settlement and cattle ranching than for the ecological requirements of wildlife (Campbell 1973). Given current funding and staff shortages in the government's wildlife management infrastructure, a lack of progressive management and conservation policies, and further expansion of human activities (Crowe 1995), Botswana's zebra numbers are expected to decline. Nevertheless, Botswana's government is currently making serious attempts to improve wildlife protection and management. If these attempts are successful, the country's protected areas should be able to support significant zebra populations for the foreseeable future.

The largest remaining Damara population in Botswana, occurring in the Okavango-Chobe region, is currently threatened by a Namibian scheme to divert water from the Okavango River, and thus the vital dry season range of the Okavango Delta (Hannah *et al.* 1997). Both this population and the neighbouring population of the Makgadikgadi Pans and Nxai Pan National Parks are totally reliant on unprotected areas for part of their seasonal migratory cycle. Human encroachment (Kgathi and Kalikawe 1993) and further fencing of the range to impede the spread of cattle diseases (Hannah *et al.* 1997) pose immediate threats to these crucial areas. The only other plains zebra in Botswana occur on the north-eastern border with Zimbabwe, where numbers have declined by more than

40% per annum since 1990 (Department of Wildlife and National Parks 1995), and in the far eastern Tuli Block, where numbers are increasing on private farms. Those on the Zimbabwe border move seasonally between the two countries and are apparently of the Chapman's subspecies (see above).

By the early part of this century, overhunting and human encroachment had extirpated two of South Africa's plains zebras – Burchell's and the quagga – and restricted the remaining Damara zebra to a narrow strip along the north-eastern edge of the country (Kruger National Park and northern KwaZulu-Natal Province: Castley and Knight 1997). However, great efforts have been made during the last several decades to preserve remaining populations and reintroduce Damara zebra to areas of their historical range. Numbers of this subspecies are stable or increasing in at least four small national parks throughout the northern half of the country. The huge Kruger National Park supports an increasing population that represents over 60% of the country's total, making it critical to the long-term welfare of this species in South Africa. The Kruger also serves as the main source of stock for founding new populations in other national parks or supplementing existing ones. Unlike the plains zebra in most other protected areas throughout Africa, those of South Africa are confined by fences, making them more vulnerable to droughts in some cases (Walker *et al.* 1987) and requiring very active population management. Poaching is less of a problem than in other countries due to better protection and an apparent dislike for the meat in most of South Africa's indigenous cultures, although snares intended for other wildlife often kill zebras instead.

More recently, Damara zebra numbers in South Africa have been augmented by a rapid growth in the size and number of populations on provincial game reserves, private game reserves, and game ranches. In many cases, stock for founding populations on private reserves and ranches have come from other private lands, creating a significant market in live animals (M. Knight pers. comm., 1997). Genetic considerations are not generally taken into account when translocating zebra – nor are quarantine measures in force in most cases – although provincial reserve managers may use multiple translocations from different areas to increase the genetic diversity of founder populations (A. Armstrong *in litt.* 9/97). Most farm and reserve populations contain fewer than 100 individuals, and many have less than 50, increasing the likelihood of further reductions in genetic diversity due to inbreeding. Active management for trophy hunting and venison production will also likely alter the age structure and adult sex ratio from what they would be in natural populations. Thus, Damara zebra are reclaiming much of their historical range in South Africa but with an unnatural population structure in most cases and possibly an altered social organisation as well. The

specific long-term effects of these changes on population viability and productivity are unknown at present, but they could be quite detrimental (Ginsberg and Milner-Gulland 1994). Research directed at these issues is urgently needed given the widespread trend in other countries towards South Africa's current situation of many small, confined plains zebra populations, managed for a range of extractive and non-extractive uses.

4.10 Captive populations

The plains zebra is widely held in zoological collections throughout the world. According to the International Species Information System (ISIS), the total global population for this species in captivity numbers approximately 1,060 individuals. Of these, over 75% derive from only two of the six subspecies: 41% are Grant's subspecies and 36% are Damara subspecies. No zoological park members of ISIS appear to hold populations of either Crawshay's or the Upper Zambezi subspecies. The ISIS database encompasses 500 zoological institutions located in 54 countries, yet this represents only half those found worldwide. The total captive population of plains zebra is thus likely to exceed 2,000 individuals, and unrepresented subspecies may actually occur in some non-ISIS collections, although they are likely to be few in number. Plains zebra apparently breed easily in captivity given that 18–24% of captive adult females in the ISIS database currently have foals.

4.11 Threats and conservation issues

The principal threats to plains zebra are similar to those faced by other large ungulates throughout Africa: loss of habitat and overhunting. Although no country within this species' range is free of either problem, loss of habitat appears to be more of a concern in the southern half of the plains zebra's range, while poaching appears to be more significant in the northern half. This difference between regions may simply reflect a more advanced state of development in the south, where fewer large tracts of unmanaged range remain.

Expanding human populations have caused settlements and crop agriculture to also expand, reducing the area of suitable habitat available and cutting off migratory corridors. This effect is most extreme in countries with long histories of development (South Africa) and smaller countries with high human population densities (Malawi, Rwanda). In such cases, free-ranging plains zebra populations have ceased to exist, introducing a new set of threats inherent to small confined populations (see below). In range areas unsuitable for crops, competition with livestock for water and grass has led to the hunting and

fencing of plains zebra off the range. But the profitability of modern livestock ranching usually requires higher stocking densities than a range can sustain, reducing its productivity and even further exacerbating competition with wild grazers such as plains zebra. In pastoralist communities (e.g. Masai of Kenya and Tanzania), plains zebra have traditionally coexisted with the livestock, but recent trends towards the development of crop agriculture and permanent settlements on these lands do not bode well for the future of this coexistence.

Illegal hunting of plains zebra for meat has severely depleted populations throughout the species' range. Legal hunting may also be responsible for plains zebra declines in some areas since rates of sustainable, but indiscriminate, harvesting, in the range of 10–15% per annum, are almost certainly unsustainable in most habitats (see above). The magnitude of the poaching threat is closely tied to the level of wildlife protection a country is able to support; a few fenced areas (Namibia, South Africa) are clearly easier to police than huge tracts of open range (Kenya, Tanzania). Insufficient resources hamper wildlife protection in many countries, often forcing authorities to focus on key areas while leaving other nominally protected areas unsupervised (Zambia). International support, in the form of training, salaries, and equipment, could have a large impact for the better on this problem. Fortunately, plains zebra are killed primarily as a source of food and the meat is mostly consumed in nearby communities, making it a locally, rather than an internationally driven phenomenon. Relatively simple solutions to this problem may then be possible. For example, revenue-sharing programs between tourist areas and the surrounding communities in order to derive an alternative value from wildlife, or community ownership of wildlife to encourage its conservation and husbandry as a valuable, utilisable resource (e.g. CAMPFIRE in Zimbabwe).

Both threats of poaching and habitat loss become greatly magnified when civil strife erodes the power of wildlife protection authorities, displaces people and their livestock from their usual homes, destroys the normal food production and distribution mechanisms creating a greater demand for game meat, and provides the weaponry to acquire this game. Indeed, given the rapidity with which plains zebra numbers have fallen to extinction levels in countries such as Angola, Mozambique, and the Democratic Republic of Congo (Figure 2) – all of which have suffered through recent civil wars – political instability may be the most critical, over-arching threat to the long-term welfare of plains zebra in the wild. Even short episodes of instability can be damaging if they scare away vital tourist revenue in countries where the wildlife protection infrastructure depends heavily on this source of support. This is likely to become an even greater problem in the future as regional and global competition within the ecotourism market increases.

A less tangible, but perhaps very important future threat to the long-term welfare of the plains zebra in the wild is, ironically, the rapidly growing industry of game ranching. If done properly, game ranching could be a very important tool for conserving plains zebra whilst also improving human welfare in a sustainable manner. However, wide-scale translocations of animals without concern for the possible genetic or disease-related consequences of these movements could, conversely, have a negative impact on remaining natural populations. The plains zebra occupies a huge range in Africa and is adapted to a large variety of habitats. Specialised adaptations to local conditions could conceivably be degraded by a human-supported influx of animals from an ecologically different part of the species' range. Similar translocations could introduce new pathogens and parasites to populations without co-evolved resistance to them. Caution must be exercised in the stock chosen for translocations and the spatial scale of these movements until we learn more about the genetics and diseases of the plains zebra.

Overall, the plains zebra is a relatively resilient species that has demonstrated a remarkable ability to recover from population declines when provided with suitable habitat and protection from overhunting. Indeed, population growth rates as high as 23% per year have been observed within a few years of reintroduction to at least one national park in South Africa (Castley and Knight 1997). In the current climate favouring the sustainable use of wildlife as the ultimate, long-term source of protection, the plains zebra should fare very well since not only is it a good source for meat, skins, and other trophies, but its natural beauty and global recognition make it an essential component of the fauna sought by ecotourists.

4.12 Proposed actions

4.12.1 Improve coverage and pace of global monitoring

The data presented within this Action Plan represent the most thorough and accurate account of the population sizes, locations, and conservation status of plains zebras globally. However, although it is more comprehensive than all similar attempts to date, there is still much room for improvement. Significant regions remain unsampled in the last ten years, even in countries with well-developed wildlife protection infrastructures. The rapid pace of change in many African nations requires annual or biennial sampling if we are to detect environmental problems in their early stages and more effectively respond to them. In this regard, international support can play a major role by establishing and maintaining vital ecological monitoring programs until host nations are able to assume these responsibilities themselves.

4.12.2 Improve risk assessment

A global perspective on the status of the plains zebra is a necessary component of any plan to conserve this species, but most of the important conservation battles will be fought population-by-population, site-by-site. This requires a more detailed and forward-looking database of development patterns in order to highlight where future conflicts with wildlife will occur, and to guide efforts for mitigating the likely human impacts. For example, many plains zebra populations centre around protected areas but, for at least part of their annual cycle, depend critically on food and water sources in unprotected regions. Future development in the latter regions will consequently have profound effects on the long-term viability of these nominally 'protected' populations.

4.12.3 Quantify and manage genetic diversity, globally and locally

On the global level we must resolve whether current subspecific designations refer to genetically distinct entities, and therefore require separate management plans. This information is becoming more critical as game ranching and efforts to reintroduce the species to former parts of its range increase the frequency and scale of artificial translocations. We also need to identify genetically critical populations or those whose loss would substantially diminish the species' global genetic diversity. More locally, we need to monitor the genetic consequences of reduced population sizes in two principal contexts: (i) as human development restricts populations, causing them to shrink into protected areas and (ii) as game ranching leads to the proliferation of small, intensively managed populations. Determining the impacts of culling and cropping programs in both these contexts is also integral to monitoring genetic diversity at the local scale.

4.12.4 Increase understanding of species' basic biology

Too little is currently known about population regulation in natural plains zebra populations to predict how they will respond to increasing human-induced changes in their environment (e.g. elimination of predators, partitioning of the range, proliferation of cattle and other livestock). Neither do we know enough about the species' basic demography to determine sustainable harvesting rates in natural populations, nor to predict the impacts of specific harvesting programs on recruitment in confined, actively managed populations. Included in these impacts are disruptions of the plains zebra's unusual social organisation, which may then indirectly lower recruitment levels. We also need to determine the extent of natal dispersal for each sex and, in specific cases, the scale and timing of seasonal migration patterns if we are to understand the processes regulating genetic diversity within and between natural populations. Finally, plains

zebras are clearly important members of the grassland communities in which they live, but their specific roles in shaping the structure and dynamics of these communities are as yet unknown.

4.12.5 Investigate the economics of alternative utilisation strategies

In acknowledgement of the changing worldwide climate in conservation towards making wildlife pay its way (Eltringham 1994), we need to study the several utilisation options available for plains zebra. This species represents an excellent source of meat and produces beautiful skins, but it is also a globally recognised symbol for Africa's savanna wildlife and therefore a powerful attractant for both ecotourism and international support for wildlife protection. The comparative economics of these alternatives must be considered, taking into account the differing circumstances within particular countries and regions, if we are to guide the global management of this valuable species. Quantifying how plains zebra are currently being utilised in each country and determining the proportional economic contributions of these uses is an urgently needed first step in this direction.

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PART 2
Species Status and Conservation Action Plans:
Asia

Status and Action Plan for the Asiatic Wild Ass (*Equus hemionus*)

C. Feh, N. Shah, M. Rowen, R. Reading and S.P. Goyal

5.1 Nomenclature and conservation status

Scientific name:

Equus hemionus Pallas 1775
Equus hemionus hemionus Pallas 1775
Equus hemionus luteus Matschie 1911
Equus hemionus kulan Groves and Mazak 1967
Equus hemionus onager Boddaert 1795
Equus hemionus khur Lesson 1827

Common names:

Asiatic wild ass, kulan, onager, khulan, khur, dzigettai

IUCN Red list categories (version 3.1):

Equus hemionus **VU** Vulnerable A3bcd, C1
E. h. hemionus N. Mongolian khulan (now thought to be the same ssp. as *luteus*) **VU** Vulnerable C1
E. h. luteus Gobi khulan **VU** Vulnerable C1
E. h. kulan kulan **CR** Critically Endangered A2bcd, 4bcd
E. h. onager onager **CR** Critically Endangered C1

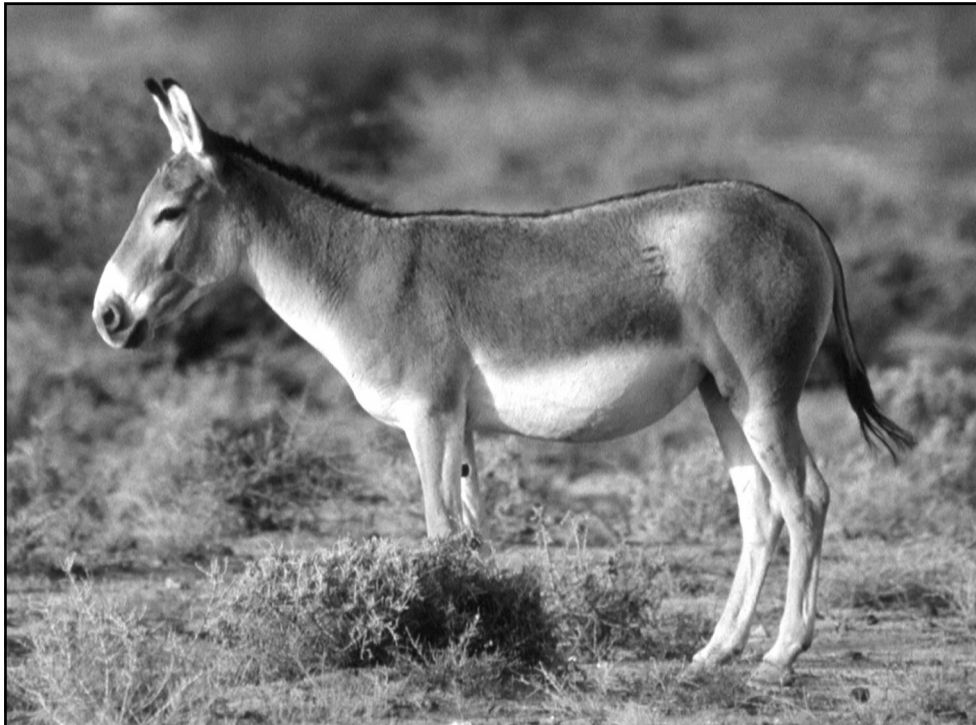
E. h. khur Indian wild ass **EN** Endangered B1ab(iii,v)C2a(ii)
E. h. hemippus Syrian wild ass **EX** Extinct (1927)

CITES listing:

Equus hemionus spp. Appendix II (default listing for all subspecies)
E. h. hemionus Appendix I
E. h. luteus Appendix I
E. h. kulan Appendix II (listed as *Equus onager*)
E. h. onager Appendix II (listed as *Equus onager*)
E. h. khur Appendix I (listed as *Equus onager khur*)

5.2 Distribution and population trends

During the late Pleistocene, 40,000 years ago, Asiatic wild ass are known to have roamed as far as West Germany (Kurten 1968). Like many other large-bodied mammals, equids vanished from numerous biogeographic regions during a mass extinction about 12,000 years ago, even though the number of species seems to have remained



The Asiatic wild ass – the onager (*Equus hemionus onager*).

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The Asiatic wild ass – the khur (*Equus hemionus khur*).

©Nita Shah 1995

more or less constant (MacFadden 1992). The range of Asiatic wild ass has continued to shrink ever since. In the 13th century, Marco Polo refers to the presence of numerous herds in Persia, the Middle East, Arabia, Turkestan, and the Gobi. During the same period, mention of khulans is made in the “Secret History of Mongolia” (Pelliot 1949). Since then, the word “khulan” has been used as a name for children in Mongolia. Today, the most abundant population of the species, representing > 80% of the total number, occurs in the southern part of Mongolia. All other populations have shrunk to a few hundred individuals (Figure 5.1).

The khur (*Equus hemionus khur*) was formerly widespread in the arid zone of north-west India (including present Pakistan), west towards Syria, and through much of Central Asia. However, it is now limited to the Little Rann of Kutch (Saline Mudflat) in Gujarat, India. It probably became extinct in Baluchistan and the extreme

south of Pakistan, on the Indian Border, during the 1960s (Corbet and Hill 1992).

Recent surveys indicated an increase in the khur population outside the Sanctuary (Shah 1993). The wild ass have emigrated out of the Sanctuary into the agricultural areas that are interspersed with fallow and saline lands around Surendranagar (45km from Dhrangadhra). The increase in irrigation facilities and the year-round availability of resources could have caused the emigration after the drought of 1987. Permanent resident herds have been established outside the Little Rann of Kutch (Shah 1993). A breeding herd is located about 60km from the south-east boundary of Little Rann of Kutch in the north-eastern part of Nal Sarovar Bird Sanctuary (Shah 1993). The khur has also been sighted in Bagodara about 50km from Velavadar Blackbuck National Park (90km from the Little Rann of Kutch) and in Lakhtar (about 30km from Surendranagar) (Y.V. Jhala pers. comm.).

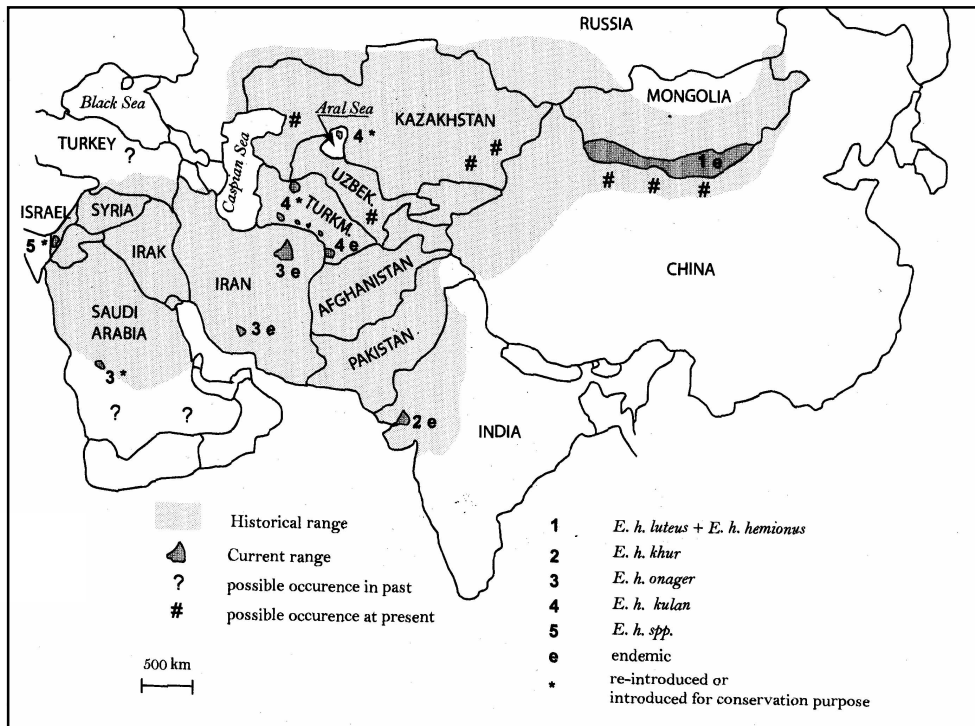


Figure 5.1. Historic and current distribution of the Asiatic wild ass (*Equus hemionus*).

In the past few years, wild ass have been sighted and found to disperse towards the Great Rann of Kutch in the west and north of Khadir Bet, Tragadi Bet, near Kala Dungar. They have been sighted on the Gujarat/Rajasthan border, Pakistan border in the north, Dhandhuka-Dholera highway in the south, and to Malia in the west.

The khur population showed a declining trend from 1946 to 1969, which can be attributed to the outbreak in 1958 and 1960 of Surra – an arthropod-borne disease, caused by *Trypanosoma evansi* (Gee 1963) – and two consecutive drought years. On the whole, the population counts were sporadic until the Little Rann of Kutch was declared a Protected Area in 1973 (Shah 1993).

The population of khur has shown an increasing trend since 1969 when the Little Rann of Kutch was declared a Sanctuary (Shah 1993). The first census in 1976 yielded a total count of 720 khur. By 1990, the Gujarat Forest Department census had counted approximately 2,072 khur in the Rann. In September 1996, a total count of 2,446 was obtained in and around the Little Rann of Kutch (S.A.M. Babi pers. comm.), whilst a count of 2,839 khur was obtained during the last census, conducted in January 1999 by the Gujarat Forest Department.

The taxonomy of wild asses for the whole of Asia is still not entirely clarified. It is now widely accepted from

morphological as well as chromosomal and mitochondrial DNA analysis that the Tibetan wild ass or kiang (*Equus kiang*), is a species of its own (Ryder and Chemnick 1990). The holotype of *Equus hemionus*, described by Pallas in 1775, was based on a specimen collected close to the north-eastern boundary of Mongolia. Six geographically isolated subspecies of *Equus hemionus* are presently recognised (Duncan 1992), of which one, the Syrian wild ass (*Equus hemionus hemippus*), became extinct in 1927. The others are the onager (*E. h. onager*) from Iran, the Turkmenistan and Kazakhstan kulan (*E. h. kulan*), the latter sometimes being referred to as *E. h. finschii*, and the Indian khur as *E. h. khur*. Within the hemionus, there are variations in the skull morphometry, the Transcaspien (kulan) and Mongolian (dziggetai) forms have narrower supra-occipital crests than the Iranian (onager) and Indian forms (khur), thus the Iranian onager seems closer to the Indian khur than to the Transcaspien form (Eisenmann and Shah 1996). Groves and Mazak (1967) differentiate between the Gobi khulan *E. h. luteus* in southern Mongolia/northern China and the North Mongolian dziggetai (*E. h. hemionus*) on the basis of colour differences. Our own observations revealed that colour contrast varies extensively between individuals and seasons, especially for breeding stallions, which become reddish in summer.

Table 5.1. Asiatic wild ass: The endemic subpopulations (IUCN criteria 1999; these populations have little demographic or genetic exchange).

Subspecies	Year	Number	National protected areas	Legal protection	Sources
<i>E. h. khur</i>	1999	2,839	Little Rann of Kutch	Indian Wildlife Protection Act (India) – 1972 – schedule I species	Gujarat Forest Dept, 1999 Shah pers. comm.
	1996	2,446			Shah 1998, pers. comm.
	AP92	2,072			Duncan 1992 (ed.) ¹
<i>E. h. onager</i>	2000	471	Touran (Iran)	Fully protected	Darreh-Shoori 2000, pers. comm.
	AP92	<400 for Iran			Duncan 1992 (ed.) ¹
	1996	96	Bahram-e-Goor (Iran)		Darreh-Shoori 2000, pers. comm.
<i>E. h. kulan</i>	2000	646	Badkhyz (Turkmenistan)	CIS – fully protected	Lukarevskii 2001, pers. comm.
	1998	2,400			Gurelov 1999
	1993	6,000			Sempéré and Pereladova 1993
	AP92	2,000			Duncan 1992 (ed.) ¹
<i>E. h. hemionus</i>	1997	1,674 ± 506	Gobi National Park,	Fully protected, Mongolian Red Book, 1997	Reading <i>et al.</i> 2001
<i>E. h. luteus</i>	AP92	2,500	Gobi NP part A (Mongolia)		Duncan 1992 (ed.) ¹
	1997	1,500	Gobi National Park, part B		Feh <i>et al.</i> 2001
	1997	39 991 ± 6 697	Baga Gobi Nature Reserve		Reading <i>et al.</i> 2001
	AP92	5,000	Zagiin Us Nature Reserve (Mongolia)		Duncan 1992 (ed.) ¹
	1992	10,000			Dulamseren pers. comm. (aerial counts)

AP92 and ¹: Estimate given in the 1992 Action Plan (Duncan 1992).

The Mongolian Red Book (Shirevdamba *et al.* 1997) refers only to *Equus hemionus hemionus* and the list of Mongolian vertebrates to *Equus hemionus* (Reading *et al.* 1998). A molecular study conducted jointly by the Equid Specialist Group, IUCN, and the Mongolian Academy of Sciences is presently underway in order to clarify whether the distinction between two Mongolian subspecies is justified or not. Similarly, Oakenfull *et al.* (2000) doubt whether *E. h. onager* and *E. h. kulan* are sufficiently different to be classified in two subspecies.

Asiatic wild ass (*E. hemionus*) is listed by IUCN as Vulnerable (VU). Both the kulan (*Equus hemionus kulan*) and the onager are Critically Endangered (CR). The kulan experienced a recent dramatic decline in the Turkmenistan population and the onager has only two very small sub-populations in Iran. The Indian khur (*E. h. khur*) is Endangered (EN). All three of these subspecies have small isolated subpopulations and, as such, are extremely vulnerable to stochastic extinction processes. The population of khulans (*E. h. luteus* and *Equus hemionus hemionus*) in Mongolia appears to be healthy, but increasing competition with livestock for water and pastures is creating political pressure to remove the khulan's protected status. Such action could potentially have negative affects on this population's viability (Table 5.1).

Asiatic wild asses were subject to numerous reintroductions and introductions for conservation purposes, with varying degrees of success (Table 5.2a and b).

5.3 Captive populations

Institutions reporting to the International Species Information System (ISIS) list a total of 151 *Equus hemionus* in captivity as of March 1999 (ISIS 1999). The actual number of Asiatic wild ass in captivity may be higher as several large private reserve populations do not report numbers to ISIS. The majority of animals are reported to be either kulan or onager with few khur or khulan listed. As of March 2001, there were 10 (5:5) khur in captivity in four Indian zoos of which Sakkar Baugh Zoo (Gujarat) have seven (5:2). The only captive breeding khur population is based in Sakkar Baugh Zoo, where the numbers are decreasing rapidly. The rest of the zoos have only solitary individuals. With no captive khur population elsewhere in the world, it is of paramount importance to upgrade the existing captive breeding centre at Sakkarbaugh Zoo in Junagadh, Gujarat (Shah 1996).

Other than the captive population used in the Israel reintroduction (a cross between *E. h. onager* and *E. h. kulan*), it is unclear whether or not there is a management goal for the Asiatic ass, and discussion is needed. Given the inadvertent mixing of the Israeli animals, it is likely that there will need to be both morphological and more genetic

sampling for the kulans and onagers in order to identify proper subspecies categories (Oakenfull *et al.* 2000).

5.4 Ecology, natural history and habitat

Asiatic wild ass weigh approximately 200–260kg. Gestation is 11 months and breeding is seasonal. Peak birthing season occurs between April and September – within any one subpopulation, births tend to occur over a two to three month span. To date, there has not been any detailed study of Asiatic wild ass feeding ecology. However, observations suggest a feeding strategy similar to that observed in other equids in xeric environments. When grass is plentiful, Asiatic wild ass are predominately grazers. During dry season and in drier habitats, Asiatic wild ass browse a large portion of their diet. While Asiatic wild ass do ingest woody plants, other forage is taken when possible. Animals have been observed eating seed pods (Shah 1993) and using their hooves to break up woody vegetation to obtain more succulent forbs growing at the base of the woody plants. In Mongolia, they readily eat snow in the winter as a substitute to water and were observed to dig holes down to 60cm in dry riverbeds to access water.

There have been a number of studies on social organisation and behavioural ecology of Asiatic asses. These studies have been conducted on several of the Asiatic wild ass populations throughout their range. While the explanations and terminology describing the species' mating system do not necessarily coincide, there are similarities in the observations. In all studies, breeding is seasonal and females with young tend to group together in relatively small groups (two to five females). Descriptions of male breeding strategies differ considerably.

Early studies were mostly descriptive. Both harem-style behaviour (Bannikov 1958; Solomatin 1973; Rashek 1973) and territorial defence (Klingel 1977) social systems were described. Since 1980, several detailed studies have been carried out on various subspecies: khur in the Little Rann of Kutch (Shah 1993), khulan in Mongolia (Feh *et al.* 1994; Feh *et al.* 2001), and the reintroduced kulan/onager hybrids in Israel (Saltz and Rubenstein 1996; Saltz *et al.* in prep.). Two studies, Shah (1993) and Saltz *et al.* (in prep.), describe systems in which individual stallions either defend territories or form all-male groups. Stallions in the Rann of Kutch exhibit both seasonal and year-round territoriality with females, forming small seasonal harems (Shah 1993). Territorial stallions defend territories throughout the year in the Rann of Kutch. Females remain on territories during the breeding season (monsoon season), with some females remaining on one territory and others moving between territories (Shah 1993). A portion of females remain on territories all year round. Shah (1993) refers to the two groupings as year-round and seasonal

Table 5.2a. Asiatic wild ass: reintroductions of subspecies.

Subspecies	Site of origin	Site of release	Years of release	Total number released	Most recent census	Number	Sources
<i>E. h. onager</i>	Touran or Bahram-e-Goor (Iran)	Khosh-yeilagh (Iran)	1973	11	-	extinct	Harrington 1977; DOE ¹ , pers. comm.
		Yazd province (Iran)	1997	6	2000	4	DOE, pers. comm.
<i>E. h. kulan</i>	Badkhyz (Turkmenistan)	Barsa-Kelmes island (Kazakhstan)	1955–1964	19	1992	96 ²	Pavlov 1999
		Maena-Chaacha (Turkmenistan)	1979 1984	14 +9	2000	200	Lukarevskii 2001, pers. comm.
		Kaakha (Turkmenistan)	1985 1989	9 +16	2000	see footnote ³	Lukarevskii 2001, pers. comm. Kuznetsov 1999
		Kopet Dag (Turkmenistan)	1981–1985	15	1995	32	Lukarevskii 2001, pers. comm.
		Kurtusu (Turkmenistan)	1982–1983	9	1999	extinct?	Kuznetsov 1999
		Germab (Turkmenistan)	1982	12	1999	extinct?	Kuznetsov 1999
		Sumbar walley, West Kopet Dag (Turkmenistan)	1988 1989	9 +33	1995	30	Lukarevskii 2001, pers. comm.
		Sarakamish lake (Turkmenistan)	1983–1987	72	1996	50–60	Lukarevskii 2001
	Barsa-Kelmes reserve	Kaptchagaiskoye (Kazakhstan)	1982–1984	29	1992	150	(Kazakhstan) Pavlov 1999
		Andasaiski reserve (Kazakhstan)	1986–1987	55	1990	85	Pavlov 1999
			1990	65	1992	164	Pavlov 1999
		Aktau-Busatchinski reserve (Kazakhstan)	1991	31	?	?	Pavlov 1999
		Djeiran Ecocenter (Uzbekistan)	1978–1979	7	1991	34	Pavlov 1999

1. DOE: Iranian Department of Environment.

2. Animals from Barsa-Kelmes were used for several reintroduction projects, so the 96 individuals censused in 1992 do not reflect the real population growth rate (in 1980, 205 animals were censused).

3. Populations of Kaakha and Maena-Chaacha are connected, so the number for Maena-Chaacha probably includes the Kaakha population, according to Atamoradov (1996) in Kuznetsov (1999).

Table 5.2b. Asiatic wild ass: introductions of subspecies for conservation purpose (outside the historic range of the subspecies).

Subspecies	Site of origin	Site of release	Years of release	Total number released	Most recent census	Number	Sources
<i>E. h. onager</i>	European zoos	Taïf (Saudi-Arabia)		5	2000	c. 5	Paillat, pers. comm.
<i>E. h. kulan</i>	Askania Nova (Ukraine)	Beruchi peninsular (Ukraine)	1982	11	1991	18	Pavlov 1999
<i>E. h. kulan</i> × <i>E. h. onager</i>	Iran and Turkmenistan	Negev (Israël)	1982	14	2000	100	Saltz, pers. comm.

harems. The term “harem” maybe misleading here, as the stallion behaviour describes resource defence rather than guarding of females, and the “item” at stake is land. Shah (1993) states that “the quality of the territory seems to be a prime determinant of dominance”. This is similar to territory stallion dominance witnessed in Grévy’s zebra (Ginsberg 1989). Within the Rann of Kutch, female movements were often limited to single territories, thereby creating “harem-like” female groupings (Shah 1993). However, females are able to move freely between territories, thereby describing a system in which female movement adapts to changing resource availability, as well as mate preference.

Similar social behaviour has been documented in the reintroduced population of wild asses in the Negev, Israel. The study in Israel is unique in that it has documented a growing population of all known individual females and territorial stallions. The study has followed the population from having one territorial stallion to more than seven. Males return to the main breeding area (an area with permanent water sources) each spring, several weeks before the females return (Saltz *et al.*, in prep.; Rowen *et al.* personal observation). The majority of males return to the same territories that they held in previous years; non-territorial males either form small all-male groups in the breeding area or remain in the winter grazing areas. Females return within a few weeks and foal almost immediately. Females form groups on territories but group membership remains fluid. This fission-fusion social system (*sensu* Rubenstein 1986) has some females remaining on one territory throughout the breeding season while others switch territories regularly.

In the Gobi B National Park (Mongolia), both Bannikov (1958) and Feh *et al.* (1994, 2001) suggest that khulan social behaviour is similar to that of feral horses. Feh *et al.* (1994, 2001) describe family groups consisting of individual males with several females and their foals moving to and from water sources, but the study is based on only a small number of identified individuals. In addition, stallions were observed to herd females. This behaviour is similar to that found in feral horses (although some of the specific postures differed) and is not common among the other subspecies studied. Shah (1993) describes generally unsuccessful efforts by stallions to herd females in the Rann of Kutch. In Gobi B, stallions were observed to defend both females and foals from predators (Feh *et al.* 1994). Feh *et al.* (1994, 2001) suggest that khulan behaviour in Gobi B is different from other populations as a direct response to predation pressure from cooperatively hunting wolves.

Further study of known individuals is necessary to fully understand the social behaviour of Asiatic wild ass. It is likely that differences in social structure and behaviour depend on climatic seasonality, vegetation cover, and hunting pressures. Additional clarification of social structure and the factors that influence animal movement

and behaviour (e.g. climatic and anthropogenic factors, grazing pressure, etc.) can provide a helpful tool in understanding threats to individual populations. The studies briefly outlined above demonstrate that there is a great deal of flexibility within the species’ social structure. With increasing levels of desertification and habitat fragmentation, all the above and future studies should be consulted in the formation of habitat and species conservation plans.

5.5 Actual and potential threats

The Persian onager (*Equus hemionus onager*), is critically endangered (CR) and is endemic to Iran, a region with few exchanges with other countries. In this order, poaching, overgrazing, competition for water, and removal of shrubs are the most important threats. Table 5.3 points to conservation problems and solutions adopted.

Geographic isolation of both populations could also be a source of danger for their viability. No exchange of animals was reported between Touran and the Turkmen population or between Touran and Bahram-e-Goor. This could severely affect the Bahram-e-Goor population. Poaching for medicinal purposes has been reported by Harper (1945) and mentioned once by an Iranian person (Tatin pers. comm., 2001), but local experts think that the main purpose for poaching is meat.

The khur (*Equus hemionus khur*) in the Little Rann of Kutch is the subspecies subject to the most direct threat from increasing human activities. The ecology of the Wild Ass Sanctuary, for example, is threatened by a canal building project – the Sardar Sarovar Project of the Narmada Development Authority (Goyal *et al.* 1999). In addition, the Wild Ass Sanctuary, established in 1973, is on the verge of being denotified as a protected area (Shah 1998a, 1998b). Even if the sanctuary remains as it is, there is growing competition for resources as an increasing number of livestock are grazed within the reserve during monsoon season. At the same time, salt mining, the major economic industry for local people, has increased 140% since 1958 (Sinha 1993 in Shah, reproduced). Such increased activity is particularly disruptive as the period for salt mining coincides with advanced stage of pregnancy in the khur (Shah 1993). Additional human pressure within the reserve has resulted in khur grazing in adjoining agricultural and pastoral areas. This, in turn, has led to more incidents where local herdsman have blamed the wild asses for declining range quality.

The kulan (*Equus hemionus kulan*) has suffered a catastrophic decline in the last three years due to poaching for the sale of meat (Lukarevskii pers. comm., 2001). The only naturally occurring population of this subspecies is in the Badkhyz Reserve in Turkmenistan. During the summer months this population migrates to

Table 5.3. Conservation problems and adopted solutions in the Touran Protected Area (T) and Bahram-e-Goor Reserve (B). * indicates that the problem or action occurs in that reserve. Source: Tatin *et al.* (2001).

Problems	T	B	Consequences for onagers	Current actions	T	B
Poaching	*	*	Reduced number of individuals	Daily control of the reserve; US\$5,000 penalty for one animal killed	*	*
Overgrazing by domestic animals	*		Food resources reduced	1) Removal of domestic animals from the fully protected area 2) compensation measures for herders (allocation of land outside the reserve) 3) Food supply (hay) near the artificial water holes	*	*
Springs intensively used by herders	*		Reduced accessibility to water	Construction of artificial watering holes at 2 sites (2001)	*	
Removal of shrubs and bushes (wood cutting)	*	*	Food resources reduced	Food supply (hay) near the artificial water places	*	
Geographic isolation of populations	*	*	Bottleneck effect on the population; genetic drift	None		
Successive droughts	*	*	Food and water resources reduced	Reduce the number of domestic animals in the reserve	*	*

the Kuska River, which is 100km outside of the protected area. The critical situation of the Badkhysh Reserve kulans clearly illustrates how swiftly isolated equid populations can be decimated and potentially driven to extinction.

Nomadic herdsman in Mongolia claim that an increasing number of khulan are damaging rangeland (Reading *et al.* 1997). In part, wildlife-livestock competition may result from an increased number of livestock following the country's shift to a market economy (e.g. livestock numbers increased from 24.6 million head to 28.6 million head, from 1989 to 1995 (Honhold 1995; Mueller and Janzen 1997; in Reading *et al.* 2001). The negative impacts of grazing in Mongolia are well documented, especially where wild and domestic livestock overlap (Honhold 1995; Mallon *et al.* 1997; Reading *et al.* 2001; Shagdarsuren *et al.* in press). Increased competition with livestock may result in further fragmentation of the wild ass population by limiting khulan to strictly protected areas.

In addition to competition for grazing land, poaching for meat and hides poses an increasing threat to khulan in Mongolia (Duncan 1992; Reading *et al.*, reproduced). High levels of hunting in the 1980s severely decreased khulan populations in inner Mongolia. Xiaoming and Schaller (1996) found very few khulan further than 100km from the Chinese/Mongolia border, suggesting that the inner Mongolian population is only a seasonal expansion of the Mongolian population. Despite harsh penalties, poaching for meat has also been reported in Iran (Tatin *pers comm.*, 2001).

International trade in *E. hemionus* subspecies does not appear to be a problem. Data from TRAFFIC (trade in Equus 1988–1997) do not include any “trophy” imports for *E. hemionus* spp., but indicate that a small amount of trade in live animals occurs from non-origin countries (zoo and private reserve trade). Unfortunately, there is very little information on the level of medicinal trade across international boundaries. To date, it appears that the illegal take of animals for medicinal purposes needs to be addressed within individual countries and does not appear to be an international trade issue. Additional investigation of the medicinal market would assist in determining the level of threat to the onager and khulan subspecies.

The greatest threat to the populations of Asiatic wild ass appears to be the potential for catastrophic loss due poaching (i.e. kulan in Turkmenistan). Disease and/or drought are “stress events” that are a constant threat to all the small, isolated wild ass populations in the Little Rann of Kutch, Iran, Israel, and Turkmenistan. For example, a disease outbreak of African horse sickness in the 1960s resulted in a major decline and the extinction of small khur populations (Corbet and Hill 1992 in Shah, unpublished). Continued fragmentation and marginalisation of the smaller populations may result in similar extinctions.

5.6 Current legal protection

The legal/protected status of the Asiatic wild ass is listed in Table 5.1.

5.7 Population growth and reintroductions

Recognising the threatened status of the dwindling kulan population in the 1940s, the Russian government gazetted the 900km² Badkhys reserve to protect the remaining 200 kulan. The population consequently grew to approximately 5,000 animals between 1945 and 1995. However, kulans then began to leave the reserve, either due to lack of water and/or forage, and subsequently the population was severely reduced by poaching for commercial sale of meat. Current estimates suggest that approximately 650 animals have survived. This history illustrates how quickly a healthy population of equids can be reduced to a critically endangered level.

The Badkhys Reserve held a single population of animals and, as such, the population is vulnerable to stochastic events. In addition, the potential for escalating human-wildlife conflict increases during droughts. A short-term study to understand the seasonal movement patterns of the population might help to address how best to protect the remaining population. This detailed information would assist a Population and Habitat Viability Analysis or similar process developing long-term management solutions.

In an effort to increase the total number of kulan populations, animals from the Badkhys and Barsa Kelmes were translocated to other areas. Table 5.2a lists the reintroduction sites in Turkmenistan, Kazakhstan, and Uzbekistan. Such assistance may be helpful in setting up additional populations. However, reintroduction management plans must include contingency plans to manage fast and unsustainably growing populations. Close collaboration with the IUCN/SSC Reintroduction and Veterinary Specialist Groups should occur at all planning stages.

To date, the introduction of *E. hemionus* species in Israel has been successful (Table 5.2b). The introduced population of Asiatic wild ass in the Negev is derived from founder stock of *E. hemionus kulan* and *E. h. onager*. The animals were introduced in 1982. Due to a high percentage of male births, the population grew very slowly at first (Saltz and Rubenstein 1995). Starting in 1991, the population began to grow more quickly with 17 births in 1994. As of the 1997 birth season, there were approximately 105 animals, of which 31 were adult breeding females. The animals are found over an area of 4,500km². The animals use three artificial water points that are maintained by the Israeli Nature Reserves Authority in addition to several natural springs. Detailed ongoing studies of the population examine population increase, range expansion, habitat use, and changes in vegetation density and species richness. Information from these studies will be used in the development of management plans for the population.

5.8 Current research activities

There are numerous Asiatic wild ass research activities underway throughout their range. The data presented in this report are compiled almost exclusively from these efforts:

- India: Status, ecology, and social structure of khur in the Little Rann of Kutch (Shah and Goyal, Shah 1998, 1999)
- Israel: Distribution, ecology, social structure, and pattern of range expansion (Saltz *et al.*, in prep.)
- Iran: No known ongoing studies. A recent survey was conducted by scientists from Iran and Tour du Valat, France (Tatin and Darreh-Shoori, reproduced)
- Mongolia: Two ongoing research projects: country-wide status and distribution (Reading *et al.* 2001); and ecology and social structure of khulan in Gobi B (Feh *et al.* 2001).

5.9 Gaps in knowledge

- A large omission in our knowledge of the Asiatic wild ass is their status and distribution within China.
- Management of the critically endangered onager and kulan would greatly benefit from increased knowledge of basic behaviour and ecology. Such information would provide a better understanding of threats to the population.
- Additional information is needed to clarify the subspecies classification of *E. h. onager* and *E. h. kulan*.
- As mentioned before, clarification is needed on the proper subspecies designation for the khulan in Mongolia.

5.10 Recommended actions

Three actions were outlined in the 1992 Equid Action Plan. Two of these focused on preserving and increasing the populations of onagers in Iran and khur in India. While critically endangered, the Iranian population appears to be relatively stable. However, increased threats to the Little Rann of Kutch may severely affect the long-term viability of the khur population (see below). The third action called for setting up conservation areas for Asiatic wild ass in Mongolia and China. Since the last Action Plan, aerial surveys indicate healthy populations in Mongolia (Reading *et al.* 2001). In 1999, the Mongolian Government created two strictly protected areas specially for the khulans, namely the Baga Gobi (18,391km²) and the Zagiin Us Nature Reserve (2,763km²). However, conservation actions are still required for the Chinese populations.

The following five actions are those deemed most important for this species.

1. The status of the Wild Ass Sanctuary in the Little Rann of Kutch needs to be maintained and strengthened. At present, it is under threat of being denotified. A strong stand needs to be made for the continued high conservation status of this sanctuary. Although the sanctuary was notified in 1973, land settlement works have not yet been completed. In the absence of clear legal status, agricultural land and new salt leases have been granted to the local people. Still, this sanctuary has been selected as a Biosphere Reserve by the Government of India and final declaration by the State Government is pending (Khachar 1994). The existing sanctuary infrastructure needs to be upgraded and the management staff of 33 is insufficient for an area of approximately 5,000m² (Shah 1993).

Efforts to mitigate the effects of various canal-building projects and continued salt mining should be made. With increased human use of the sanctuary, the focus should be on the increasing viability of other areas where the khur are periodically found (e.g. Nal Sarovar Bird Sanctuary and Velavadar Black Buck National Park) (Shah 1998, 1999). In addition, it is strongly recommended that the captive population (currently, n=14) be increased to provide animals for reintroduction (Shah, reproduced).

2. The kulan population in Badkhyes Reserve has declined by approximately 90% in the last three years. Improved protection from poaching is needed both within the reserve and along the summer migration route to the Kushka River. The ecological requirements of this population need to be determined and an ecosystem analysis made of their habitat in order to prepare a long-term sustainable management plan.
3. Taxonomic questions need to be clarified and subspecies ranges should be demarcated. These data are needed for the wild ass subspecies in Mongolia and for the kulan/onager populations in Turkmenistan and Iran. Information from the latter investigation could also affect the taxonomic listing of the introduced Israeli population.
4. Investigation and development of plans are needed to address conflict between local human groups and wild ass populations. Today, grazing outside reserves and encroachment into agricultural areas threaten to decrease "good-will" towards Asiatic wild ass populations in Turkmenistan and Mongolia. Whether now or in the future, all wild ass populations will probably be in conflict with local pastoralists and agricultural groups. Conflict with human populations will lead to loss of habitat quality and increased susceptibility to high mortality during drought and disease outbreaks. Efforts need to be made to address current problems and to limit their occurrence in the future.
5. The reintroduced populations of kulans in Turkmenistan should be surveyed. Their current

status needs to be evaluated and appropriate management plans determined.

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Status and Action Plan for the Kiang (*Equus kiang*)

Nita Shah

6.1 Nomenclature and conservation status

Scientific name:

Equus kiang Moorcroft 1841

Equus kiang kiang Moorcroft 1841

Equus kiang holdereri Matschie 1911

Equus kiang polyodon Hodgson 1847

The kiang was considered to be a subspecies of the *Equus hemionus*, but recent molecular studies indicate that it is a distinct species (Ryder and Chemnick 1990). The kiangs are the largest of the Asiatic wild asses.

The three subspecies of kiang have geographically distinct populations (Groves 1974) and their morphology is different based on such features as skull proportions, angle of incisors, shape of rump, colour pattern, coat colour, and body size (Groves and Mazak 1967). The eastern kiang (*Equus kiang holdereri*) is the largest subspecies (142cm at shoulder), the southern kiang (*E. k. polyodon*) is the smallest (100–105cm at shoulder). The western kiang (*Equus kiang kiang*) are slightly smaller than *E. k. holdereri* and also have a darker coat (Groves 1974).

The kiang has a large head, with a blunt muzzle and a convex nose. The mane is upright and relatively short. The coat is rich chestnut colour, darker brown in winter and a sleek reddish brown in late summer, moulting its woolly pelage. The summer coat is 1.5cm long and the winter coat is double the length (Groves 1974). The legs, undersides and ventral part of the nape, end of the muzzle, and the inside of the pinnae are all white. A broad, dark chocolate-coloured dorsal stripe extends from the mane to the end of the tail, which ends as a tuft of blackish brown hairs. Kiang have very slight sexual dimorphism.

Common names:

Asiatic wild ass, kiang, Ye Lü, Chang Lü

IUCN Red List Category (version 2.3):

Equus kiang **LR/lc** Least Risk

E. k. holdereri Eastern kiang **LR** Least Risk

E. k. kiang Western kiang **DD** Data Deficient

E. k. polyodon Southern kiang **DD** Data Deficient (?EN)

CITES Listing:

Equus kiang (all subpopulations) Appendix II



The kiang (*Equus kiang*).

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Table 6.1. Kiang (*Equus kiang*) subspecies range states.

Country	Western kiang <i>E. k. kiang</i>	Southern kiang <i>E. k. polyodon</i>	Eastern kiang <i>E. k. holdereri</i>
China	Central and West Tibet, S.W. Xinjiang	South Tibet	E. Tibet, Gansu, S.E. Xinjiang, Qinghai
India	E. Ladakh	N. Sikkim	-
Nepal	Mustang	?	-
Bhutan	-	?	-
Pakistan	Khunjerab	-	-

Table 6.2. Kiang population estimates.

Country	Province/Reserve	Estimate	Source
China	Qinghai and Gansu	15,000	Schaller 1998
	Xinjiang	4,500 – 5,500	Schaller 1998
	Arjin Mountain Nature Reserve	2,000 – 3,500	Shah and Huibin 2000
	Tibet	37,000 – 48,000	
	Chang Tang Reserve	22,000 – 28,000	
	Outside CT reserve	15,000 – 20,000	
India	Ladakh	1,500 – 2,000	Jammu and Kashmir Wildlife Dept. Chundawat and Rawat 1994; Fox <i>et al.</i> 1991; Shah 1996
	North Sikkim	74 – 120	Shah 1994
Pakistan	Khunjerab NP	25	Rasool 1992
Total kiang population		60,000–70,000	Schaller 1998

Note: To date, all the available literature, records, and sightings of the kiang had been recorded as one of the subspecies of *Equus hemionus*. At this juncture, care has been taken to identify almost all the kiang sightings and records to their distribution ranges put forth by Groves (1974). Moreover, the author (NS) has also considered the physical barriers and the geography of the kiang distribution ranges.

6.2 Distribution and population estimates

Kiang inhabit a large range in Asia and occur in China, India, Nepal, and Pakistan, and possibly Bhutan. All three subspecies are found in China. The eastern kiang is found only in China, while the southern and western kiangs are transboundary species, occurring in the border areas of several countries. To date, there have been few studies or population estimates conducted.

All three subspecies of kiang occupy the Tibetan Plateau, which consists of vast rolling terrain, dissected by hills, snow-capped ranges, and river basins. The highlands of Tibet cover an area of 2,164,000km² (Schaller 1998). Kiang may have been isolated on the Tibetan Plateau for several thousand years, and today, 350km separate it from the nearest *Equus hemionus* in northern Gansu and Inner Mongolia (Schaller 1998). Schaller (1998) has observed all

three subspecies and discerned no difference in size or colour. Although there may be slight regional variations, Schaller considers the subspecific designations to be premature. The geographical boundaries of Tibet include the Kunlun and Astin Tagh Ranges in the north, the Great

Figure 6.1. Distribution of kiang (*Equus kiang*).



Himalaya in the south, Karakoram in the west and the longitude, 102°E, approximately marks the eastern limit (Figure 6.1).

Kiang distribution has become increasingly fragmented. This can be attributed to an increase in human population numbers and the increased demand for intensive land use for both man and domestic animals. At present, most of the kiang populations are found in protected areas or in areas under army jurisdiction (Shah 1995). Recent available records in the literature refer only to kiang at the species level and do not provide information at the subspecies level.

6.2.1 China

Current Legal Protection: First Class Protection

Ninety per cent of the kiang population is confined to China (Rodney Jackson pers. comm., 1998) in the provinces of Qinghai, Gansu, Xinjiang, and Tibet (Xizang). Kiang have markedly decreased in number during this century, especially in areas with many nomads and their livestock. The species is still found within much of its former range of 1.5 million km² and, in some of the areas, it appears to be on the increase. To make an actual estimate of kiang numbers is very difficult (Schaller 1998).

Most Tibetan Plateau species have declined in recent years, perhaps because transportation has improved and the lives of resident pastoralists have become increasingly linked to outside market forces (Harris and Miller 1995). A highway was constructed during the 1950s, and from 1958 to 1961, when there were severe food shortages, there was intensive hunting of the animals all over this part of the plateau (Zhang 1984; Schaller 1998).

Qinghai Province

Historical Distribution: Kiang were once abundant in eastern Qinghai, except for parts of Qaidam Basin; there were once “several hundred” near Qinghai Hu (Prejevalsky 1876), but they are now rare in the region (Schaller 1998). Farther south, on the great rangelands around the headwaters of the Yellow River, the species was once abundant. Rockhill (1891) saw at least a thousand kiang west of Donggi Co (also called Hei Hai Hu, Tossum Nur). In the western end of Anayemaqen range, Kaji *et al.* (1993) counted 186 kiang (Schaller 1998). Schafer (1937) sighted over 1,000 kiang in north-west Sichuan, in the upper Yalong Valley across the border in Qinghai.

Present Status: Kiang have been almost exterminated in the eastern third of Qinghai Province and are now uncommon in and around the periphery of Qaidam Basin. They now occur mainly in the south-western quarter of the Province (Schaller *et al.* 1988).

The kiang population in Qinghai appears to be fragmented. There are large areas of the Province where the kiang is quite rare, particularly where the pastoralists are in greater numbers. All kiang observed are in remote areas with low human population densities or, in some cases, are found in the valleys and plains north of Qinghai Hu (also known as Koko Nur, Blue Lake), but mainly in the season during which pastoralists are not present (Marc Foggin *in litt.* 1999).

The south-western part of Qinghai comprises some 100,000km² in which can be found the highest kiang density. Kiang also extend east to Ngoring Hu and in the north across the Qaidam Basin to the Qilian Shan, but only at low densities. This is a vast tract for which no real population estimates have been made.

Areas between Kunlun Pass around Wudaoliang and Totohe were surveyed for wild ungulates. On the whole, the survey areas had about 1,500–2,000 kiang – a density of about 0.1 animal/km² (Schaller *et al.* 1991).

In Yeniugou, west of Kunlun Pass, Harris (1993) estimated a population of 843 in 1,051km² in 1991, counted less than 100 in 1992, and in 1997 counted 418 kiang (Harris *et al.* 1999). In Wudaoliang, 213 were seen in 2,100km² and 1,500–2,000 estimated in 20,000km² (Schaller *et al.* 1991). On the Qinghai-Tibet border, 510 kiang were counted in 2,736km² (Feng 1991b) and 1,000–1,500 kiang were estimated to be in a 75,000km² area. It is estimated that 15,000 kiang reside in Qinghai (Schaller 1998).

Three hundred and twenty kiang were counted between March and July 1997 north of Qinghai Hu, Huashixia (Maduo county) and Tuotuoheyang (Marc Foggin *in litt.*).

Xinjiang Province

Arjin Mountain Nature Reserve (Altun Mountain Nature Reserve), with an area of 45,000km², was declared a reserve in 1983. It is located on the northern edge of the Tibetan Plateau (IUCN 1993), which is contiguous with Tibet's Chang Tang Reserve (Schaller 1998). Kiang have replaced Tibetan antelope as the most numerous animal at the Arjin Shan Reserve and seem to be flourishing (Julie Gaw *in litt.*, 1997).

There are records of large numbers of kiang in this reserve. In the 1980s, about 30,000 were reported from this reserve (Butler *et al.* 1986). The reserve has an estimate of over 60,000 kiang (Wong How Man – Chief Advisor for the reserve: *in litt.*, 1997).

Along the southern margin of Arjin Shan (Tula Valley), 56 kiang were sighted in a 300km drive. Numbers fluctuate with season in the Tula Valley as they travel to and from the adjoining Arjin Shan Reserve (Schaller *et al.* 1991).

West of Arjin Shan Reserve, 108 kiang were sighted in a 4,000km² area (Schaller 1998). A survey of 23,000km² in the western half of the reserve showed that most kiang were

concentrated in about 5,795km² (Achuff and Petocz 1988). Kiang were more abundant in the eastern half of the reserve, where over a 1,000 kiang were sighted by Butler *et al.* (1986), whilst Feng (1991a) had recorded 770 kiang in 1,030km², which was extrapolated for the whole reserve by Gao and Gu (1989), thereby getting an estimate of 41,262 kiangs, which is considered much too high (Schaller 1998).

The eastern Arjin Mountain Nature Reserve survey in the winter of 1998 had an encounter rate of 2.56 kiang/km (333.5km of vehicle survey, Bleisch 1999a). The 1999–2000 survey had an encounter rate of 2.34 kiang/km (1,854 kiang in 792km of travel, Shah and Huibin 2000). The total kiang population in the area was estimated between 2,000 and 3,500 (Shah and Huibin 2000).

The western Arjin Mountain Nature Reserve had a very low kiang density of 0.137/km², especially in the vicinity of gold-mining camps. Kiang were estimated to number 1500 in this area of the Arjin Mountain Nature Reserve (Bleisch 1999b).

Taxkorgan Nature Reserve is situated in the south-west corner of the Xinjiang Province at the juncture of the Tajikistan, Afghanistan, and Pakistan borders. This reserve is contiguous to Khunjerab National Park in Pakistan (IUCN 1993). *Equus kiang* once occurred along the upper Yarkant and Oprang Rivers (Shipton 1938), but, according to local people, was last seen during the 1950s (Schaller *et al.* 1987).

Kalamaili Mountain Nature Reserve has a “large population” of kiang (Gao and Gu 1989), although there is no available estimate of population numbers.

Bogdhad Mountain Biosphere Reserve is reported to have kiang (MAB China 1990). This area is in close proximity to the Kalamaili reserve and either eastern or western kiang, or both, may be present in this reserve. The subspecies presence and their numbers need to be confirmed.

In the Aksai Chin region of Xinjiang, Shaw ([1871] 1984) reported 100 kiangs at the head of the Karakax River. Kiang still occur in the area, but there have been no surveys (Schaller 1998).

Gansu Province

Kiang were the second most commonly observed ungulate during the winter survey, when 0.255 kiang/km were encountered in a 679km vehicle survey (Bleisch 1996). In Yanchiwan Reserve, 58 kiang were sighted in 1985 (Schaller 1998). Kiang occur in the Aksai area adjacent to the Qinghai Boundary (Richard Harris *in litt.*, 1999)

Tibet (Xizang)

Historical Distribution: Kiang were once abundant on the southern rangelands. Bailey (1911), for example, noted that the kiang could be seen anywhere while travelling south and east of Gyanze. Sven Hedin’s books also indicate

the abundance of kiangs just a century ago. Near Dogai Coring, he noted that “a little higher up the hillside was dotted with yak, and there were more kiangs and antelopes than we could count”; north of Yako Basin, Hedin noted that “the region was swarmed with kiangs” (Hedin 1898). Travelling west of Nyima in 1906, Hedin recorded, “kiangs are very numerous; we had never seen so many animals of this kind gathered on so small an area” (Hedin [1922] 1991). And, north-west of Gerze in February 1908, Hedin found kiangs in “enormous numbers ... at least one thousand were seen at a time” (Hedin [1922] 1991).

Present Distribution: South Tibet – Kiang in the eastern part are separated from the northern populations as a result of intensive agricultural practices and human settlements along the Tsangpo River valley (Rodney Jackson, pers. comm., 1998). During a wildlife survey in 1995, Schaller made an attempt to delineate the current distribution between Bhutan and Yarlung Tsangpo. The local people reported that kiang were exterminated in most areas between the 1960s and 1980s (Schaller 1998). However, scattered populations survive along the Himalaya, west of Bhutan, west of about 89°E. They are sighted north of Sikkim (Shah 1994) and about 200 to 300 exist in the Qomolangma Reserve.

South-west Tibet – The kiang population is fragmented in southern Tibet along the foothills of the Himalaya (R. Jackson pers. comm.). A vehicle survey was conducted in September 2000 in south, south-west and central Tibet, which covered Nyalam-Lhatse-Saga-Mansarovar-Gar-Gerze-Dong Co-Cogen-Saga-Paika-Tso-Nyalam areas, and had 421 kiang sightings in 2,660km of travel (Shah and Gruisen 2000). An encounter rate of 1.4 kiang/km was observed between Mayumla and Mansarovar (Shah and Gruisen 2000). Kiang were also sighted in the Gakyi, Gerze, Tsochen, and Raga areas (Shah and Gruisen 2000).

In the eastern part of their range, kiang occur around Chigo Co in three populations, in total no more than 200 animals, and others persist just south of Yamdrok Co (Schaller 1998).

Kiang in Tibet are reported to occur in Chang Thang Reserve, Xianza Reserve, and Qomolangma Nature Reserve.

Chang Tang Nature Reserve was established in 1992 and has an area of 334,000km² (Schaller 1998). It is located in the north-western part of the Tibetan Autonomous Region of the People’s Republic of China. The eastern limit of the reserve follows the border of Qinghai Province. The Kunlun Mountains and the border of Xinjiang Uygur Autonomous Region form its northern boundary (Miller and Schaller 1997).

The eastern Chang Tang, east of a line from Nam Co to Siling Co, is now almost devoid of kiang (Schaller 1998). West and North of Siling Co, including the whole

Chang Tang Reserve, kiang are widely distributed and moderately common. They are sighted along the road that crosses Chang Tang north to Coqen and west in Gerze and Shiquanhe (Schaller 1998). In 1990, Aru Basin had an estimated 250 kiang in 1,800km² (0.14/km², Schaller and Gu 1994). A team of Chinese scientists carried out research in the Karakoram and Kunlun Mountain systems and reported the occurrence of large herds of kiang roaming around the Memar Lake (Rasool 1992). Kiang have been reported from Phala (300 miles north-west of Lhasa) and Motsobunnyi Lake (Goldstein and Beall 1989). A concentration of 806 kiang south of Yibug Caka was sighted in October 1993 (Schaller 1998).

Based on Schaller's work, the number of kiang in the reserve would be between 21,743 and 28,006 in an area of 334,000km² (or 18,488 to 23,813 in the official area of 284,000km²).

Qomolangma Nature Reserve centres around Mt Everest, and extends from the Arun River/Pung Chu in the east to the remote mountains north of Nepal's Annapurna and Maraslu ranges in the west. Local people reported that up to 400 kiang used to roam the plains surrounding Pegu Tso, whereas less than 50 were left in 1991 (Jackson 1991). Recent observations, however, indicate a population of at least 200–300, with one herd of 60 individuals. The population appears to be on the rise according to the local people (Rodney Jackson pers. comm., 1998).

Kiang outside of China

India, Pakistan, Bhutan, and Nepal contain the remaining 10% of the kiang population. India alone is home to more than 8% of the population, with the remaining kiang occurring in East Ladakh, North Sikkim, and along the borders of Jammu – Kashmir and Himachal Pradesh.

6.2.2 India

Current Legal Protection: Schedule-I of Indian Wildlife, Protection Act of 1972.

Ladakh

Kiang are inhabitants of the open, flat, and rolling plains of eastern Ladakh. Historically and currently, their range encompasses the area between Rupshu and Changchenmo (Stockley 1936; Fox *et al.*, 1991). Although their range covers an area of 6,000km² in Ladakh, kiang numbers have been greatly reduced in many areas (Fox *et al.* 1991). Approximately 1,500 to 1,600 kiang are distributed over an estimated range of 15,000km² in the Trans-Himalayan region with no protected areas (Chundawat and Rawat 1994). Reports state that kiang are numerous in the Eastern Plateau in Ladakh around Tso Moriri (Mallon 1991). The

Jammu and Kashmir Wildlife Department Leh conducted a census in 1988 and estimated a total of 1,500 kiang, and in 1994 counted 1,518 kiang in East Ladakh (Ladakh Wildlife Department, Jammu and Kashmir State Forest Department).

An encounter rate of 1.17 kiang/km was obtained (497 kiang in 426km) during the June 1995 survey covering areas around Pangong Tso, Chushul, Hanley, Tso Moriri, Tso Kar, and Demchok; Chumur was not surveyed due to bad weather (Shah 1996). A high encounter rate of 12.64 kiang/km was obtained along the Indus (278 kiang counted, Shah 1996), whilst 574 kiang were counted in a survey in July 2000, comprising an encounter rate of 0.92 kiang/km (Bhatnagar 2000). The kiang is a trans-border species, and their propensity to make large-scale movements makes any attempt to quantify their numbers in any given area difficult (Shah 1996).

Other kiang habitats in Ladakh include the More Plains between Tanglang la and Leh (Qamar Qureshi pers. comm., 1996), and Nurosumdo and Korzok, south-east of Ladakh (Charudutt Mishra pers. comm., 1998). Kiang have been reported by locals from Kharnak (upper Zaskar) in Ladakh (Yashveer Bhatnagar pers. comm., 1999). According to local Lahul and Spiti informants (Himachal Pradesh), kiang in small numbers have been sighted north of Kibar, along the Jammu and Kashmir/Himachal Pradesh state boundary (Yashveer Bhatnagar and Charu Mishra pers. comm.).

Sikkim

Until recently, southern kiang were thought to be extinct (Duncan 1992). However, two surveys by Shah in 1994 and 1995 in North Sikkim (India) support their existence. They are distributed in a 200km² area of the plateau in north Sikkim on the Indo-Tibetan border (Shah 1994, 1997). The plateau has no protected area status as it comes under army jurisdiction (Shah 1994, 1997). Very sporadic reports were available from Sikkim and no status reports on the species existed (Shah 1994).

Kiang sightings were made along the Indo-Tibetan border at an altitude between 5,100m and 5,400m. An encounter rate of 0.54 kiang/km was obtained in a 138km vehicle survey in November 1994. A vehicle survey between May and June 1995 recorded an encounter rate of 0.092 kiang/km (26 kiang counted in 283km). The largest herd of kiang (n=48; foals were seen, but not counted) was observed across the border, west of Bamchola (Shah 1994). Seasonal movements across borders have caused the indeterminate status of the subspecies (Shah 1994, 1997). Ali (1981) reported 17 kiang in a 1978/79 survey. In 1993, an army officer surveyed the Sikkim Plateau and gave an estimate of 90 kiangs (Maj Rao pers. comm.). In 1994, the kiang population was estimated between 74 and 120 (Shah 1994).

6.2.3 Pakistan

Current Legal Protection: Protected Status – Northern Areas Wildlife Preservation Act 1975.

The presence of the species on the Pakistan side of the border has been confirmed (Wegge 1988). An isolated population of 20 to 25 kiangs is sporadically distributed towards the eastern-most boundary of Khunjerab National Park, beyond Shamshal in Pakistan, adjoining the area between the Aghil range and the Kunlun Mountains of Chinese Turkistan (Rasool 1992). This forms the western-most limit of the kiang range. Kiang are restricted to a belt stretching along the Oprang and Muztagh Rivers, which form the Pakistan-China border. High altitude porters in June 1985 reported kiang sightings in Chikar, Furzin, and Muztagh Kayul Ridge (Rasool 1992). As the area is isolated, having no proper road network, the population status remains unknown (Rasool 1992).

6.2.4 Nepal

Current Legal Protection: Unknown.

Through correspondence with some officials from the Department of National Parks and Wildlife Conservation in Nepal, there are indications of the species' probable existence. However, such predictions need to be confirmed by employing surveys in the following potential areas of occurrence:

- No sightings of kiang have been reported in Makalu-Barun National Park and Conservation Area, although there is potential habitat in the northern end of the Park (J.B. Karki pers. comm.).
- Shey-Phoksundo National Park is located in the western mountain region, covering parts of the Dolpa and Mugu districts of Nepal. Much of the park area lies north of the great Himalayan range. Sightings of kiang are frequent on the Tibetan side of the park, but they have not yet been seen on the Nepal side, for unknown reasons (J.B. Karki, *in litt.*, as told to him by the Park Warden).
- Mustang, Annapurna Conservation Area reported ten kiangs in 1993, but it is uncertain if they still occur in this area (J.B. Karki, *in litt.*, as told by an officer posted in the area). P. Wegge recently sighted kiang in the Mustang area (Rodney Jackson pers. comm.).
- Two potential habitats for the kiang were observed in Chhujung in Mustang district and Damodar Kunda or the Chang Valley of Surkhang VDC (Village Development Committee) at an elevation of 4,800m. Based on the information from the pastoralists there are large numbers of kiang roaming in Chhujung when there is scarcity of grass on the Tibetan side. A hundred kiang, for example, were sighted in Pija in the Spring.

Kiang have also been sighted in Gunja (near Chhujung), Kiangchummi (between Nepal and the Tibetan border), Lapchagawa, and in the watershed areas of Salekhola, Yarchakhola, and Itikhola (Gurung 1999).

Nepal has around 500 western kiangs (Equid Camp Taxon Report draft 1995: source not quoted).

6.2.5 Bhutan

Current Legal Protection: Unknown.

There have been no reports or observations of kiang in Bhutan. There is a possibility of locating kiang in the extreme north and north-west Bhutan (Shah 1997). The Jigme Dorji Wildlife Sanctuary has unconfirmed reports of kiang, but their presence is very unlikely (Jackson 1981; IUCN 1993).

6.3 Captive populations

The International Species Information System (ISIS 1999) reports that there are 72 (31:41) Eastern kiang held in captivity in zoos. There are no records for the other two subspecies. Chinese zoos have kiang in captivity but their numbers are unknown, Urumuqi zoo in Xinjiang has four kiang in captivity, whilst Indian zoos have no kiang.

Given that the Eastern kiang has an IUCN Lower Risk classification, it may be necessary to develop breeding programmes for the other subspecies. In setting up a new breeding programme, or maintaining the current programmes, diligent attention must be given to proper subspecies classification (both in the wild and in captivity). At this point it is important to determine the subspecies status by augmenting morphological taxonomic information with molecular genetic analyses.

6.4 Ecology and social organisation

The kiang is an animal of open terrain, of plains, basins, broad valleys, and hills—wherever suitable forage, especially grass and sedge, is abundant. It reaches its highest densities on the vast alpine meadows and steppes. However, it also occurs in desert steppe and other arid habitats, such as in the Qaidam Basin. Altitudinally, kiangs range from 2,700m to as high as 5,300m (Schaller 1998).

Kiang were found in largest numbers in xeric, south-facing basins and in smaller numbers throughout Yeniugou ("Wild Yak valley" in Chinese) in Qinghai Province (Harris and Miller 1995). Kiang in Pakistan have been sighted along the river and stream basins in patches of *Myricaria*, willow, and *Hippophae* (Rasool 1992). Major sightings in Ladakh (India) were along the Indus and Hanley Rivers

and were very common around high altitude lakes (Shah 1996).

Kiang preferred to feed in swales, gullies, or areas of dissected terrain within these large xeric basins. They appeared to use the broad, open flats in the middle of these basins as escape terrain. *Stipa* spp. constituted almost 95% of their diets, whereas forbs were rare and legumes were significantly avoided (Harris and Miller 1995). There are direct observations of kiang feeding on *Carex* spp., *Kobresia* spp., and *Stipa* spp. in Sikkim (India) (Shah 1994, 1997). In Xinjiang Province, major activity occurred along the *stipa* meadows and in winter, mixed herds spent 50% of their time feeding with two feeding peaks per day (Shah and Huibin 2000).

In Xinjiang Province, in the East Arjin Mountain Nature Reserve, kiang were sighted between 3,345m and 4,355m during the winter survey (Shah and Huibin 2000). In south and central Tibet, sightings ranged between 4305 and 5,431m in September (Shah and Gruisen 2000). In Gansu Province, sightings ranged from 3,400 to 4,200m (Bleisch 1996). They have been sighted at elevations of 3,500m to 4,700m in Ladakh (Shah 1996), while in north Sikkim (India), the major kiang sightings were in the undulating and rolling plains and meadows at an altitude of 5,100m to 5,400m (Shah 1994).

Limited observation indicates that the social organisation of the kiang is similar to that of Grévy's zebra, African wild asses, and Asiatic asses. Kiangs normally foal in July and August, which is also the period of time in which females appear to come into estrus (Schaller 1998). During this season, males are often solitary and spaced in such a fashion as to appear to be territorial. Group sizes also tend to be smaller during this season. Females of the same reproductive stage are often associated. Large aggregations may form on good pasture during the fall and winter (Schaller 1998).

Kiang mares have a gestation period of 355 days. The kiang experience their peak breeding and foaling period from June to September – almost the same time as those of the *Equus hemionus khur* in the hot arid area of the Rann of Kutch (Shah 1993). Both these species occur in xeric habitats and forage availability is comparatively high from July through to September. Kiang foals in Ladakh were seen in July (Rashid and Meera pers. comm.).

The kiang are usually solitary or are found in small herds. Herds congregate on good pastures in autumn and winter, at times in herds of 300 to 400 (Schafer 1937; Schaller 1998; Shah and Huibin 2000). The largest of such aggregations consisted of 261 individuals (Schaller 1998), in east Arjin Mountain Nature Reserve, more than 500 were seen in December 1999 (Shah and Huibin 2000). There is no evidence that kiang migrate, but the large aggregations suggest considerable local movements in some areas (Schaller 1998).

6.5 Actual and potential conservation threats

6.5.1 China

Qinghai

Conservation problems are mainly social and economic, not scientific (Schaller 1998). The Yenniugou is the finest and most accessible wildlife area in Qinghai. This area has a continuing influx of Tibetan and Mongolian nomads who, unlike the nomads in Tibet, lack allocated rangelands (Harris 1993). There are plans to make this valley a hunting reserve (Schaller 1998).

In 1994, 2,000 to 3,000 gold diggers from Qinghai Province moved into the Nyima area (Southern boundary of the Reserve). Oil exploration teams were also in the area at the same time. Such extractive works should be monitored to avoid damage to the environment and to control illegal hunting by oil workers and miners (Miller and Schaller 1997). Gold miners from eastern Qinghai Province first began entering the Yenniugou Valley in the late 1980s and were still using it as a transportation corridor to mining sites in 1997 (Harris *et al.* 1999).

Xinjiang

In the Arjin Mountain Nature Reserve (AMNR), densities of wildlife in the north and west of Aqik Lake are very low as the area is overused by tractors and supply trucks travelling to and from two large gold mines within the nature reserve (Bleisch 1999b).

Pastoralists have settled in the eastern part of the Reserve and their domestic horses have been observed feeding with kiang in its winter range. Such use of the area needs to be analysed and monitored, with special attention to the possibility of disease transmission.

Tibet (Xizang)

In the Chang Tang Reserve, most of the area is uninhabited and only a belt of rangelands in the southern and western parts supports Tibetan pastoralists and their livestock. Today there are approximately 19,000 people and 1.5 million head of livestock dependent on the rangelands of the reserve (Miller and Schaller 1997). Commercial hunting is one of the main threats in this reserve, and the advent of roads, vehicles, and modern weapons has resulted in considerable depletion of wildlife populations (Miller and Schaller 1997).

Changes in traditional pastoral production systems pose a danger in the Chang Tang. Remote pastoral areas that used to take months to reach on horseback and by caravan are now accessible in a few days by vehicle from Lhasa (Miller and Schaller 1997).

The complex system of rotational grazing, which has succeeded in maintaining the rangelands, is being modified. Nomad groups now fence winter pastures and some have

built long fences across valleys and hills to keep wildlife out, which will affect the kiang and chiru populations (Miller and Schaller 1997; Shah and Huibin 2000; Shah and Gruisen 2000).

The current development priorities that will affect the kiang is “sedentarisation” of pastoralists. This will intensify land use and problems of overgrazing, and will increase competition for forage. Consequently, there are demands from herders to control kiang populations (Miller and Schaller 1997; Marc Foggin *in litt.*).

6.5.2 India

Sikkim Plateau

The habitat on the Indian side of the Sikkim plateau is the only area that has water when compared to the adjacent Tibetan plateau. The Tibetan pastoralists and livestock inevitably visit the Indian side for watering during the dry period, effectively preventing the kiang from accessing water sources. The livestock could also potentially transmit diseases.

Seventeen Dokpa families (nomads) have ‘Nangs’ (temporary settlements) on the Sikkim plateau (200km²). Approximately 1,000 yaks and 1,500 sheep are dependent for grazing on the plateau areas from October to April each year (Shah 1994).

Ladakh

Approximately 140,000 domestic livestock (90% represented by sheep and goat and 10% by yaks and horses; Kurup 1996) compete with an estimated 5000 wild ungulates (Kitchloo 1997) in the Changtang (Ladakh). Hence there is an increased pressure on the pastureland. Jammu and Kashmir Government has encouraged nomads to keep pashmina goats for production of wool by giving incentives that will sustain their living standards.

Other disturbances also arise from, 1) road networks being established for strategic reasons; 2) the State Tourist Department planning to open up new areas in the upper Indus Valley towards the Tibetan border, allowing pilgrims to visit the holy “Mount Kailash” directly from Ladakh (Pfister 1998), which would occur through the major kiang habitats in Dungti and Fukche areas.

6.5.3 Pakistan, Nepal, and Bhutan

No threats are discussed since kiang presence has lately not been confirmed.

6.6 Current research activities and gaps in knowledge

While an increasing number of surveys are providing range information, there is very little information on the species’

ecology or seasonal movement patterns. These two types of data are necessary to develop sound management plans. In addition, information on species’ requirements (e.g. forage, water, range) would be helpful to ensure that other species-specific or ecosystem management plans incorporate aspects important to kiang biology.

6.7 Recommended actions

Basic research is needed on a number of subjects, including:

- Molecular genetics of the taxonomic status of the three subspecies of kiang.
- The present distribution, range, and ecology of the three kiang subspecies.
- Ecosystem analysis of habitat and forage requirements of domestic livestock and kiang. Initial efforts should concentrate on known areas of seasonal overlap between kiang, pastoralists and their livestock.
- Mitigation management plans to reduce conflict between kiangs and domestic livestock.
- Develop a Protocol for Disease Monitoring.
- Conservation education and awareness – these should be promoted amongst the army in areas where the kiang habitat come under their jurisdiction, in order to help conserve the kiang and other wildlife. This is especially important in areas where kiang may be moving between protected, non-protected, and/or military areas.
- Non Governmental Organisations/Agencies/Individuals – these should be identified for conducting kiang research programmes in various countries. For example, China Exploration and Research Society in Hong Kong, in collaboration with the Arjin Shan Nature Reserve staff, has initiated a detailed research programme.
- The transboundary aspects of management for both western and southern kiang. Where possible, data sharing and management collaboration should be fostered between the park rangers and wardens who manage the same animals on either side of a border. In addition, a Kiang Population and Habitat Viability Analysis would bring all the scientists and managers associated with the species on one platform to develop a Conservation Action Plan.
- A review of the management actions, every two years. This would help to portray the true conservation status of the species as it exists in the field.

Country specific actions

- China: A province-wide status survey of the eastern kiang is needed. The status of western and southern kiang in China needs to be determined. Research is needed on whether or not there is an area of overlap in

the central Tibetan Plateau between the western and eastern kiangs. The taxonomic status of the three subspecies is critical in understanding the distribution of the species and subspecies.

- India: Periodical monitoring of the status of the southern and western kiang should continue.
- Pakistan, Nepal and Bhutan: Surveys are needed to confirm whether or not the kiang occurs/occurred in these countries.

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Status and Action Plan for the Przewalski's Horse (*Equus ferus przewalskii*)

Simon Wakefield, John Knowles, Waltraut Zimmermann and
Machteld van Dierendonck

7.1 Nomenclature and conservation status

Scientific name:

Equus ferus przewalskii (Groves 1986)

Important synonyms:

Equus przewalskii, *Equus caballus przewalskii*

Common names:

Przewalski's horse, Przewalski's wild horse, Asiatic wild horse, Mongolian wild horse, Takhi

Indigenous names:

Takh or Takhb (Mongolia)

IUCN Red List Category (version 2.3):

Equus ferus przewalskii EW Extinct in the Wild

CITES Listing:

Equus ferus przewalskii Appendix I

7.2 Biological data

7.2.1 Introduction

Although Przewalski's horse can hybridise with domestic horses to produce fertile offspring (Ryder *et al.* 1978; Trommerhausen-Smith *et al.* 1979), the existence of $2n=66$ chromosomes in Przewalski's horse identifies it as being more different from its domestic relatives ($2n=64$) than are any two breeds of domestic horse (Ryder 1994). They also show a number of other consistent differences in their appearance: the manes of Przewalski's horses are erect with no forelock, and the upper part of the tail has short guard hairs, unlike domestic horses, which have long, falling manes and long guard hairs all over the tail; a dark dorsal stripe runs from the mane down the back and dorsal side of the tail to the tail tuft; three to ten dark stripes can be present on the carpus and, generally, the tarsus (Groves 1994). Przewalski horses, contrary to domestic horses, shed their tail and mane hair once per year.



Przewalski's horse (*Equus ferus przewalskii*).

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Other studies of the genetic differences between Przewalski's and domestic horses have indicated very little genetic distinction between them. Only four alleles at four separate serological marker loci have been identified as specific to Przewalski's horse (Bowling and Ryder 1987), the vast majority of blood protein variants are present in both Przewalski's and domestic horses and even the fastest evolving DNA region known in mammals (the mitochondrial DNA control region), does not show significant differences between the two types of horse (Ishida *et al.* 1995; Oakenfull and Ryder 1998). Thus it is clear that Przewalski's and domestic horses are very closely related and have in the past interbred, but the fixed chromosomal number difference between them indicates that they are distinct populations (Oakenfull *et al.* 2000).

7.2.2 Historic distribution

The first visual account of Przewalski's-type wild horses date from more than 20,000 years ago. Rock engravings, paintings, and decorated tools dating from the late Gravetian to the late Magdalenian (20,000–9,000 BC), consisting of 2,188 animal pictures were discovered in caves in Italy, western France, and northern Spain; 610 of these were horse figures (Leroi-Gourhan 1971). Cave drawings in France, at Lascaux and Niaux, show horses that look like Przewalski's horse (Mohr 1971). In prehistoric times, the species probably roamed widely over the steppes of central Asia, China, and western Europe (Ryder 1990).

The first written accounts originate from Tibet. The monk Bodowa, who lived around 900 AD, recorded them. In the “Secret History of the Mongolians”, there is also a reference to wild horses that crossed the path of Genghis Khan during his campaign against Tangut in 1226, causing his horse to rear and throw him to the ground (Bokonyi 1974). That the wild horse was a prestigious gift, perhaps denoting its rarity or that it was difficult to catch, is shown by the presentation of a Przewalski's horse to the emperor of Manchuria by Chechen-Khansoloj-Chalkaskyden, an important Mongolian, circa 1630 (Zevemid and Dawaa 1973). In a Manchurian dictionary of 1771, Przewalski's horse is mentioned as “a wild horse from the steppe” (Dovchin 1961).

Przewalski's horse was not described in Linnaeus's “Systema Naturae” (1758) and remained largely unknown in the West until first mentioned by John Bell, a Scottish doctor who travelled in the service of Tsar Peter the Great in 1719–1722 (Mohr 1971). His account of the expedition, “A Journey from St Petersburg to Peking”, was published in 1763. Bell and subsequent observers all located horses known at that time within the area of 85–97° E and 43–50° N.

Wild horses were reported again from what is now China by Colonel Nikolai Michailovich Przewalski, an eminent explorer, at the end of the nineteenth century. He made several expeditions by order of Tsar Alexander the Second

to central Asia, aiming to reach Tibet. While returning from his second expedition in central Asia, he was presented with a horse's skull and hide at Zaisan on the Chinese-Russian border. The horse had been shot about 80km north of Gutschen. The remains were examined at the Zoological Museum of the Academy of Science in St Petersburg by I.S. Poliakov, who concluded that they were a wild horse, which he gave the official name *Equus przewalskii* (Poliakov 1881). However, current scientific review of the taxonomy wild equids (Groves 1986) describes Przewalski's horse as *Equus ferus przewalskii*.

Further reports came from the brothers Grigory and Michael Grum-Grzhimailo, who travelled through western China from 1889–1890. In 1889, they discovered a group in the Gashun area and shot four horses, three stallions, and a mare. The four hides and the skulls of the three stallions, together with an incomplete skeleton, were sent back to the Zoological Museum in St Petersburg. They were able to observe the horses from a short distance and gave the following account: ‘Wild horses keep in bands of no more than ten, each herd having a dominant stallion. There are other males, too, but they are young and, judging by the hide of the two-year old colt that we killed, the dominant male treats them very cruelly. In fact, the hide showed traces of numerous bites’ (Grum-Grzhimailo 1892).

7.2.3 Historical population estimates and trends

Since the ‘rediscovery’ of the Przewalski's horse for western science, western zoos and wild animal parks became interested in this species for their collections. Several long expeditions were mounted to catch animals. Some expeditions came back empty handed and some had only seen a glimpse of Przewalski's wild horse. It proved difficult to catch adult horses, because they were too shy and fast. Capture of foals, with possible killing of the adult harem members, was considered the only option (Bouman and Bouman 1994). Four capture expeditions that managed to catch live foals took place between 1897 and 1902. Fifty-three of these foals reached the west alive. Between the 1930s and the 1940s only a few Przewalski's horses were caught and most died. At least one mare was crossbred with domestic horses by the Mongolian War Ministry. One mare (Orliza III), particularly through her son Bars, was of great importance to breeding in the west (Bouman and Bouman 1994).

Small groups of horses were reported through the 1940s and 1950s in an area between the Baitak-Bogdo ridge and the ridge of the Takhin-Shara-Nuru (which, translated from Mongolian, means “the Yellow Mountain of the Wild Horse”, Figure 7.1), but numbers appeared to decline dramatically after World War II. A number of causes have been cited for the final extinction of Przewalski's horses. Among these are significant cultural and political changes

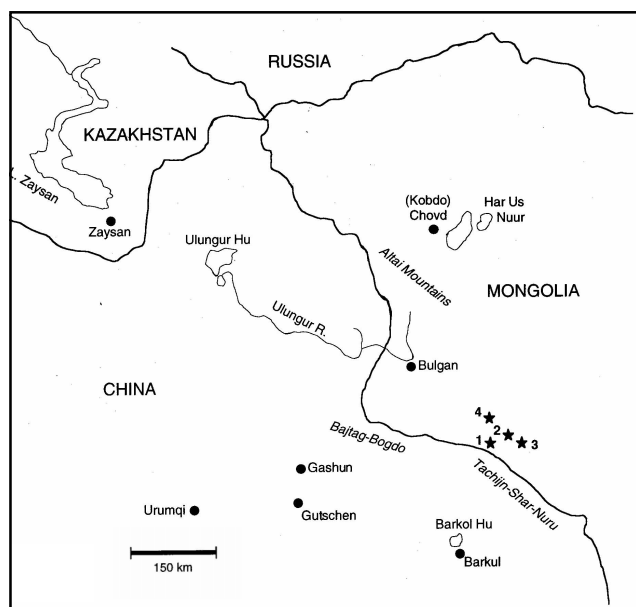


Figure 7.1. Area of the known geographical range and last sightings for Przewalski's horse (*Equus ferus przewalskii*) prior to extinction.

Starred locales are natural wells or springs where wild horses were sighted: 1. Jargat-us 2. Todgijn-us 3. gun-Tamga 4. Tachijn-us.

(Bouman and Bouman 1994), hunting (Zhao and Liang 1992; Bouman and Bouman 1994), military activities (Ryder 1993), climatic change (Sokolov *et al.* 1992), and competition with livestock and increasing land use pressure (Sokolov *et al.* 1992; Ryder 1993; Bouman and Bouman 1994). Capture expeditions probably diminished the remaining Przewalski's horse populations by killing and dispersing the adults (S. Dulamtseren in Van Dierendonck and de Vries 1996). The harsh winters in 1945, 1948, and 1956 probably had an additional impact on the small population (Bouman and Bouman 1994). Increased pressure on, and rarity of waterholes in their last refuge should also be considered as a significant factor contributing to their extinction (Van Dierendonck and de Vries 1996).

The last confirmed sighting in the wild was made in 1969 by the Mongolian scientist N. Dovchin. He saw a stallion near a spring called Gun Tamga, north of the Tachin-Shara-Nuru, in the Dzungarian Gobi (Paklina and Pozdnyakova 1989). Annual investigations by the Joint Mongolian-Soviet Expedition have since failed to find conclusive evidence for their survival in the wild (Ryder 1990). Chinese biologists conducted a survey in north-eastern Xinjiang from 1980 to 1982 (covering the area of 88–90° E and 41°31'–47°10' N) without finding any horses (Gao and Gu 1989). The last wild populations have almost certainly disappeared.

7.2.4 Present distribution

The only free-ranging populations are those associated with the recent reintroduction projects in Mongolia.

7.3 Ecology and habitat

The historic range is not known and there has been much debate about the areas in which Przewalski's horses were last seen: was it merely a last refuge or was it representative of the typical/preferred habitat? The Mongolia Takhi Strategy and Plan Work Group (MTSPWG 1993) concluded that the historic range may have been wider but that the Dzungarian Gobi, where they were last seen, was not a marginal site to which the species retreated. Although grass and water is more available in other parts of Mongolia, these areas often have much harsher winters. Of all the wild horse species, the Takhi was the one with the most eastern distribution and was most likely well adapted to the arid steppe of the Dzungarian Gobi (Zimmermann 1999).

An alternative viewpoint of the desert-steppe controversy is that the Eurasian steppe should be considered the Takhi's optimal habitat (Van Dierendonck and de Vries 1996). This would suggest that Przewalski's horses were forced into sub-optimal ranges such as the arid Gobi, as the more favourable steppe region was colonised by nomadic pastoralist people over several millennia. Studies of feral horses have shown that they are able to live and reproduce in semi-desert habitats but their survival and reproductive success is clearly sub-optimal compared to feral horses on more mesic grassland (Berger 1986). Van Dierendonck and de Vries (1996) suggest that the Takhi is primarily a steppe herbivore that can survive under arid conditions when there is access to waterholes.

Lomolino and Channell (1995) examined the patterns of range collapse in 31 species of endangered terrestrial mammals. Extant populations of 23 out of the 31 cases were located along the periphery, not the centre, of their historic range. They attributed this to two characteristics of peripheral populations: (i) isolation from (mainly anthropogenic) disturbances; and (ii) because they tend to be ecologically and genetically dissimilar from each other and from populations at the centre of the species range – one of the many and diverse peripheral populations may, therefore, be pre-adapted to the disturbances that drove the more central populations to extinction. Lomolino and Channell (1995) concluded that sites along the periphery of a species' historic range (including islands) may actually represent critical refugia for many endangered species.

7.4 Captive populations

7.4.1 Captive breeding

The Przewalski's horse is extinct in its natural habitat and survives due to captive breeding (Ryder 1994). The total number of living specimens recorded in the studbook as of

31/12/1999 is 1590 (Kus pers. comm.). These individuals are mainly descended from Przewalski's horses, but have a significant and incompletely documented contribution from domestic stock (Seal *et al.* 1990).

Of the 53 animals recorded in the studbook as having been brought into zoological collections in the west, only 12 contribute any genes to the current living population. Of these, 11 were brought into captivity in 1899–1902 and the last of them died in 1939. The one wild horse that has been bred into the population since then is the mare 231 Orlitza III, captured as a foal in 1947. A thirteenth founder is stallion 56 Halle 1, born in 1906 in Halle (Germany) to a wild caught stallion and a domestic Mongolian mare, which was one of the foster mothers used to nurse the Przewalski's foals during their journey to European collectors. Although the 12 founders taken from the wild are officially recorded as being of truly wild origin, one of them, a mare (18 Bijsk 8) is suspected, on the basis of phenotypic evidence, as having domestic horse ancestry (Dolan 1982). Because of this suspicion 18 Bijsk 8 is usually assumed to be an F1-hybrid (Przewalski's $\times$ domestic horse) in genetic analyses (Geyer and Thompson 1988; Geyer, Thompson, and Ryder 1989). Accounts of travellers in Mongolia and of those associated with the transfer of Przewalski's horses to European and American buyers at the turn of the century have also questioned their purity (Mohr 1971). In addition, recent research has identified at least one other domestic founder, 175 Domina, from the Askania Nova line, who was most likely a tarpan-like domestic horse (Bowling, in press).

Genetic drift and bottlenecks in the history of the captive population have resulted in the loss of some of the genetic diversity represented by the original founders. In fact, taking into account the combined effects of skewed founder contribution and gene loss, the number of new founders that would be required to start a captive population with the level of genetic diversity currently retained in the existing populations (known as the Founder Genome Equivalent) is 3.31 (Ballou 1994). The genetic bottleneck that conclusively defined the extent of the surviving gene pool occurred as a result of the capture, transfer to captivity, and variable reproductive rates of the individuals removed from the wild, with these initial poor breeding successes resulting in a slow rate of population growth. In addition, there has been artificial selection, orientated largely towards the production of a phenotype that resembles the descriptions made of museum specimens of wild individuals (e.g. Salensky 1907), which biased the genetic contribution of each founder.

Inbreeding depression also played a role in the population genetic history of Przewalski's horse. Studies have indicated that inbreeding was associated with increased juvenile mortality and shorter lifespan (Bouman and Bos 1979; Bouman-Heinsdijk 1982). Additional studies by Ballou (1994) have shown that there is a decrease in

survival of about 2–3% for each 10% increase in inbreeding in the Przewalski's horse – this is substantially less than for many other mammalian species (Ralls *et al.* 1988). Inbreeding depression only becomes a significant mortality factor in extremely inbred ($F > 0.4$) Przewalski's horses; at this level of inbreeding, infertile stallions were also produced. It is believed that Przewalski's horse did not have a system of close inbreeding in the wild, so it is surprising that they do not show higher levels of depression when inbred (Buisman and van Weeren 1982). However, the level of their susceptibility also reflects stochastic sampling of founders; by chance alone the founders may have been free of the deleterious alleles that cause inbreeding depression.

A study of outbreeding depression (potential detrimental effects of breeding conspecifics too distantly related to each other, as when founders have been acquired from geographically different sources) looked at the potential for outbreeding depression from several sources (Ballou 1994): 1) the domestic mare founder, 2) founder #18 Bijsk 8 (if treated as an F1 domestic/Przewalski's hybrid), and 3) founder #231 Orlitza III, who entered the population much later than the other founders. None of the outbreeding effects was negative; in fact, there was a significant positive effect of hybridisation on survival from founder #231, reflecting the beneficial effects of a new founder being brought into an inbred population.

At the end of World War II there were only 31 Przewalski's horses in captivity. Of these, only 12 were reproductive (Zimmermann 1997). A more organised captive breeding effort was needed to secure the future of the species. An important development came in the 1950s with the creation of the studbook, which first appeared as a supplement to the monograph "Das Urwildpferd" (Mohr 1959), and contained entries for the 228 animals in captivity between 1899 and 1958. Updated studbooks were published annually thereafter by Prague Zoo (Volf 1960–1990; Volf and Kus 1991; Kus 1995, 1997). The Przewalski's horse symposia on genetic management, inbreeding depression, and hereditary disease were further steps to a better understanding of the breeding history and its influence on population development and management (Bouman and Bos 1979). Prague Zoo organised the First International Symposium on the Preservation of the Przewalski's Horse in 1959, and four more symposia were held in 1965, 1976, 1980, and 1990. The Sixth International Symposium was held in Kiev and Askanya Nova, Ukraine, in October 1999.

By 1979, there were 385 Przewalski's horses in captivity, distributed over 75 institutions in Europe, North America, and Cuba. However, with the likelihood that the species was now extinct in the wild, the potential problems of long-term breeding of the captive population with no hope of additional founders became a reality. Therefore, in

1979, breeders of Przewalski's horse met to form a North American breeders group, which became the Species Survival Plan (SSP) for the Przewalski's horse. In 1986, the European Endangered Species Programmes (EEP, from the Europäisches Erhaltungszucht Programm) were accepted for several endangered species, including Przewalski's horse. This now includes the horses from the former Joint Management of Species Group Programme in the UK. There is an Australasian Species Management Programme (Wilkins 1995) and captive breeding efforts in the former Soviet Union are coordinated through the All-Union Federation of Zoological Parks. About half of the global captive population is now within these managed programmes and represents almost all of the surviving founder genes (Ryder *et al.* 1993). The main objective of these programmes is to retain 95% of the current average individual heterozygosity for at least 200 years. Husbandry guidelines have been produced (Zimmermann and Kolter 1992) and a comprehensive summary of the biology of the species has been published (Boyd and Houpt 1994).

An additional objective of the programmes is to produce animals for reintroduction into the wild. The captive space required by Przewalski's horse also has to be balanced against the requirements of programmes for other equid taxa. This is to be addressed through Regional Collection Plans drawn up by the regional Equid Taxon Advisory Groups, which have started in Europe, North America, and Australasia. A Captive Management Masterplan (Ryder *et al.* 1993) determined that the captive populations in Europe and North America could be reduced to make space available for other equids, without compromising the goals of the Global Masterplan. The growth rate of the population can be manipulated relatively easily through the use of single sex groups and immuno-contraceptive vaccine (Kirkpatrick *et al.* 1993).

7.4.2 Research activities

There is an active research programme involving horses in zoological collections, release, and reintroduction projects. The lack of the appropriate forms and quantities of vitamin E in the diet in captivity has led to locomotion problems (ataxia) and is being investigated. The social behaviour of Przewalski's horses may differ from that of other harem-forming equids and the correct development of social behaviour, particularly in stallions, is also a crucial aspect in the development of released groups. In addition, research projects are underway or have been carried out in semi-reserves, wild animal parks, zoos, museums, and research laboratories on a whole range of topics, including communication systems, drinking behaviour, helminthic infections, dunging behaviour, feeding ecology, time budgets, coat colour genetics, physiology, social structure, and mating strategies in relation to paternity.

Similar to the effect of other herbivores, a certain grazing pressure by Przewalski horses was shown to increase plant diversity (at Eelmoor Marsh, a semi-reserve in the UK, and at Le Villaret, France) and there is clear potential for using Przewalski's horses as a means of managing certain habitat types to achieve other nature conservation goals.

7.4.3 Release projects outside the historic range

Many semi-reserves are established worldwide to breed Przewalski horses in more natural environments, to keep bachelor herds, and to prepare some of the individuals for reintroduction. Four release projects occupying large areas have been conducted at Le Villaret (Massif Central, France), in Bucharra (Uzbekistan), the Hortobágy-National Park, Hungary, and Chernobyl, Ukraine – with a view to establishing self-sustaining breeding populations that can demonstrate natural social processes. The largest of these, in a predator-free fenced area (5126ha) is in Uzbekistan (Pereladova *et al.* 1999). In Uzbekistan, four stallions and six mares were introduced in a 5,126ha fenced acclimatisation area at the Bukhara Breeding Centre in the Kyzylkum Desert between 1987 and 1990 (Pereladova *et al.* 1999; studbook data 1997). Since 1992, 17 foals have been born and the population numbered 16 in 1998. A monitoring study (Pereladova *et al.* 1999) concluded that zoo-bred horses were able to adapt to the desert conditions. Twenty-one individuals were released in the Chernobyl exclusion zone, Ukraine, in 1998; four foals were born in 1999 (Dvojnok *et al.* 1999). At Le Villaret, 11 horses (five stallions, six mares) were released in 1993/1994 to a 400ha secondary steppe area. In the absence of human intervention, the population increased to 40 animals by the end of 2000. The herd naturally organised itself into four family groups and one stallion group.

The reduction of genetic variation through past genetic bottlenecks and many generations in captivity raised concerns that today's horses have reduced abilities, behaviourally and genetically, to survive in the wild. However, release projects have shown that they can adjust successfully to free-ranging conditions and develop functional social structures. Furthermore, observations of the first free-ranging groups in Mongolia provide additional confirmation of their ability to survive (Van Dierendonck *et al.* 1996; Bouman 1998).

7.5 Current conservation measures

There is a strong will among those working with Przewalski's horses to conserve the species using modern techniques of gene pool management and by the reintroduction of the

species to its historic range (Ryder 1990). In 1985, an expert consultation was organised by the Food and Agricultural Organisation of the United Nations and the United Nations Environment Programme in Moscow to draw up an action plan for the reintroduction of the Przewalski's horse into Mongolia (Food and Agricultural Organisation 1986). At the Fifth International Symposium on the Preservation of the Przewalski's Horse (Leipzig Zoo, 19–23 May 1990), breeders and delegates from Mongolia, China and the former Soviet Union reiterated their interest in the reintroduction of the species.

As with any reintroduction, genetic bottlenecks will occur unless every effort is made to ensure that the re-established populations have the gene pool resources available to the species (Ryder 1994). The Przewalski's Horse Draft Global Conservation Plan (Seal *et al.* 1990) called for Przewalski's horse to be re-established in free-ranging populations in wild habitat in sufficient numbers to allow continuing evolution by natural selection. Five to ten wild populations were recommended, each with an effective population size (N_e) of at least 50 (or 250 adult animals) in order to avoid extinction by predation or stochastic events (Seal *et al.* 1990). An essential aspect of these and future projects will be their integration, economically and culturally, into the local community's programme of development, particularly as suitable reintroduction sites are likely to also be utilised by domestic livestock. Where there is the possibility of contact with feral or domestic horses, additional measures will be necessary, which will also need to be acceptable to the local people. To achieve this, the semi-permanent presence of relevant experts—management, ecology, behaviour, and veterinary—is important.

7.5.1 Release projects inside the historic range

At present, three release projects are currently in different phases in China (Figure 7.2). All of them include an adaptation phase in a restricted area. The founder animals either come directly from zoos or have been kept for some generations in semi-reserves. However, the successful establishment of viable populations may vary considerably between projects, principally due to the availability of suitable resources and habitat at the release site: Jimsar (desert, China), Gansu (desert, China), and Anxi (desert, China). These programmes are each using different approaches and methods (Van Dierendonck and Wallis de Vries 1996).

In China, the Wild Horse Breeding Station in Jimsar County, Xinjiang began a breeding programme in 1985 with horses from several zoos; at the end of 1996, the centre had 20–41 animals but are unlikely to be able to release any due to the lack of water in the surrounding desert. Horses have also been brought to the Gansu National Breeding Centre in western Gansu Province in 1989. A release of 10–

15 animals into an adjoining 67km² semi-reserve was proposed for 1996, with eventual release to the planned Gansu National Park (Wiesner pers. comm.), but again doubts have been expressed as to the availability of sufficient water and forage. Finally, the Howletts and Port Lympne Foundation have sent horses to the Biodiversity Centre in Beijing as part of a planned release in the Anxi Gobi Nature Reserve in Gansu province; however, there has been no update since the end of 1994, when there were 7–11 horses (Zimmermann pers. comm.). At the VIth International Symposium, plans were presented concerning reintroductions/releases in Kazakhstan (Pereladova pers. comm.).

7.5.2 Reintroduction projects in Mongolia

Przewalski's horses have been present in two locations in Mongolia since 1992: Takhin Tal and Hustain Nuruu.

The Takhin Tal Project was initiated through an agreement with the Mongolia Ministry of Nature and Environment and financed by an international sponsor group (Christian Oswald Stiftung of Germany, W. Trense of Austria, and D. Stamm of Switzerland) (MTSPWG 1993).

The Hustain Nuruu Project was initiated by the Foundation Reserves Przewalski Horse (FRPH) and the Mongolian Association for the Conservation of Nature and Environment (MACNE). On 2 March 1991, the Parliament of Mongolia ratified the project. The reintroduction programme is complementary to a project supported by the Directorate General for International Cooperation (DGIS) from the Dutch Ministry of Development Aid.

Another release site in Mongolia, in Khomii tal, is in the advanced stages of preparation. The Governmental Commission on Endangered Species, previously the Takhi Commission (founded in 1991), is involved in all projects in Mongolia.

The Takhin Tal Project is located in semidesert close to the boundary of the western section of the Gobi National Park and consists of an acclimatisation area where the horses are kept in enclosures until they are released. A small stream, the Bjiin Gol, runs through the enclosures and provides water. In June 1992, the first group of Przewalski's horses arrived which consisted of two adult males and three females from Askanya Nova. One of the females, 1831 Golovushka, gave birth in the autumn of 1992, the first recorded birth of a Przewalski's horse in Mongolia since their extinction in the wild (Oswald 1992). In June 1993, a second transport of six females and two males arrived from Askanya Nova; there have also been subsequent shipments of horses from Switzerland, Australia, Austria, and Germany. In total, 59 horses in ten transports were shipped to Takhin Tal between 1992 and 1999.

Soft releases have taken place directly from the acclimatisation area at Takhin Tal. The first group was soft released, but had to be herded back into the enclosure due to concerns with wolves. In 1997 and 1998, horses were successfully released. Three mares with foals were recaptured before the winter of 1998/99 because the foals were injured by wolves; they were released again in the following spring.

In 1997, the International Takhi Group (ITG) was formed to review the structure and running of the project. The ITG is constituted from the Mongolian Takhi Committee, representatives from private foundations and a few European zoos. It has reviewed the organisation of the project and developed an active research programme, which includes veterinary research that has provided very important information on the impact of tick-borne diseases on reintroduced Przewalski's horses (see Disease chapter, chapter 12).

By the end of 1999, 25 foals had been born of which 14 have survived. There were a total of 44 horses present, 2–11 in the enclosures and 13–18 free-ranging, in two harem groups and one bachelor group. Monitoring of reproductive hormones in the faeces showed that 14 of the mares were pregnant at that time. In June 2000, seven foals had been born in the free-ranging harem group.

The reintroduction of Przewalski's horse in Hustain Nuruu is set within the context of the broader goals of the restoration and protection of biodiversity within a reserve (Bouman 1998). The DGIS Project is focused at the ecosystem level, but the Przewalski's horse, as a top herbivore, represents an important part of the ecosystem. The Hustain Nuruu Reserve covers 50,200ha and is situated

100km west of Ulaanbaatar, the capital, in an area of upland steppe, mountain steppe, and some forested areas. The upgrading of the Hustain Nuruu Mountain Steppe Reserve (designated in 1993) to the Hustai National Park (HNP) in November 1998 (Parliament Decree No. 115) and the subsequent adoption of the zoning plan for the park have sensibly improved the nature conservation situation in the protected area (Bouman pers. comm.). Nature management of the HNP was officially delegated by the Mongolian Government to MACNE. There is a training programme for reserve and nature conservation management, warden and ranger tasks, and applied monitoring and research of all relevant biological aspects of the ecosystem.

The support and involvement of the local people has been secured from the beginning. Socioeconomic activities, such as an afforestation programme, establishment of a cheese factory, provision of a basic health service for local villages and herdsman, a training centre for women in the surrounding villages, a veterinary programme for livestock, and the renovation of water wells, have been started in the buffer zone of the reserve with the participation of local people (Bouman 1998). The Mongolian legislation has been revised almost completely after the transition to a democratic government in 1990 and, in accordance with the law on buffer zones, three Buffer Zone Committees have been established, one in each village, which are represented in a Buffer Zone Council for HNP. A decision from the Council of Ministers on the borders of the buffer zones was made in November 2000 concerning the area surrounding the park, allowing controlled development that should protect the park from negative impacts and

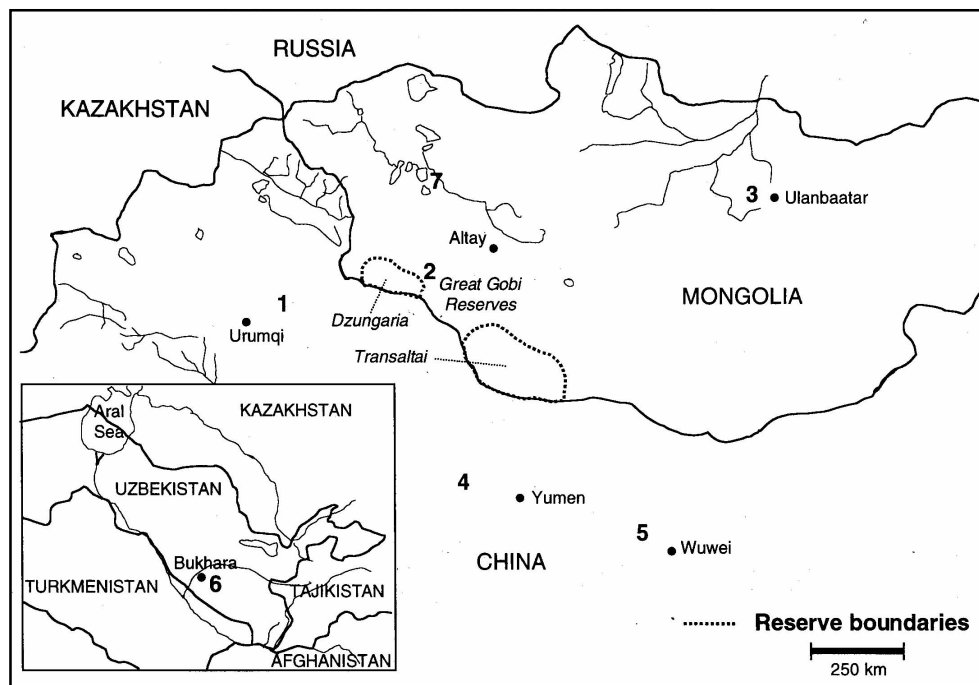


Figure 7.2. Current and proposed Przewalski's horse release and reintroduction areas.

1. The Wild Horse Breeding Station, Jimsar release project.
2. Takhin Tal reintroduction project.
3. Hustain Nuruu reintroduction project.
4. Anxi Gobi Nature Reserve release project.
5. Gansu National Breeding Centre release project.
6. Bukhara Breeding Centre release project.
7. Khomintal future reintroduction project.

allow the local population to draw benefits from having the park nearby.

The goal of the project is a free-ranging, self-sustaining population of 300–500 Przewalski's horses (Bouman 1996). The first group of 16 Przewalski's horses (of different bloodlines and low inbreeding coefficients) arrived in June 1992 and the first foal was born in June 1993, which was also the first foal to be conceived in Mongolia in recent times. A second group of 16 was sent in July 1994. In total, five visually and acoustically separated acclimatisation areas of 50ha each have been established, where the groups spend at least a year after their arrival to allow the harems to fully-integrate before release. All enclosures have year-round access to fresh running water from nearby natural springs (Bouman 1998). In total, 84 horses in five transports (1992, 1994, 1996, and 1998) have been shipped to Hustain Nuruu; the last transport took place in 2000. The horses have come mainly from the FRPH semi-reserves in the Netherlands and Germany, and also from Askania Nova (Ukraine), a semi-reserve of the Cologne Zoo, and Port Lympne (UK) (Bouman 1996). In 1998, the first surviving (at least one year) second generation foals were born in HNP. As per 1/12/2000, Hustai National Park had 122 Przewalski horses, with nine groups roaming freely in the park. 114 foals were born in the period between 1993 and 1/12/2000, of which 42 foals died.

Each released group is monitored daily. It has been noted that the overall body condition of the horses is better in the second year after their arrival than the first year; the free-ranging horses showed generally better condition than those in the enclosures. This suggests that the adaptation process may take some years. The free-ranging Przewalski horses, however, seem to defend their foals much better than the domestic horses monitored in the buffer zone. Up until the beginning of 1997, only two foals were lost to wolves and these belonged to released groups that were experiencing their first winter, when wolves predate in packs. This compares very favourably with a survey made of domestic horses from 1 October 1994 until the end of August 1995, where 11.3% of all domestic horses in the monitored area were killed by wolves, especially foals (Hovens 1997). In 1997 and 1998, the predation pressure on foals increased. Three foals were attacked by wolves in 1997 and died from the inflicted wounds, five in 1998, two in 1999, but only one in 2000.

There are large differences between the home ranges of the released groups; in 1995, they varied between 200–1,100ha and were almost non-overlapping, whilst between 1995 and 1997, the average home-range size of three harems was 995.4ha. With an average of 11.6 horses per harem, this gave an estimated population of 590 horses for the reserve – a clear indication that the numbers were not limited by food availability, but by social considerations (Bouman 1998).

Recently, initiatives have been taken to investigate the goals and possibilities for cooperation and exchange of information between all current and future Mongolian projects. A workshop took place in June 2000 that brought together representatives from the following institutions:

- Mongolian National Commission for Conservation of Endangered Species, Mongolia;
- MACNE, Mongolian Association for Conservation of Nature and the Environment, Mongolia;
- FRPH, Foundation Reserves Przewalski Horse, Netherlands;
- ITG, International Takhi Group, Switzerland and Germany;
- IUCN/SSC, Equid Specialist Group;
- WWF office Mongolia, Mongolia;
- Association pour le cheval de Przewalski/TAKH, France.

Among many other subjects, the possibility of a third reintroduction project in Mongolia was discussed and met with general approval. The Khomiin tal region is a buffer-zone (2,500km²) to the Khar Us Nuur National Park in western Mongolia. It is surrounded by lakes in the west, a river in the east, and sand dunes to the south. The site qualifies as an “Important Bird Area”. Vegetation types include riverbeds, reed marshes, desert, and mountain steppes. Only a few wolves are present. The project was approved by the local and district governments. In collaboration with local people, alternative activities to herding will be developed.

7.6 Current legal protection

The statute of the Great Gobi Reserve (or “The Gobi National Park”, in English) was ratified by the Great People's Khural of the Mongolian People's Republic on 31 December 1976. Recently, the Mongolian Parliament has passed a series of environmental laws and greatly extended the protected area system (Bouman 1998). In 1993, the Reserve Status category III was declared for the Hustain Nuruu area; conservation measures were approved and have been implemented since April 1994. At the end of 1998, the 60,000ha area received final approval for the status of a national park.

7.7 Actual and potential threats

The long-term threat to the retention of heritable variation in the captive population is loss of founder genes. Sixty percent of the unique genes of the studbook population have been lost (Ryder 1994). Losses of founder genes are irretrievable and further losses must be minimised through close genetic management. Furthermore, inbreeding

depression could become a population-wide concern as the population inevitably becomes increasingly inbred (Ballou 1994). However, correct management of the population can slow these losses significantly, as has been achieved since the organisation of the regional captive breeding programmes.

There are potential threats to the reintroduced populations. Wherever Przewalski horses come into contact with domestic horses, there is a strong risk of hybridisation and transmission of diseases. In Hustain Nuruu, it has been noted that overgrazing of the buffer-zone and continued pressure on the reserve are possible consequences of the enhanced economic activity in this area (Bouman 1998); however, the second phase of the project (1998–2003) will pay much more attention to sustainable development of the buffer-zone. In the western section of the Gobi National Park (Gobi B), habitat degradation by nomads and military personnel and their livestock continues; there is no core zone here that is free from human influence all year round.

7.8 Recommended actions

7.8.1 Maintain the captive population and its genetic diversity

The primary objective of the management of the captive population is to maintain a population of sufficient size and character to protect the species from extinction, and produce animals for release programmes. Specifically, consideration must be given to the demographic stability and retention of genetic variation.

New information from on-going pedigree analysis, such as the recent identification of additional domestic founders, should be assessed for its implications for management of the population. The significance of a restricted number of patrilineages should be addressed. At the present time, only two lines are still represented, and not equally. The possible implications should be assessed.

Integration of the regional breeding programmes into a global programme, with breeding recommendations in each region reflecting global goals should be a priority.

Re-analysis of past, current, and future genetic and demographic trends of the population is needed.

Calculation of gene survival in population sub-groups to identify genetically important individuals in order to manage their reproductive contributions should also be carried out.

Additional data should be collected on breeding opportunities v. breeding successes in order to examine the effects of both inbreeding and outbreeding on reproductive components of fitness. Such records should be routinely maintained by the institutions holding the animals and regularly compiled by the studbook keeper for such analyses.

7.8.2 Reintroduction to the wild

1. Continue the search for appropriate release/reintroduction sites. The important role of the IUCN/SSC Reintroduction Specialist Group in this process should be recognised. Research that has been done at the Takin Tal reintroduction site clearly indicates the need for specialised veterinary research and care. The expertise of the IUCN/SSC Veterinary Specialist Group should be incorporated whenever possible.
2. Careful monitoring of Przewalski's horse population dynamics and ecology in all current and future projects should be carried out. Standardisation of methods across projects and exchange of information would greatly assist understanding of the criteria for success. Monitoring efforts should include:
 - health, including possible vitamin E/selenium deficiencies;
 - fecundity, including influence of female age;
 - mortality, sources of mortality and survivorship;
 - habitat utilisation and feeding ecology;
 - behavioural ecology and mating systems related to reproductive success;
 - social organisation and its development.
3. In light of new information from release and reintroduction projects, and other advances in minimum viable population (MVP) studies, determine, in the next five years, the conditions that should be satisfied to secure free-ranging populations of Przewalski's horses in the wild. An important aspect of this will be the development of strategies to address potential hybridisation with domestic horses and thus introgression of domestic genes into the reintroduced population.
4. Only molecular pedigree analyses of all horses will allow to control for hybridisation. These can easily be made from dung samples. The data for all horses in Mongolia should be analysed and coordinated by the Genetic Department of the Mongolian Academy of Sciences.

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PART 3

Equid Biology and Ecology

Taxonomy of Living Equidae¹

Colin P. Groves

Taxonomy, like any other branch of science, is dynamic and subject to change as our understanding changes. There is not, and cannot be, any one “official” taxonomy. It is subject to fluctuation as past errors are corrected, as new data accumulate, and as concepts change. The following examples illustrate this.

8.1 Past errors

8.1.1 Individual variation

The explorers and big-game hunters of the 19th and early 20th centuries were certainly wont to mow down the large mammals of Africa in great numbers, but rarely did they think to preserve more than one or two for scientific study. So we have Matschie, Lydekker, Pocock, and others erecting new species and subspecies of plains zebra based on single specimens that looked different from any they had seen previously. Turn-of-the-century taxonomists had no idea what the variation from one individual to another encompassed; nowadays we do – and we can often see several of these “subspecies” in a single photograph of living zebras in an East African reserve!

8.1.2 Age-related variation

Again, our predecessors had little idea how an animal changed as it matured. Wild asses, onagers and plains zebras were becoming more common in Europe by the early years of the century; Grévy’s zebra, however, was still a rare beast in zoos, and Pocock was not to know that sub-adults of that species have brownish rather than jet-black striping, so he described *Equus grevyi berberensis*, a brown-striped race from further north than specimens previously seen by him. Ironically, the type specimen of *Equus grevyi* itself is a brown-striped sub-adult – a fact perhaps not sufficiently stressed by the describer, Oustalet.

8.1.3 Erroneous identification

Lydekker (1905) described and figured some living onagers in the Duke of Bedford’s collection, including a specimen said to have come from Meshed (now Mashhad) in north-eastern Iran, which he incorrectly identified as the Ghor

Khar or Indian onager and named *Equus onager indicus*; and a specimen of unknown origin, which he ascribed to the Persian onager and named *Equus onager onager*. The Mashhad animal in Lydekker’s figure has an extensive coloured zone on the flanks, and the boundary between white and coloured areas on the face follows the contour of the jaw angle; it is surely a Persian onager. His “Persian onager”, however, has the white extension well up on the flanks and the high crown and raised nasals, typical of the Indian form. In other words, he had got them the wrong way round.

Pocock (1947), who by that time used the generic name *Microhippus* for onagers, accepted Lydekker’s identifications. The only three Iranian specimens that Pocock had actually seen were three skins from Yazd (now Yazd) in the British Museum; because they were unlike Lydekker’s supposed *Equus onager onager*, he described a new subspecies *Microhippus hemionus bahram* based on them. It is a pity to quash such a poetically inspired name, but Pocock, misled by Lydekker’s erroneous identification, had simply redescribed the ordinary Persian onager.

8.1.4 Odd philosophies

Some of our predecessors were a little bit eccentric, and none more so than Paul Matschie, who worked in the Berlin Museum from about 1890 until his death in 1924. When he started work, Darwinian evolution was only 30 years old and there were a few hold-outs, mostly of the older generation – but not all. For Matschie, the elucidation of species and subspecies and their geographic distribution was the discovery of the Lord’s masterplan. As he had no truck with evolution, so he did not believe in individual variation either – the localities must be wrong or insufficiently precise, that’s all. Matschie is known as a great “splitter”, a describer of vast numbers of (mostly spurious) species and subspecies, and that is why. In his final days, he came to believe that the Great Plan was probably connected with half-degree units, so that if two specimens of a species or genus came from localities more than half a degree apart they must be taxonomically different, even if he was the only one who could detect exactly what the differences were. In equids, he described *Microhippus tafeli* which, because it came from the specified distance away from what he called *Microhippus holdereri*

1. Taxonomy in this chapter differs from the official Red List taxonomy. As Colin Groves points out, taxonomy is an evolving science and with new techniques, data, and theory, current categories will be questioned, reviewed, and perhaps changed.

(now *Equus hemionus holdereri*), simply must be distinct. I should perhaps add that I have seen the types of both *tafeli* and *holdereri*, and they are very similar.

8.2 Changes in viewpoint

8.2.1 Generic limits

The genus *Equus* was proposed by Linnaeus (1758) to include *E. caballus* (horse), *E. asinus* (ass) and *E. zebra* (mountain zebra), and the type species was tacitly accepted by his successors as the first of these. From time to time during the 19th century different authors proposed to set aside one or more species of living equids into genera other than *Equus* on the general grounds that they were “different enough”. Part of the philosophy was, no doubt, that horses, ass, onagers, and zebras are all the living species that we have in the family Equidae, and there is sufficient “taxonomic room” for several genera. The wish to divide up the genus in this way persists in the modern era: Trumler (1961), Groves and Mazák (1967), and Bennett (1980) are examples of this. There is a different philosophy behind Quinn’s (1957) multigeneric scheme: the author saw the different modern groups as the end-points of lineages that could be traced back deep into the Miocene, and had even achieved monodactyly independently.

Quinn was wrong. Although proposals have been made to link taxonomic ranking to time depth, these have not achieved general acceptance and the only widely acknowledged criterion for taxonomic categories (above the species level, at least) is monophyly. So, the single v. multigeneric schemes are essentially a matter of taste. The fossil record of the Equidae is one of the best known among mammals and is replete at every level with genera, leaving much less ‘room’ for multiple genera among the living fauna. There is also some doubt what these genera would actually be: will *Equus*, *Asinus*, and *Hippotigris* suffice, or must we have *Hemionus*, *Dolichohippus*, and *Quagga* as well? What, really, are the inter-relationships of the living species? For the moment, the less formal category of subgenus will have to do and I suggest that, because the six living species-groups are very clearly separate and there are fossil species to accommodate as well, six subgenera may be appropriate, at least until we learn more about the finer degrees of relationship. Groves and Ryder (2000) proposed to reduce this to three, and further studies are needed to confirm relationships.

It is worth adding that Pocock was a great splitter of genera, as he was of subspecies, but rather a lumpner at the species level, with the result that he ended up with a lot of monotypic genera. He placed onagers in a genus *Microhippus* following Matschie, but the name *Microhippus* was originally proposed by von Reichenow (1915) for Przewalski’s horse. So, Matschie and Pocock

were both wrong. As Trumler (1961) pointed out, the earliest available generic name for onagers is *Hemionus* (Stehlin and Graziosi 1935).

8.2.2 The species question: what is a species?

Most non-taxonomists still operate on a misunderstanding of the Biological Species Concept (BSC) of Mayr (1942). The popular misconception is that different species cannot interbreed; some go a step further, believing that species are sometimes able to interbreed, but hybrids between them are sterile. This is not in fact what Mayr said. He proposed that species “do not interbreed under natural conditions”, and emphasised that this reproductive isolation might be the result of either pre- or post-mating isolating mechanisms. The post-mating mechanisms are those that cause hybrids to be sterile; the pre-mating ones include such things as ethological mechanisms (e.g. different courtship displays), which can be broken down under unnatural conditions, such as captivity. If the pre-mating mechanisms break down, we may well discover that post-mating mechanisms are not in place – and perfectly fertile hybrids will result.

Clearly, sympatry between two taxa is *prima facie* evidence for the existence of reproductive isolating mechanisms between them; under the BSC, however, allopatric taxa are simply not amenable to being objectively assessed unless we are able to conduct breeding experiments in captivity. Even then, if crossing them is unsuccessful or hybrids between them are sterile, we can say that they are reproductively isolated and so are distinct species. Alternatively, if they interbreed to give fertile hybrids, we are not thereby enabled to claim the converse, namely that they are members of the same species. In any case, usually breeding experiments are simply not feasible, which in practice means that the vast majority of sexually reproducing species cannot even be tested.

We must remember, too, that we are faced with a dynamic biological reality, where reproductive isolating mechanisms may be partial, so that we can speak of hybrid fertility being reduced, but not abolished; and, at times, we can even demonstrate that some well-established species are themselves of hybrid origin. *Rana esculenta*, the Edible Frog, is perhaps the best known example of this.

Several variants of the BSC have been proposed, for example, to extend the concept to asexually reproducing organisms; and Simpson’s Evolutionary Species Concept – that a species has its own unitary evolutionary role and history – gives the BSC a time depth. But is this really applicable in practice? Don’t we need an operational definition of this concept, the species, which we all agree is so basic?

When I survey drawers full of sad skins in a museum, and try to sort them into species and subspecies, I have

no difficulty with the sympatric ones: they are consistently different, they coexist geographically, they are (inferentially!) reproductively isolated. They are distinct species. Excellent. Now what about the allopatric ones? – they may well differ, but at what level should I represent this taxonomically? The heretical thought has surely occurred to every museum taxonomist at some time or other: should I not apply exactly the same criterion? If they are consistently different, should not they too be classified as distinct species? Cracraft (1983) gave voice to such thoughts when he pointed out what an arbitrary decision it could be, to assess whether two taxa might or might not interbreed were their ranges to meet, and proposed the Phylogenetic Species Concept (PSC), whose operational criterion is simply the diagnosability (or, as I put it above, the consistency) of the candidates for species status.

Where does this leave the reproductive factor? Its potential importance is unquestioned but, in itself, it can never be a criterion. We usually do not know whether there is interbreeding between two species, or we may even know that there actually is; the significant factor is that, if there is interbreeding, any resulting gene-flow does not affect the character discontinuity between them.

8.2.3 The subspecies question

Conceptually, there is no disagreement about what subspecies are: they are geographic segments of a species that are morphologically differentiated to some extent. They are geographic; by definition, they can never be sympatric. They are morphologically differentiated – by how much? Not consistently 100% which, under the PSC, would make them different species. Mayr's 75% rule – three-quarters of individuals of one subspecies must be distinguishable from all individuals of all the others – is usually upheld, but this is a rule-of-thumb. The subspecies is just a point on the continuum of degrees of differentiation at which it becomes helpful (or desirable, or simply convenient) to recognise that differentiation with a trinomial.

Subspecies are often the steps on a stepped cline. If the clinal gradient is insensibly smooth, obviously to dignify its two ends as subspecies is rather arbitrary. A stepped cline, however, is something else; one can say that, within limits, subspecies A ends *here* and subspecies B begins *there*, and between the two points is a more rapid change in gene frequencies, metrical averages, or whatever one is talking about.

NB: Either a species has at least two subspecies, or it has none. Subspecies exist in relation to one another; there is no such thing as a species having one single subspecies. One of the subspecies is called the nominotypical subspecies and its subspecific name repeats its specific name; this will be the subspecies that exists at the species' own type

locality. There is no assumption that one subspecies is more "typical" of the species than another.

8.2.4 Nomenclature of domestic animals: are domestic animals the same species as their wild relatives, or different species?

I have argued that there is and can be no definitive answer to this (Groves 1995). They are not subspecies because they are sympatric; they are not, or generally not, different species because, except in a few outstanding cases, they are not diagnosably different. I have called them 'paraspecies'. Corbet and Clutton-Brock (1984) argued that, in most cases, it is convenient to maintain the fiction that, for nomenclatural purposes at least, they are different species.

The wild species may have subspecies; the domestic species does not. Domestic breeds, however distinct they are, are sympatric; they arise and merge within very short periods of time.

8.3 Subgenera

8.3.1 Subgenus *Equus*: horses

Externally, horses are recognisable by a number of features: the long-haired tail; the mane that is both long and thick and tends, at least in winter and/or with increasing age, to fall to one side; the rounded croup; the usual presence of chestnuts on hindlimbs as well as forelimbs; the broad, rounded hoofs; and the poor countershading, weak dorsal stripe, and dark lower limbs with generally traces of stripes on carpus and tarsus. Cranially, they have a relatively small skull, reduced cranial flexion, long diastema, large pterygopalatine fossa, and long, rounded occipital crest. The nasal end of the premaxilla is truncated or rounded, so that it forms the angle of the narial notch. Postcranially they have a long scapula and stout metapodials and phalanges, and the metacarpus is short compared to the metatarsus. The pelvis is broad and splayed compared to other subgenera, biischial breadth being high compared to biacetabular. Finally, the height of the pelvic inlet is strongly sexually dimorphic.

Groves (1986, 1994) argued that all horses that survived into historic times belonged to one species, *Equus ferus* Boddaert 1785, with three subspecies: *E. f. ferus*, *E. f. sylvestris*, and *E. f. przewalskii*. The evidence that the Przewalski's horse is the eastern representative of the species that contained the European tarpan is admittedly inferential; a gradation of colours from west to east and, apparently, the occasional appearance of Przewalski-like colours in Europe (including, as many people have noticed, on the walls of terminal Pleistocene caves like Lascaux, France).

There is no evidence that there were any subspecies within what has conventionally been considered the range of *E. f. przewalskii*.

8.3.2 Subgenus *Hemionus*: onager and kiangs; Asian wild asses

The subgenus is characterised externally by the short, seemingly clipped mane, tufted tail, chestnuts (which are very large) on forelimbs only, short erect hair forming a broad dorsal stripe 50–100mm broad, and white underparts and lower limbs. Cranially, by the very narrow, squared, upturned occipital crest, shortened braincase, long vomer, short diastema, and short pterygopalatine fossa. The nasal end of the premaxilla is truncated or rounded, so that it forms the angle of the narial notch. The tuber maxillae extends back, hiding the pterygopalatine fossa in ventral view, like *Quagga* and unlike other subgenera. Postcranially, the subgenus is distinguished by the short scapula, humerus and femur, the elongated, slender metapodials and the elongated distal phalanx. The metacarpus is short compared to the metatarsus, the biischial breadth high compared to the biacetabular, and the height of the pelvic inlet is strongly sexually dimorphic.

Groves and Mazák (1967) argued that the kiang, of the Tibetan plateau, is a distinct species from the onagers of the more low-lying Asian deserts. The differences are very striking and this separation has been widely followed. The subspecies *onager*, *kulan*, *hemionus*, and *castaneus* form an intergrading series, overlapping (at the extremes) in their traits, but each strongly distinct as a unit. The subspecies *hemippus* is much smaller than any other and as a result is in fact a diagnosable taxon (in the PSC sense), while the supposed subspecies *E. h. khur* is also, unexpectedly, diagnosable.

Equus kiang Moorcroft 1841: kiang

Description: The kiang or Tibetan wild ass is of large size, with its large head and thick muzzle, a relatively long mane, and long hairs, which are not restricted to the tail

tuft, but extend some way up either side of tail. The pattern on the contrasting dark (reddish) body blocs and white underside is characteristic; the demarcation between them on the flank is oblique from withers to mid-flank, and the white rump patch is infused with the reddish tone of the haunch. The dorsal stripe is thin and never bordered with white, and it extends to tail tuft. A dark ring surrounds each hoof, whilst the ear measures 165–178mm long.

The skull resembles *E. hemionus*, although the incisors tend to sit more vertically in the jaws (except in aged individuals, in which alveolar recession tends to reveal the oblique roots) and the highest point on the cranial profile is often directly above the posterior rim of the orbit instead of behind it.

For skull measurements, see Table 8.1.

1. *Equus kiang kiang* Moorcroft 1841: Western kiang

1841 *Equus kiang* Moorcroft. Eastern Ladakh.

Colour: The colour is dark red-brown in summer, dark brown in winter. The size is large, the nasal bones short, and the tooththrow relatively short.

Localities: “Little Tibet” (=Ladakh); Shooshal, Ruckshal; Kuluang and Chibra, both Hanle; L.Tsor Chum and Takalung, both Rupshu; Spanglung; Apo Tso, Sundschilling Plain; Gunlay, >5,000m; Gnari Khorsum.

2. *Equus kiang holdereri* Matschie 1911: Eastern kiang

1911 *Equus (Asinus) kiang holdereri* Matschie. Kuku Nor.

1924 *Microhippus tafeli* Matschie. Tosson Nor.

Colour: The colour is not so dark, and is a strong red in summer, whilst darker red-brown in winter. The white of the underside advances higher up the flanks, and the size is large, the nasals very long, and the tooththrow also long.

Table 8.1. Skull measurements of *Equus kiang* (mm).

	<i>E. h. kiang</i>	<i>E. h. holdereri</i>	<i>E. h. polyodon</i>
Males	10	6	4
Greatest length	518.4 (492–537)	533.5 (525–547)	475.0 (473–479)
Nasal length	200.3 (179–217)	220.2 (214–226)	195.5 (191–197)
Tooththrow length	161.1 (155–167)	168.3 (164–173)	158.8 (153–165)
Females	5	8	3
Greatest length	514.2 (504–531)	552.1 (495–538)	481.0 (474–494)
Nasal length	203.7 (200–208)	223.3 (212–238)	198.3 (192–205)
Tooththrow length	154.0 (145–163)	165.1 (158–171)	155.7 (151–160)

Localities: Tosson Nor; Wahou Mts., 4,000–4,500m, north-east of Tosson Nor; Kuku Nor (=Ching Hai); Seshu, Sichuan; Lhasa.

3. *Equus kiang polyodon* Hodgson 1847: Southern kiang

1847 *Asinus polyodon* Hodgson. Tibet, just north of the Sikkim border (fixed by Groves and Mazák, 1967).
1959 *Hemionus kiang nepalensis* Trumler. “Nepal”; more probably the region of Tibet just north of the Sikkim border (see Groves and Mazák, 1967, who discuss the status of the skin and skull of the type specimen).

Colour: The colour is as dark as in *E. k. kiang*, the size very small, and the nasals and tooththrow are long, as with *E. k. holdereri*.

Localities: Gyam Tso (=Lake); Sikkim.

***Equus hemionus* Pallas 1775: onager**

Description: The onager varies from kiang-sized to khur-sized. The mane is very short – “clipped”, and the dorsal stripe is thick, often bordered with a white line on either side. The white of the rump is not infused; the demarcation between the reddish flank bloc and whitish underside runs parallel to the body outline, before turning sharply up towards the dorsal stripe; the dorsal stripe extends to tail tuft; and there is a dark ring round each hoof. Nasal bones are relatively straight and the skull resembles *E. kiang*.

For skull measurements, see Table 8.2.

1. *Equus hemionus castaneus* Lydekker 1905: Xinjiang kulan or dziggetai

1905 *Equus onager castaneus* Lydekker. Supposedly from Kirghis Nor, Kobdo (now Jirgalanta)

1911 *Equus (Asinus) hemionus finschi* Matschie. North-east of Zaisan Nor

Description: The height at withers is 110–130cm. The dorsal stripe has a clear white border on either side, which becomes obfuscated with age and eventually disappears. At least the lower 30% of flank is whitish. The white wedge between the haunch and flank is clear, white, but does not reach the spine. The legs are strongly infused with body tone. The white zone on the muzzle occupies nearly half of the snout-to-ear distance. On the head, the demarcation between reddish tone of the face and the white of the interramal region cuts diagonally across the jaw angle. In the skull, the orbit sits high and tends to interrupt the dorsal outline, whilst the nasals are low and straight; the highest point on the profile is just behind the posterior margin of the orbits.

Localities: Urungu, 350km south-west of Kobdo; Ebi Nor; Dzungaria; “Desert Kirgisorum”; Kichik-Ulan-Ussu, west of L. Barkul, N. Tianshan. A head-skin in the London collection from Golodnaig Steppe, Bokhara (London Zoo, 1907–1916) is identified with this subspecies, rather than *E. h. kulan*, because the white on the muzzle extends fully halfway to the eye, and the same is true of two skins from the Zaisan Nor region in Berlin (one of them being the type of *finschi*).

Groves and Mazák (1967) called this subspecies *Equus hemionus hemionus*, but recently it has been argued by Denzau and Denzau (1999) that Transbaikalian dziggetai were “grading”, like those from the Gobi, so the disruptively-coloured form has to be called *E. h. castaneus*. Groves and Ryder (2000) accepted this argument.

There is, unfortunately, no recent evidence that this attractively patterned subspecies continues to exist.

Table 8.2. Skull measurements of *Equus hemionus* (mm).

	<i>E. h. hemionus</i>	<i>E. h. castaneus</i>	<i>E. h. kulan</i>	<i>E. h. onager</i>	<i>E. h. Blanfordi</i>
Males	13–15	1	4–8	8–9	1
Greatest length	518.0 (504–544)	518	495.7 (487–503)	491.1 (479–501)	484
Occiput br.	54.1 (50–58)	59	52.0 (45–55)	59.8 (57–66)	42
Diastema l.	80.5 (76–90)	91	77.4 (70–83)	72.6 (63–82)	70
Nasal l.	215.0 (205–226)	205	199.5 (195–203)	202.8 (186–214)	245
Tooththrow	166.3 (153–171)	152	156.1 (149–163)	164.1 (159–176)	-
Females	12–13	4–5	7–8	5–6	1
Greatest length	510.4 (489–527)	516.0 (497–525)	492.0 (475–502)	487.5 (469–509)	498
Occiput br.	53.9 (47–64)	56.4 (52–63)	48.7 (45–51)	53.8 (51–59)	53
Diastema l.	83.1 (75–102)	81.0 (70–94)	80.3 (68–93)	74.3 (56–85)	72
Nasal l.	213.4 (193–232)	214.8 (199–231)	195.4 (189–205)	198.2 (174–214)	198
Tooththrow	165.9 (158–174)	168.3 (163–174)	161.8 (152–175)	154.8 (145–168)	158

2. *Equus hemionus hemionus* Pallas 1775: (= *E. h. luteus*) Gobi kulan or dzigettai

1775 *Equus hemionus* Pallas. Tarei Nor, Transbaikalia
1911 *Equus (Asinus) hemionus luteus* Matschie. Surin Gol, Ganssu

1911 *Equus (Asinus) hemionus bedfordi* Matschie.
Supposedly from Kobdo (now Jirglanata), Mongolia

Description: The size is as in *castaneus*. The colour pattern is very graded, with hardly any real demarcation between the sandy tone of the flanks and the yellow-white of the underside; only the lower 20% or less of the flank is whitish. No white border exists to the dorsal stripe at any age. The white wedge between the haunch- and flank- blocs is vague and strongly infused with body tone. The legs are very strongly infused with body tone. The white zone on the muzzle occupies less than 30% of the snout-to-ear distance. On the head, the demarcation between the reddish tone of the face and the white of the interrampal region follows the curve of the jaw angle. The skull resembles *E. h. castaneus* in size, nasal form, and in the position of the highest point, but the orbit sits low on the profile because of the greater convexity of the interorbital space.

Localities: Transbaikalia; Surin Gol, between Chami (=Hami) and Su-tschou; Tsagan Nor, north of Bago Bogdo, eastward limit of Altay; Gobi Altay; Artsa Bogdo; Ikhe Bogdo; Loh; Tacin Gol. Denzau and Denzau have published some excellent, close-up photos of living examples taken at Chonin Us, Dzungarian Gobi, Mongolia.

The type specimen of *bedfordi* Matschie was figured by Lydekker (1905); it was a living animal shipped from Kobdo to the Duke of Bedford's collection; it was later donated to London Zoo, where it died in 1918. The skin and skull are now BM 1939.2472.

3. *Equus hemionus kulan* Groves and Mazák 1967: Turkmenistan kulan

1967 *Asinus hemionus kulan* Groves and Mazák. Badkhyz, Turkmenistan

Description: The height at withers is 108–120cm. It is less red than *E. h. hemionus*; in winter, the dark brown of the body is strongly demarcated from the white of the underside; in summer, the contrast is less strong. The dorsal stripe has a clear white border on either side; this becomes obfuscated with age and eventually disappears. On the head, the demarcation between the reddish tone of the face and the white of the interrampal region cuts diagonally across the jaw angle.

The lower 30% at least of flank is whitish. The white wedge between the haunch- and flank-blocs is clear white, but does not quite reach the spine. Legs are strongly infused with body tone, and the white zone on the muzzle occupies nearly 40% of the snout-to-ear distance.

The skull is smaller than in *E. h. hemionus* and *castaneus*, but proportionally similar except for relatively larger teeth; the orbit is low like *E. h. castaneus*; the highest point may be back on the crown; the nasal ends may be slightly raised.

Localities: Badkhyz.

4. *Equus hemionus onager* Boddaert 1785: Persian onager or Gur

1785 *Equus onager* Boddaert. Qazvin, Iran

1947 *Microhippus hemionus bahram* Pocock. Yazd, Iran

Description: The height at withers is 108–126cm; the weight of six adults (not extremely aged) from Hamburg Zoo was between 179–220kg. The demarcation between the brown of the body and the white of the underside is less strong with more grading at comparable seasons, than in *E. h. kulan*. The dorsal stripe has a clear white border on either side, which becomes obfuscated with age and eventually disappears. On the head, the demarcation between the reddish tone of the face and the white of the interrampal region follows the curve of the jaw angle. At least 30% of the lower flank is whitish. The white wedge between the haunch- and flank-blocs is vague, and strongly infused with body tone. The legs are strongly infused with body tone. The white zone on the muzzle occupies 30% or less of the snout-to-ear distance.

The skull size and general shape are the same as those of *E. h. kulan*, but with a broader occipital crest. The male has even larger teeth. The orbit is high-placed – the highest point always being on the crown. Eisenmann and Shah (1996), using larger samples than those available to Groves and Mazák (1967), confirm that this subspecies differs craniometrically from *E. h. kulan*, but also note that it exhibits unusually wide variability.

Localities: Abarguh; Siakuh, west of Tehran; Siah Parde, near Tehran (now in Kavir National Park); Damghan Province, near Semnan; 50km south-west of Garmab, Dasht-i-Kavir. A clear, close-up photo taken by Mr Bijan Dareshuri in Touran Reserve, north-east Semnan Province, Iran, shows an animal with more white on the jaw angle than those from these more westerly localities (including the Hagenbeck-import

zoo stock, and a clear photo by the same photographer taken in Bahram-e-Gur Protected Area), and it also appears to have more white on the muzzle; this suggests some approach towards *E. h. kulan*. The graded coloration and inconspicuous stifle-wedge are, however, very typical of *onager*.

5. *Equus hemionus blanfordi* Pocock 1947

1947 *Microhippus hemionus blanfordi* Pocock. Sham Plains, Baluchistan

Description: These have a skull size similar to *E. h. kulan* and *onager*, with a relatively narrow occipital crest, and long nasals that end slightly raised; the orbit is high-placed; the highest point on the skull is either just behind the orbit or on the crown.

This subspecies is not, *contra* Groves and Mazák (1967), intermediate between *onager* and *khur*. It has the low flat nasals, short diastema, large teeth, and extensive dark areas on flanks that are characteristic of what is here regarded as the species *Equus hemionus*. The main point of similarity with *E. khur* is that the dorsal stripe fades out halfway down the tail.

Localities: Sham Plains, near Quetta; Kandahar.

Equus khur Lesson 1827: (= *Equus hemionus khur*)
Khur; Indian wild ass

1827 *Equus khur* Lesson. Little Rann of Kutch (fixed by Groves and Mazák, 1967)

1862 *Asinus indicus* George 1869. India

Description: The Indian wild ass or khur is sharply distinct from *E. hemionus*. The coloured blocs on the flank and haunch are very small, so the predominant colour is white, and the lower 45% or more of the flank is whitish; the demarcation on the lower haunch slants upward from front (stifle) to back. The dorsal stripe has a clear white

border on either side, which becomes obfuscated with age, but probably never entirely disappears. The white wedge between haunch- and flank-blocs nearly or fully reaches the spine. Legs are pure white. The white zone on the muzzle occupies nearly 40% of the snout-to-ear distance. On the head, the demarcation between the reddish tone of face and the white of the interramal region cuts diagonally across the jaw angle. The dorsal stripe fades out halfway down tail. There are no dark rings around the hooves.

The facial profile is concave; the nasal bones are raised (making the whole facial profile strongly concave) and comparatively short (Groves 1986, fig. 1); and the teeth are small. The skull is noticeably high-crowned. The choanae are small. The orbits are high. The height at withers is 110–130cm. The metapodials are less elongated than those of *E. hemionus*. The ear is very long, measuring some 187–210mm.

For skull measurements, see Table 8.3.

Localities: Kutch; Thar Parkur, Sind.

Equus hemippus I. Geoffroy St Hilaire 1855: (= *Equus hemionus hemippus*) Syrian wild ass

1855 *Equus hemippus* I. Geoffroy St. Hilaire. Syria

1869 *Equus hemionus* var. *syriacus* Milne-Edwards. Damascus.

The extinct Syrian Wild ass or Achdari was very small in size; the evidence implies that this difference has come about since the end of the Pleistocene (Turnbull 1986).

Description: The height at withers is about one metre. The colour is very grading: the sandy-brown flank patch extends well down, grading into off-white on the underside; only the lower 20% or less of the flank is whitish. The dorsal stripe has a clear white border on either side, which becomes obfuscated with age, and eventually disappears. The white wedge between the haunch- and flank-blocs is vague and strongly infused with the body tone. The legs

Table 8.3. Skull measurements of *Equus khur* and *E. hemippus* (mm).

	<i>E. khur</i>	<i>E. hemippus</i>
Males	3	3
Greatest length	505.3 (493–519)	412.7 (403–419)
Occiput breadth	60.0 (57–62)	44.3 (35–49)
Diastema length	86.3 (82–92)	52.7 (50–55)
Nasal length	189.3 (184–194)	179.3 (174–189)
Toothrow length	149.3 (140–156)	142.3 (140–145)
Females	6	5–6
Greatest length	492.3 (468–511)	423.0 (409–439)
Occiput breadth	54.2 (49–60)	47.0 (44–49)
Diastema length	79.5 (71–92)	58.5 (52–61)
Nasal length	181.8 (171–198)	189.7 (183–198)
Toothrow length	155.4 (152–160)	146.7 (145–149)

are also strongly infused with body tone. The white zone on the muzzle occupies under 30% of the snout-to-ear distance. On the head, the demarcation between the reddish tone of the face and the white of the interramal region follows the curve of the jaw angle. The dorsal stripe fades out halfway down the tail, and there are no dark rings around the hooves.

The nasal bones are raised and are longer than in other onagers (Groves 1986, Fig. 1), whilst the teeth are relatively large. Otherwise, the skull, with its concave profile, high-placed orbit, and high crown, resembles that of a small *E. khur*. The metapodials are more elongated than in other species, and the terminal phalanges are shorter.

For skull measurements, see Table 8.3.

Localities: Aleppo.

8.3.3 Subgenus *Asinus*: true asses

These asses are characterised externally by a long, thin “scruffy” mane, a tufted tail, chestnuts on the forelimbs only, a thin dorsal stripe, usually with traces of stripes on the legs (at least the fetlocks) and a restricted white (or pale) region on the underside. Cranially, it is distinguished by a very long cranium, a short palate, long diastema, and large pterygopalatine fossa, and a squared, upturned occipital crest. The nasal end of the premaxilla is narrow and insinuated into the corner of the narial notch. The external auditory meatus is wide; the orbit is high, rounded, and not anteroposteriorly elongated like other subgenera (except *Hippotigris*). Postcranially, it has a short scapula and very short, narrow distal phalanges. The metacarpus is short compared to the metatarsus. Biischial breadth is high compared to biacetabular breadth, and the height of the pelvic inlet is strongly sexually dimorphic.

Eisenmann (1995) has recently reviewed the palaeontological evidence for the evolution of the genus, and the evidence for extinct early Holocene populations.

Equus africanus Heuglin and Fitzinger 1866: African wild ass

Description: All African wild asses tend to be more reddish in summer, greyer in winter, with contrastingly white legs and less contrastingly whitish underside; the white wedges behind the shoulder and in front of the haunch, so prominent in hemiones, are evanescent.

Groves (1986) showed that, to some degree, there is clinal change from the Atbara population via the Red Sea coastal populations to Somalia. There is quite a marked change, a distinct step in the cline, between northern and southern Eritrea, perhaps representing a bottleneck to gene flow in the Massawa region, where the highlands approach the sea.

For skull measurements, see Table 8.4.

A North African wild ass, with strong, often doubled, shoulder-cross and well-marked leg-stripes was depicted in both rock art and Roman-era mosaics, and was stated to survive at Siwa, on the Libyan-Egyptian border, in the 1960s by Hufnagel (1965). Eisenmann (1995) discusses whether the name *Equus melkiensis* Bagtache, Hadjouis and Eisenmann 1984 (from the late Pleistocene of Allobroges, Algeria) might apply to this form. In the earliest Holocene, wild asses were also present in northern Arabia (Ducos 1986; Groves 1896); a subspecies *Equus africanus mureybeti* Ducos 1986 has been described from pre-pottery levels in Iraq, but Eisenmann (1995) is not convinced that the remains are ass rather than onager.

1. *Equus africanus africanus* Heuglin and Fitzinger 1866: Nubian wild ass

Asinus africanus Heuglin and Fitzinger 1866. Ain Saba, Eritrea (fixed by Schlawe 1980).

Asinus asinus diana Dollman 1935. Wadi Hafta, Tokar, Red Sea Hills.

Description: The ears are longer than other subspecies, measuring 182–245mm; the shoulder height averages 115–121mm; the hooves are narrow, and the breadth of its sole is 69–84% of its height. A dorsal stripe is always present and nearly always complete from mane to tail-tuft. Leg-stripes, where present, are restricted to a few bands at the fetlocks. The skull length is usually less than other subspecies; the diastema is relatively short, and the postorbital constriction well marked. The orbit is high-placed, generally interrupting the dorsal cranial profile in lateral view; the crista facialis extends forward to above the first molar. The nasal process of the premaxilla ends bluntly. There is never a “bridge” between the metaconid and the metastylid in the lower premolars and molars.

As shown by Groves (1986), specimens from the Atbara differ, on average, from those from the Red Sea Hills (Sudan) and Eritrea.

In the Atbara population, the colour is more buffy (reddish-buff in summer, brown-grey in winter); the transverse stripe across the shoulder is thick (15–65mm at spine), well-marked, but usually short (110–150mm long, although it occasionally extends up to 230mm). The diastema is shorter and the occipital crest is narrower. In this population there are never even traces of leg-stripes.

In the Red Sea population, the colour is greyer (reddish-grey in summer, ashy-grey in winter); the shoulder-cross is nearly always thin (12–24mm at the spine) and poorly expressed, and sometimes absent altogether – when present, the length is between 100

and 150mm. The diastema is longer and the occipital crest broader.

These differences are fairly pervasive, and probably reach the 75% rule-of-thumb for subspecific differentiation. I will investigate the problem further to see if a new subspecies ought to be described for the Atbara.

Localities for Nubian wild asses are as follows:

1. <i>E. a. africanus</i> , Atbara population:	N	E
Jalalub (?=Gulalab)	18.15	33.45
Nakheila (South bank of Atbara)	17.25	34.18
Regeb, Atbara		
Ruins of Wadi Safra	16.53	35.49
Kassala	15.24	36.30
“Abyssinia east of the Nile”		
2. <i>E. a. africanus</i> , Red Sea population:		
Plains south of Erkowit	18.49	37.01
Khor Sabbat, Tokar Plain	18.27	37.41
Agahet el Homar	18.08	37.12
Wadi Sharag	17.52	37.57
Wadi Hafta	17.43	37.30
Ain Saba	16.00	38.00
Upper Barca (=Baraka)	15.50	37.20

2. *Equus africanus somaliensis* Noack 1884: Somali wild ass

1884 *Equus somaliensis* Noack. Berbera, Somalia.

1885 *Equus asinus somalicus* Sclater. Based on the same specimens as Noack’s name.

Description: As in previous papers, I reiterate my opinion that *Asinus taeniopus* Heuglin (type locality: Little Dobar, south of Berbera) is a cross between a Somali wild ass and a domestic ass. The ears are short, measuring some 187–200mm; the shoulder height is 120–125mm; the hooves are wider, with the breadth of the soles being 89–90% of their height (N.B. taken from only two specimens!). The dorsal stripe is often absent and, when present, is often incomplete and broken at some point along the dorsum. The shoulder-

cross, when present, is 130–200mm long, but only 20mm broad where it crosses the spine. Leg-stripes are present from the hooves to above the carpus and tarsus. Skull length averages greater; the diastema is relatively long, and the postorbital constriction less marked. The orbit is placed well below the cranial dorsal outline; there is a thickened bar of bone behind the orbits, marking the highest point on the profile; the crista facialis extends to the posterior premolar region. The nasal process of the premaxilla is thin and pointed. There is always at least a trace of a “bridge” between the metaconid and the metastylid in the lower premolars and molars. Somali asses seem to be longer-legged and shorter-bodied than Nubian ones.

Differences between Somalian and Danakil plus Djibouti populations are less marked than those between the two populations of *E. a. africanus*. The more northerly individuals (from Danakil and Djibouti) more frequently have a shoulder-cross and they are less iron-grey; the single available adult skull has a rather narrow occipital crest and only a weakly expressed metaconid-metastylid bridge.

Localities for *E. a. somaliensis* are as follows, with coordinates where known:

	N	E
Assaorta, Plain of Salt		
Assab		
Curub-Bahari, plains near Cayele		
Near Sardo	11.58	41.18
Obock, Djibouti	11.59	43.20
Issituggan valley, south of Bulhar	10.30	44.20
Hekebo Plateau, S.E. of Bulhar		
50 miles from Berbera	10.30	45.30
Bir Kaboba	10.26	42.38
Lafa Rug, between Hargeisa and Berbera	10.00	44.42
Haili, Durhan	10.09	46.14
Las Dureh (Lasdero, Durhan)	10.09	46.00
South of Upper Sheikh	9.56	45.13
Cianno, near Ebili, Awash River		
Road by L. Abiata		

Table 8.4. Skull measurements of *Equus africanus* (mm).

	<i>E. a. africanus</i> Atbara	<i>E. a. africanus</i> Red Sea	<i>E. a. somaliensis</i>
Males	5	1	6
Greatest length	515.2 (483–526)	503	520.3 (513–543)
Occiput breadth	56.4 (53–60)	66	63.0 (57–68)
Diastema length	78.6 (74–83)	87	87.2 (85–105)
Postorbital br.	73.4 (71–80)	77	82.2 (75–87)
Females		3–4	7
Greatest length		502.3 (485–528)	517.6 (507–544)
Occiput breadth		59.3 (57–61)	59.7 (53–64)
Diastema length		80.8 (78–92)	89.9 (79–94)
Postorbital br.		66.0 (63–68)	79.1 (74–87)

L. Hertale, east of Addis Abeba	9.55	40.24
Nogal valley, Las Anod, Dodi Plain	8.26	47.19
Wadi Run, upper Nogal	8.30	48.50
Imi, Webi Shebeli	6.28	42.10

3. *Equus africanus* subspecies: Saharan wild ass

1966 *Equus asinus africanus sahariensis* Dupuy. Nomen nudum.

Description: Best authenticated for Ahaggar, Tibesti, and Fezzan, the (apparently indigenous) wild ass of the Sahara was reconstructed by Groves (1986) as similar to *E. a. africanus*, but smaller and greyer, and with a long, thin shoulder-cross.

8.3.4 Subgenus *Hippotigris*: Mountain zebras

Characterised externally by the long, rather thick upright mane, tufted tail, chestnuts on forelimbs only, small dewlap, and striking black and white stripes (except on venter) that form what has been called a “gridiron” pattern (with short transverse stripes meeting the uppermost of a long, thick, oblique/longitudinal series) on the croup.

Cranially, the occiput is high and raised, the postorbital constriction deep, the muzzle and vomer long, whilst the nasal end of the premaxilla is truncated or rounded, so that the nasal forms the angle of the narial notch. The external auditory meatus is wide and (uniquely) directed horizontally instead of upward and backward. The ventral bar of the orbit, which is high and rounded like that of asses, is slender. Postcranially, the scapula is short; the distal phalanges are short and narrow. The metacarpus is long compared to the metatarsus. The skull is relatively large. The biischial breadth is low compared to the biacetabular breadth, and the height of the pelvic inlet is not strongly sexually dimorphic.

Equus zebra zebra Linnaeus 1758: Cape mountain zebra

1758 *Equus zebra* Linnaeus. Paardeberg (fixed by Roberts 1951)

1822 *Equus montanus* Burchell. “Wagenpadsberg [=Wagenpadskop?], beyond the Snow Mountains” (see Grubb, 1999).

1905 *Equus zebra frederici* Trouessart. Northern Cape

Mountains of Southern Cape.

Description: The size is smaller, and black stripes are broader than white interspaces. Groves and Ryder (2000) proposed that the two subspecies could be better treated as

distinct species; they are instantly recognisable externally and some of the skull measurements do not overlap, although sample sizes are small. For example, the occipital crest breadth is 63–71mm in male *zebra*, 74–78mm in male *hartmannae* (n=5 of each); 63–68mm in female *zebra*, 70–86mm in female *hartmannae* (n=3 and 6, respectively). In the present sample, there is a sexual size difference in *zebra* (mean skull length is 516.0mm in males and 530.8mm in females, although $P>0.05$), but not in *hartmannae* (548.0mm and 549.9mm respectively).

Smuts and Penzhorn (1988) claimed that females have a broader occipital crest than males, but this does not hold in my opinion.

Equus hartmannae Matschie 1898: (= *Equus zebra hartmannae*) Hartmann’s zebra

1898 *Equus hartmannae* Matschie. Between Hoanib and Unilab Rivers

1900 *Equus penricei* Thomas. Moninho valley, Angola

1924 *Hippotigris hartmannae matschiei* Zukowsky. Swakopmund, Namibia.

Arid, hilly regions from southern Angola formerly to north-western Cape.

The size is much larger, and the black stripes are narrower than the white interspaces.

8.3.5 Subgenus *Quagga*: Plains zebras

Externally, the mane varies from long, thick, and neat to shorter, thinner, and even absent altogether; the tail is tufted and chestnuts exist on the forelimbs only; striping varies from dark brown and white on the head and neck only to striking black and white over the whole body, including the venter, and a simple oblique/longitudinal pattern on the croup and haunch.

Postorbital constriction is relatively narrow, the vomer is long, the diastema long, the teeth relatively small, and the occiput extremely raised. The narial notch is less deep than other subgenera. The interorbital part of the frontal bone is strongly convex. The bizygomatic width generally exceeds that of the biorbital. The nasal end of the premaxilla is narrow and insinuated into the corner of the narial notch. The premaxilla, unlike other subgenera, curves downward below the level of the alveolar line of the cheekteeth. The tuber maxillae extends back, hiding the pterygopalatine fossa in ventral view, like *Hemionus* and unlike other subgenera. The foramen magnum is a uniquely rectangular shape. The metapodials are somewhat lengthened. The metacarpus is long compared to the metatarsus. The distal phalanges are less reduced than in *Hippotigris*. The biischial breadth is low compared to the biacetabular breadth; the height of the pelvic inlet is not strongly sexually dimorphic.

The cranial differences between plains and mountain zebras are given by Eisenmann and de Giuli (1974) and Smuts and Penzhorn (1988), who agree in most respects, though the latter add a few characters, notably the important difference in the foramen magnum, in which the subgenus *Quagga* is unlike any other subgenus.

***Equus quagga* Gmelin 1788: (= *Equus burchellii*) Plains zebras**

The true Quagga (*E. q. quagga*) lived west of the Drakensberg and south of the Vaal-Orange system. The

available museum material was fully discussed by Rau (1974, 1978), who showed that there was no sharp division between it and *burchellii*, to the extent that some specimens (especially the Mainz female and another specimen in Mainz, the type of *paucistriatus* Hilzheimer) are difficult to allocate; they are surely correctly placed in the same species. The physical barriers between the two are, however, sufficient to make a step in the cline, and so confirm their subspecific distinction.

I have measured only three adult male skulls from the wild (Leiden, Berlin and Frankfurt). They range from 485

Table 8.5. Distinguishing characters of living subspecies of *Equus quagga* (measurements in mm).

	Zulu	<i>burchellii</i> Etosha	SE Afr	<i>zambeziensis</i> Angola	<i>WZam.</i>	<i>crawshayi</i> all	<i>boehmi</i> EAFr	NW
Skull: Male								
Mean	518.3	530.5	531.2	535.1	-	522.2	501.3	527.2
s.d.	19.14	11.88	11.56	15.98	-	13.31	16.09	14.92
n	6	6	16	7	-	20	64	13
Range	500–552	508–542	509–548	504–553	-	489–545	450–548	498–540
Skull: Fem.								
Mean	513.5	524.5	525.1	545.8	522.0	520.3	496.4	517.4
s.d.	23.05	13.77	17.47	12.37	12.83	12.51	16.85	9.56
n	6	4	10	4	4	10	47	5
Range	476–540	516–545	500–557	530–559	510–540	500–534	466–547	511–534
Belly stripes								
3–4	5	23	36	4	7	-	25	3
5	-	-	2	-	1	13	3	-
>5	-	-	-	-	-	15	-	-
Body colour								
ochery	2	8	5	1	2	-	-	-
off-wh	2	6	25	3	2	10	7	-
white	-	-	-	-	4	18	27	3
Shad stripes								
++	5	10	2	-	-	-	-	-
+	1	21	27	3	1	-	3	-
±	-	4	23	2	2	1	13	-
-	-	-	6	1	5	29	36	4
Leg stripes								
—	-	5	1	-	-	-	-	-
-	5	10	2	-	-	-	-	-
±	6	14	15	-	-	-	-	-
+	1	3	24	5	-	-	-	-
++	-	-	3	1	7	28	52	4
Infun.								
pres.	1	2	3	1	-	1	1	-
cup	-	-	6	6	1	10	15	-
abs.	-	-	1	-	-	7	11	4
Abbreviations:								
Skull: greatest skull length. Belly stripes: number of stripes making contact with median ventral line between elbow and “saddle”								
Shadow stripes: ++ broad, approaching prominence of main stripes								
+ less well expressed but still noticeable								
± vaguely expressed								
- absent								
Leg stripes: — none; stripes barely reaching even to haunch								
- none, but stripes do cover haunch								
± a few stripes above carpus and tarsus								
+ stripes present, broken, below carpus and tarsus								
++ stripes complete to hooves								
Infun: presence of infundibulum on I _{1,2}								

to 528mm in length, and so average smaller than other subspecies apart from *boehmi*.

For skull measurements and other distinguishing characters of the surviving subspecies of *E. quagga*, see Table 8.5.

1. *Equus quagga burchellii* Gray 1824: (= *Equus burchellii burchellii*, *Equus burchellii chapmani*, *Equus burchellii antiquorum*) Burchell's zebra

1824 *Asinus burchelli* Gray. Little Klibbolikhoni Fontein (=Modder River, Northern Cape at 27°33'S, 23°33'E, according to Skead, 1980).

1841 *Hippotigris antiquorum* Hamilton Smith. Molopo (Mafeking district), Northern Cape (see Grubb 1999).

1841 *Hippotigris isabellinus* Hamilton Smith. Apparently based unknowingly on the same specimen as *antiquorum* (Grubb 1999)

1865 *Equus chapmani* Layard. Between Zambezi and Botletle Rivers, Botswana (=about 30 miles east of the south-flowing loop of the Boteti River, according to Grubb, 1999)

1897 *Equus burchellii wahlbergi* Pocock, 1897. Kwazulu-Natal

1897 *Equus burchellii selousi* Pocock. Manyami valley, Zimbabwe

1897 *Equus burchellii transvaalensis* Ewart. Northern former Transvaal

1912 *Equus (Hippotigris) kaufmanni* Matschie. Caprivi Peak.

1924 *Hippotigris chapmani kaokensis* Zukowsky. Kaokoveld, Namibia

Description: Their size is large. Three or four stripes (very rarely two or five) meet (or sometimes do not quite meet) the median ventral line between the elbow and the stripe that bends back to form the “saddle” of the lumbar region. The colour is ochery or off-white, but never pure white. The shadow stripes are usually well marked, and the leg stripes are absent or poor, and almost never complete to hooves. The infundibulum on the lower incisors is better expressed than in other subspecies. The mane is well developed.

This subspecies exists (or existed) throughout southern Africa, from Kwazulu-Natal north to the Zambezi, but not it seems in Mozambique, except for the southernmost part; published photos of zebras from Gorongosa, for example, are clear *crawshayi*. Populations in Zimbabwe and former Transvaal average palest, being offwhite, more rarely ochery, with less strikingly marked shadow stripes and more complete leg stripes than other populations. Those from Kwazulu-Natal and northern Namibia (Etosha and Kaokoveld) average more ochery with

stronger shadow-stripes and fewer leg-stripes; as a whole, these two populations, though geographically separate, strongly resemble each other, although shadow stripes are stronger in Kwazulu-Natal and leg stripes are less developed in Namibia, where the haunch itself may even be unstriped. The Kwazulu-Natal population averages smaller than the other two.

Some may prefer to regard these three populations as distinct subspecies from each and from *burchellii*, in which case the prior names are *chapmani* (Zimbabwe/Transvaal), *wahlbergi* (Kwazulu-Natal) and *kaokensis* (Etosha/Kaokoveld), though the name *burchellii* probably takes precedence over *wahlbergi* (see below). But the overlap in characters is so great that many specimens could not be correctly identified; overlap is least in leg-striping (Table 8.5).

Rau (1978) has pointed out how little evidence there is for “the extinct true Burchell's Zebra”; the distinguishing feature from extant forms (that is, the failure of the flank stripes to meet the median ventral line at all) is sometimes seen in Kwazulu zebras, as well as in the type (from the Kuruman district), and in a zoo specimen known only to have been from Botswana. There is as little evidence that such a feature typified the zebras from the Free State and that it was confined to them.

2. *Equus quagga crawshayi* de Winton 1896: (*Equus burchellii crawshayi*) Crawshay's zebra

1897 *Equus burchellii crawshayi* de Winton. Henga, Malawi

1899 *Equus (Hippotigris) foai* Prazak and Trouessart. Mozambique, opposite Tete

1906 *Equus annectens* Rothschild. Fort Jameson, Zambia.

Description: The size is large. Stripes are numerous and narrow; always at least five stripes (often six to eight) meet the median ventral line between the elbow and the “saddle” stripe. The body tone is white or off-white. There are almost never even traces of shadow-stripes, and leg stripes are complete to hooves.

This is the subspecies from east of the Luangwa, as far north-east as the Tendaguru district, south-eastern Tanzania; but it also occurs south of the Zambezi in Mozambique as far as the Gorongosa district.

3. *Equus quagga zambeziensis* Prazak 1898: (= *Equus burchellii zambeziensis*) Upper Zambezi zebra

1898 *Equus burchellii zambeziensis* Prazak. Barotse, Upper Zambezi.

Description: The size is large and stripes are broad, of which only three or four meet the median ventral line between the elbow and the “saddle” stripe. Colour varies from ochery through off-white to white. Shadow-stripes vary from fairly prominent to absent. Leg stripes are usually complete, or nearly so.

Externally, this subspecies most resembles *E. q. boehmi*, but is separated from it by *E. b. crawshayi*. Angolan and western Zambian populations differ somewhat. The Angolan population averages larger and more ochery, with better shadow-stripes and more broken leg-stripes; in other words, it somewhat approaches *E. q. burchellii*, although it is the Zimbabwe/Transvaal population that it resembles, and is strikingly different from the nearby Namibian population.

4. *Equus quagga boehmi* Matschie 1892: (= *Equus burchellii boehmi*) Grant’s zebra

1892 *Equus boehmi* Matschie. Pangani River, Tanzania

1896 *Equus burchellii granti* de Winton. Thika, upper Tana River, Kenya

1902 *Hippotigris chapmanni jallae* Camerano. Southern Ethiopia?

1906 *Hippotigris muansae* Matschie. Mwanza, N.W. Tanzania

1911 *Equus quagga* var. *goldfinchi* Ridgeway. Rift valley, Kenya

1914 *Equus quagga cunninghamei* Heller. Archer’s Post, north-east Kenya

1922 *Equus borensis* Lönnberg. Bor, south-east Sudan

1959 *Zebra burchelli isabella* Ziccardi. Lower Juba, Somalia

Description: The size is small, and the stripes are few and broad – rarely more than three or four meet the median ventral line between elbow and “saddle” stripe. The colour is generally pure white. Shadow-stripes are usually absent, but sometimes are vaguely expressed. Leg stripes are always complete to the hooves. The infundibulum is generally absent.

The northerly populations of this subspecies have high frequencies of manelessness. From Mt Kenya, north-west via Lake Baringo to Karamojong and the south-eastern Sudan, manes are, in three-quarters of individuals, either sparse and tufty or completely absent; inadequate evidence suggests that the situation is the same north-east of Mt Kenya (the type of *granti*, from the upper Tana River, is maneless) to the Juba River in Somalia, where the character is apparently fixed.

In these same populations, the ears are either very vaguely striped or completely white. A maneless, white-eared zebra brought from “Abyssinia” to the Emperor Jahangir’s court in Delhi is depicted in a Mughal

painting of 1621, now in the Victoria and Albert Museum, London.

There might be grounds for recognising a distinct subspecies with these two characters, except that another character, size, separates the north-eastern and north-western populations. The north-eastern zebras average small like other *boehmi* or even smaller (mean skull length 496.2 in both sexes, n=6 males and six females), while the north-western ones are large, like the more southerly subspecies (Table 8.5).

8.3.6 Subgenus *Dolichohippus*: Grévy’s zebras

Externally, it has a long thick upright mane, a tufted tail, chestnuts (very small) on the forelimbs only; there are short erect black hairs along the dorsal stripe; narrow, almost dazzling, black and white stripes occur over the whole body except venter and croup, and there is a complex triradial pattern on croup.

Cranially, the occiput is high and raised; the postorbital constriction is deep; the muzzle is long; the vomer is long. The nasal end of the premaxilla is rounded and wedged into the nasal. The scapula is lengthened. The metapodials are somewhat lengthened. The metacarpus is long compared to the metatarsus. The distal phalanges are small. The skull is very elongated, exceeding the cervical spine in length unlike other subgenera. The biischial breadth is low compared to the biacetabular breadth; the height of the pelvic inlet is not strongly sexually dimorphic.

Equus grevyi Oustalet 1882: Grévy’s zebra

Provisionally, two subspecies can be recognised, based entirely on size, although they need to be tested on larger samples. There appears to be no sexual dimorphism in size in the species, so values for the two sexes can be combined; moreover, maximum size seems to be achieved by the time the second molars have erupted.

1. *Equus grevyi grevyi* Oustalet 1882

1882 *Equus grevyi* Oustalet. Galla country, Ethiopia

1898? *Equus faurei* Matschie. Lake Rudolf (now Turkana), Ethiopia (the name ‘*faurei*’ is not definitely a synonym of *E. g. grevyi*).

1902 *Equus grevyi berberensis* Pocock. Ogadain, northern Somalia.

The greatest skull length recorded was 587.1mm (529–615mm; n=8).

Localities: Arussi; Webi River, 8°N, 41°E; Harrar; Diredawa; Northern Frontier District, Kenya. These all lie in the Somali Arid zone.

2. *Equus grevyi* subspecies

Greatest skull length was 624.0mm (608–639mm; n=7).

Localities: Meru; Guaso Nyiro; Longaya Water.

Three specimens from Archer's Post average 602.3mm (596–608mm), and five from Isiolo average 590.0mm (554–621mm). These are therefore intermediate, though closer, to the arid zone form.

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Genetics of Equid Species and Subspecies

E. Ann Oakenfull and Oliver A. Ryder

9.1 Introduction

9.1.1 Background

During the Pleistocene, numerous species of equids were found in North and South America, Asia, and Africa. Of these, only seven or eight species remain today (depending on whether the domestic and Przewalski's horse are counted as one or two species). Although the fossil record of Equidae is one of the classic examples of the evolutionary process, there are still many aspects of the evolution and the relationships of both extinct and extant equids that remain unclear. Understanding the relationships and genetic distinctiveness of populations, subspecies, and species is both of academic interest and of importance to conservation management. Resources for conservation are limited and it is in this context that we need to determine the conservation priorities. Should we attempt to conserve all populations and subspecies, or would it be better to direct our efforts to saving representatives of each species? This question can only be answered by determining what is required to ensure the preservation of the evolutionary heritage of the genus and thus protect its evolutionary potential. In short, we need to know what *are* the evolutionary significant populations for equids (Ryder 1986; Moritz 1994; Crandall *et al.* 2000), the answer to which may be found through further genetic studies along with ecological information (morphological, behavioural, habitat).

9.1.2 Defining subspecies and species

Defining subspecies is a difficult and often controversial process. Significant factors in defining a subspecies are the geographic location, habitat, and the amount of interaction between populations. Behavioural characteristics, coat colour, and other morphological differences are also used as defining characteristics. The recent use of genetic markers to examine variation in DNA (which can be extracted from a variety of samples, including blood, dried skin, hair roots, and faeces) is proving to be beneficial in defining subspecies.

In general, there is broad agreement about species definitions for the extant members of the genus *Equus* (see Taxonomy section). However, perhaps one of the most contentious issues is whether domesticated and wild forms, such as domestic and Przewalski's horse, are different species and whether they should be conserved separately.

Because domesticated forms of horses and donkeys have been co-evolving with humans, and separately from wild forms, for approximately 6000 years (Clutton-Brock 1992), we believe there is little doubt that they should be conserved separately. As the human population expands and there is increasing habitat overlap between wild and domestic/feral animals, it becomes increasingly important to distinguish hybrids of these types.

Although consensus on the number of extant equid species may be envisaged, determining the relationships between each of these species has been a notoriously difficult problem (George and Ryder 1986; Forstén 1992; Oakenfull and Clegg 1998). Nevertheless, resolving how the species group together within the genus is necessary because it can help to determine the conservation priorities within that genus (Nee and May 1997).

9.1.3 Genetic tools for conservation

Often conservation questions involve looking at closely related species and subspecies. It is therefore important to use genetic markers that are rapidly evolving so that differences can be observed between these closely related taxa. The most commonly used markers are random amplified polymorphic DNA (RAPD), microsatellites and the control region of mitochondrial DNA (mtDNA). RAPD analysis examines different patterns of randomly amplified fragments of DNA, which are generally caused by base changes in the DNA sequence, and compares them between individuals. It is a relatively inexpensive and easy technique to establish but has the disadvantage of poor reproducibility. Reproducibility is not such a problem with microsatellites (regions of DNA sequence that vary in length due to differences in the number of simple repeats) and they provide additional information because we have a better understanding of how they are inherited. However, this can be a relatively expensive technique compared to RAPD analysis. MtDNA sequence analysis examines base changes in the DNA sequence and is the most costly and labour intensive technique for examining populations, but is particularly useful for studying evolutionary relationships. An additional advantage of mtDNA is that, because it is inherited maternally, it can be used for tracing the female genetic lineages and female dispersal patterns without requiring direct observation of the animals. Chromosomes can also be used as a marker system, analysing the differences in chromosome number

and morphology can be useful for distinguishing species, but has the disadvantage of requiring fresh blood or skin biopsy samples.

9.2 Genetic action proposed in the first Equid Action Plan

The original Action Plan to conserve the genetic diversity of equids recommended:

1. determining the genetic variation between the subspecies within African asses, mountain zebras, Asian wild asses, and plains zebra;
2. a study of the genetic differences between wild and feral asses in Africa, and;
3. the collection of genetic information to identify populations of feral horses of national and international importance.

9.3 Action since the first Equid Action Plan

Since the original Action Plan, considerable progress has been made in the collection and analysis of samples. Table 9.1 describes these samples along with genetic markers already studied and those that are to be examined in the immediate future. The progress made for each species and in determining the relationships between these species is summarised here:

- *Somali wild ass/domestic donkey* – A mtDNA study has indicated that the domestic donkey is, as expected, most closely related to the Somali wild ass (Oakenfull *et al.* 2000). A high rate of chromosome rearrangement was found in a small group of captive Somali wild ass (Houck *et al.* 1998). The utility of the identified polymorphisms in the interpretation of relationships between populations would require samples from additional specimens, including wild individuals. Unfortunately, however informative such a study might be, it is currently not feasible.
- *Asian wild asses* – A focus of the research in this group of equids has been to determine the genetic distinctiveness of onagers and kulans. These are the two hemione subspecies that are commonly in captivity and, due to limited space, it has been asked whether they need to be managed separately. Both DNA analyses (RAPD [Schreiber *et al.* 1996] and mtDNA [Oakenfull *et al.* 2000]) and morphological (Eisenmann and Shah 1996) analyses have shown that there is a large overlap in their variation, which suggests that they do not come from genetically distinct populations, but data from more animals and other genetic loci are required to confirm this. DNA studies are also starting to examine the taxonomic status of kiangs, to ascertain whether

they should be classified as species or subspecies. However, this work is hindered by the lack of samples from the western and southern regions of their range.

- *Plains zebra* – The plains zebra is probably the least endangered equid, but their habitat is gradually being taken over by domestic livestock and they are also over hunted in some areas. It is therefore important that we understand their genetic diversity to make informed decisions about priorities for their conservation. Two studies have suggested that mtDNA divergence between populations increases with geographical separation of the populations (Georgiadis unpublished; Oakenfull *et al.* 2000). However, both these studies are lacking samples from the central subspecies (Crawshaw's and Upper Zambezi zebras). Samples from these central subspecies will help us to discern if the observed mtDNA variation reflects historical or current movements of the populations. A study of geographically separated populations in the Natal region of South Africa provides an interesting model for the estimation and management of genetic diversity in small populations of plains zebra (Bowland *et al.* 2001).
- *Mountain zebra* – The first DNA studies to describe the genetic variation between Cape and Hartmann's mountain zebras have been initiated and plan to include samples from the last three indigenous remnant populations of Cape mountain zebra. Microsatellite markers have been used for parentage verification in Hartmann's mountain zebra, which has assisted in their management in captivity (Breen *et al.* 1995).
- *Przewalski's horse* – The debate over whether the Przewalski's horse is the ancestral type of domestic horse has continued with studies of mtDNA, but has not been resolved (Ishida *et al.* 1995; Oakenfull and Ryder 1998). Fox colouring is a character found in the European captive population and is believed by some to be undesirable because it may be a domestic horse trait derived from the domestic horse influence in the Przewalski's horse population (one of the 13 founders was a domestic horse and one founder is thought to be a domestic × Przewalski's hybrid). A test has been developed to detect carriers of this gene and therefore make it possible to exclude the fox colour from the population (A. Bowling, more details can be found at www.vgl.ucdavis.edu/horse/redtest.html; Pistacchi 1998). Both microsatellites and mtDNA sequence have been used for Przewalski's horse parentage verification (Breen *et al.* 1994; Oakenfull and Ryder 1998; Bowling, Zimmermann and Ryder, unpublished).
- *Feral and domestic horses* – Studies of the genetic variation of feral horses and domestic horse breeds have continued and are being used to identify genetically unique populations that are conservation priorities (Cothran 1994; Oom and Cothran 1994; Cothran 1996; Cothran *et al.* 1998; Lister *et al.* 1998; Cothran *et al.* 2001).

- *Relationships between extant equid species* – In comparisons between extant equid species, three recent investigations have all shown it to be difficult to determine the order in which they diverged from each other, but there is some evidence that the horses diverged first (Ishida *et al.* 1995; Oakenfull and Clegg 1998; Oakenfull *et al.* 2000). These results suggest that the speciation events separating these species occurred rapidly and are therefore difficult to distinguish.

9.4 Conclusions on the genetic proposals in the first Action Plan

The genetics proposals laid out in the first Equid Action Plan were all-encompassing and did not set specific goals. Therefore, it was not expected that all the actions could be completed within the time since that Action Plan was written, although progress has been made in all sections of the original proposal. As the status of each species in the wild becomes better known, the priorities for genetic research become clearer. The advances in genetic technology also help to make the goals more achievable.

9.5 Priorities for future action

9.5.1 Sample collection

The most urgent requirement for action is the collection of samples from wild populations. Samples for DNA analysis can be collected by a variety of methods. Hair roots, desiccated skin, and fecal samples are all potential sources of DNA and can be transported simply in dry conditions to the laboratory. If a recent carcass is found, a rich supply of DNA can be retrieved by preserving a piece of tissue in alcohol. Methylated spirits are sufficiently pure for this purpose and vodka has also been used successfully (Oakenfull 1994). The tissue should be soaked in alcohol for several days, after which the alcohol can be drained away and the sample sealed in any container and mailed to the laboratory. A more invasive and expensive collection method is to use a biopsy dart to obtain skin samples that are then transported frozen. If the skin biopsies are frozen in appropriate media they have the potential to be grown in the laboratory to provide additional DNA and important information from chromosome preparations, along with RNA and protein for genetic studies. Chromosomal analysis can also be carried out using fresh blood samples.

All samples collected should have the necessary permits:

1. Permits from local governing authorities to collect the material;

2. Permission to transport the samples from the agricultural authorities of both the exporting and importing countries;
3. CITES permits for transporting samples from endangered species, obtained from both the exporting and importing countries.

Samples are most urgently needed from animals in the countries listed below:

- African ass (*E. africanus*) – Eritrea, Ethiopia, Somalia, and Sudan.
- Domestic donkey (*E. africanus* [domestic]) – Eritrea, Ethiopia, Somalia, and Sudan.
- Asian asses (*E. kiang* and *E. hemionus*) – Nepal, China, India, Mongolia, Iran, Israel, Turkmenistan, and Kazakhstan.
- Mountain zebra (*E. zebra*) – Hartmann's mountain zebra from Angola and Namibia.
- Plains zebra (*E. burchellii*) – Malawi, Zambia, Mozambique, Tanzania, Uganda, and Namibia. Less urgently needed are samples from Botswana, Zimbabwe and west and central South Africa.
- Domestic horse (*E. ferus caballus*) – Mongolia, and feral populations worldwide.

9.5.2 Analysis of genetic variation

Unlike the relatively clear distinctions between the equid species, the subspecies and their evolutionary significance are not so well defined, so a priority for equid conservation is to distinguish the genetic differences of the subspecies of African asses, Asian asses, mountain zebra, and plains zebra, and ascertain which are the highest priority for conservation.

More information about the genetic diversity of feral horse populations is required and the continued studies using blood group and protein markers will prove important in this respect.

At reintroduction sites of Przewalski's horse in Mongolia, there are substantial domestic/feral horse populations in the surrounding areas and therefore the potential for hybridisation of the wild and domestic taxa (whether similar risks of hybridisation exist at reintroduction sites in China is uncertain). If the Przewalski's horse genetic make-up is to remain unsaturated by interbreeding with domestic/feral horses, then it will be necessary to develop genetic tests for identifying these hybrids. The control region of mtDNA sequence and microsatellites are potential markers for these tests, but their use will require a detailed knowledge of their variation in the local horse populations. The same type of hybrid detection should be carried out in the regions where the habitats of wild and domestic/feral African asses overlap.

Table 9.1. Equid samples collected and genetic analyses in progress.

Species	Subspecies	Location	Samples Collected	Analysis – current and planned
African wild ass	Somali wild ass	Ethiopia	27 fecal 4 tissue	mtDNA sequence and microsatellites
		Eritrea	17 fecal 1 tissue	mtDNA sequence and microsatellites
		captive	17 blood and tissue	Chromosome and mtDNA sequence
	domestic donkey	Eritrea Ethiopia	1 fecal 3 tissue 1 tissue	mtDNA sequence mtDNA sequence
<i>Equus hemionus</i>	onager	captive	~25 blood and tissue	RAPD mtDNA sequence
		captive and wild	25 skull	morphological
	kulan	captive	~25 blood and tissue	RAPD mtDNA sequence
		captive	30 skulls	morphological
<i>Equus kiang</i>		captive and wild	25 skulls	morphological
	Eastern	captive	~6 blood and tissue	RAPD mtDNA sequence
Plains zebra	Grant's	Kenya	58 skin biopsies	mtDNA sequence
		captive	~12 blood and tissue	mtDNA sequence
	Chapman's	Zimbabwe	27 skin biopsies and 3 tissue	mtDNA sequence
		captive	~4 blood and tissue	mtDNA sequence
	Damara	Botswana	7 tissue	mtDNA sequence
Mountain zebra		S. Africa	61 blood and 6 tissue	mtDNA sequence and microsatellites
		captive	~7 blood and tissue	mtDNA sequence
	Hartmann's	captive	~10 blood and tissue	mtDNA sequence and microsatellites
		S. Africa	~12 fecal	mtDNA sequence and microsatellites
	Cape	S. Africa	~12 fecal	mtDNA sequence and microsatellites

9.5.3 Coordination of genetics actions

1. The sample collection should proceed by communication between the species coordinators (who have the most recent and detailed knowledge of the remaining populations of their species) and the genetics coordinators (who can identify the most appropriate laboratories for the analyses, in addition to suggesting suitable genetic markers). This action has begun for all the species, but the Asian ass studies are most in need of further coordination.
2. A register of equid DNA samples should be established. This would involve each laboratory entering their DNA sample details on a database that could be searched by all. Then, at the start of any genetic diversity studies, the relevant laboratories could be approached to see if their samples are available for inclusion in a collaborative project.
3. Where possible, the genetic analysis of samples should be carried out in their country of origin. Although this is an unlikely possibility for many of the equid species, efforts should be made to facilitate this in the future.

4. Once the genetic analyses are complete, studies from different laboratories should be collated in preparation for recommendations on conservation priorities.
5. Meetings between local wildlife and government officials, and the relevant scientists should be arranged to discuss the priorities (including genetic priorities) for the next stage of conservation action.

9.6 Conclusions

Most species of equid are endangered and, as integral parts of the ecosystems in which they live, their conservation is not only important for their own survival, but also for the species with which they interact. Over the last few years there has been an increasing interest in the genetics of this genus, both in understanding how the species are related to each other and in the genetic diversity within the species. This interest has come at an opportune time because the studies are providing valuable information for the formulation of conservation strategies for the endangered species. It is hoped that the proposals set forward in the Genetics chapter of this Action Plan will be useful in

coordinating these studies for a common aim of saving the genetic diversity of this genus.

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Equid Reproductive Biology

Cheryl S. Asa

10.1 Introduction

An extensive literature exists for the domestic horse and, to a lesser extent, for the domestic ass, but there have been almost no studies of the reproductive physiology of wild equids. Information about the length of the ovulatory cycle and of gestation are based almost solely on behavioural observations of estrous and mating behaviour and of the time of birth. The little that is known of the reproductive anatomy of the Hartmann's and plains zebra, for example, comes from dissections following culling (Westlin-van Aarde *et al.* 1988; Smuts 1976a).

Fortunately, however, the domestic horse may be an adequate model, since what we do know about wild equid reproduction appears not to deviate significantly from that general pattern. Differences in cycle and gestation length, for example, are minor and do not suggest different mechanisms. Comprehensive reviews of reproductive physiology and behaviour of the domestic horse can be found in Stabenfeldt and Hughes (1977); Ginther (1979, 1986, 1992); Rowlands and Allen (1979); Rowlands *et al.* (1975, 1982, 1987, 1991); Asa *et al.* (1979); and Asa (1986).

10.2 Seasonality

As with most other taxa, temperate-zone equids are more strictly seasonal than are their tropical-zone cousins. Photoperiod is probably the most important environmental

cue for seasonal reproduction in temperate regions (see Ginther 1979, 1992). However, even in the tropics, seasonal birth peaks suggest that nutritional factors related to rainy seasons are important (see Grubb 1981; Penzhorn 1988; Churcher 1993). All equids are polyestrous with estrus recurring until conception or the end of the breeding season.

10.3 Puberty

Estimates of the age of puberty are remarkably variable due to disparate definitions and methods of detection (Table 10.1). Earliest estimates are based on observations of estrous behaviour, which seems to occur in most species earlier than first mating (it is not clear whether failure to mate at first estrus is due to inadequate endocrine stimulation, social inexperience, or lack of opportunity in the natal group). The later estimates of puberty are based on observations of first birth, then subtracting gestation length to give age at first conception. It appears that even after estrous periods are accompanied by mating, these early attempts are usually infertile; hence, age at first conception may be considerably later than age at first observed estrus or mating.

For males, observation can only provide evidence of first mating and, unfortunately, this may be greatly delayed past physiological puberty for social reasons. Age of first reproduction is typically one to several years later for males than for females. Physiological evidence of first

Table 10.1. Age at puberty, which may be age at first estrus, first mating, or first conception.

Species	Age in months (and gender)	Source
<i>Equus zebra</i>	12–13 (female) 13–30 (female) 42 (male)	Joubert 1974 Penzhorn 1979 Joubert 1974; Penzhorn and Lloyd 1987
<i>E. burchellii</i>	16–22 (female) 13–15 (female) 24 (male)	Smuts 1976a; Wackernagel 1965 Klingel 1969 Smuts 1976b; Wackernagel 1965
<i>E. grevyi</i>	36–48 (female) 48 (male) 7–60 (male)	King 1965 King 1965 Read <i>et al.</i> 1988
<i>E. ferus przewalski</i>	4–26 (female) 31 (male)	Veselovsky and Volf 1965; Volf 1975 Veselovsky and Volf 1965; Volf 1975
<i>E. asinus</i> and Feral <i>E. caballus</i>	30–36 (female) 12 (female)	Lang 1983 Woodward 1979
<i>E. hemionus</i>	36 (female)	Pehle 1972; Treus and Lobanov 1974

ovulation has been obtained from examination of ovaries acquired from culled animals (e.g. Smuts 1976a). Likewise, examination of testes from culled males has provided evidence of age of first sperm production, as well as testis size (Smuts 1976b).

10.4 Estrus and ovulation

Ovulation is spontaneous and occurs at the ovulation fossa, a structure unique to equids and nine-banded armadillos (King 1965; Ginther 1979, 1992; van Tienhoven 1983; Rowlands and Weir 1984). It consists of a depression, lined with the germinal cells destined to develop into ova, at the free, ventral edge of the ovary.

Estrous cycles of equids are of moderate length relative to other mammals, ranging from about 19 to 35 days (Table 10.2), and are comparable to the range for cattle and antelope. However, in contrast to those taxa, the estrous phase is longer in equids, ranging from several days to a week, with a mode of five or six days. In Bovidae, estrus is typically only one to two days (Asa 1996). Estrus may be protracted in old or young mares, or at the beginning of the breeding season (Ginther 1974). Estrus is followed by either pregnancy or a diestrous period of about two weeks before the next estrus and ovulation. Non-pregnant cycles recur every 19 to 35 days, depending on the species (Table 10.2).

Estrous behaviours of domestic mares include increased frequency of urination, separation from other mares, and proximity to the stallion (see Asa *et al.* 1979; Asa 1986). The tail may be deflected to one side or held straight out from the perineum, and rhythmic eversion of the clitoris occurs during but also independently of urination.

The facial expression of adult estrous domestic (Asa 1986) and Przewalski (Haupt and Boyd 1994) horse mares is characterised by a slightly lowered head, ears held back and to the side, and relaxed facial muscles. However, the facial expression of estrous zebra and donkey mares may include the retraction of the lips to expose the incisors, often accompanied by a high-pitched vocalisation (Klingel 1974; Penzhorn 1984; Clayton *et al.* 1981). Younger horse mares may snap at the approach of a stallion, a behaviour commonly seen in mature as

well as young estrous donkeys (Clayton *et al.* 1981; Crowell-Davis *et al.* 1985).

The urination posture of an estrous mare is in itself attractive to stallions, although the urine also elicits intense interest, typically followed by the characteristic flehmen response, then over-marking with urine (Asa *et al.* 1979; Feist and McCullough 1976; Haupt and Boyd 1994; Klingel 1969, 1974; Penzhorn 1984). Mounting is often preceded by resting the head briefly on the mares hindquarters. Copulation includes multiple thrusts, with ejaculation accompanied by tail-flagging (rhythmic contractions that pull the tail to the perineum) in some species. The sexually refractive period (time to next mount) in domestic stallions is about 20 minutes, but varies greatly by individual (Asa *et al.* 1979). Likewise, the number of copulations per day varies individually.

10.5 Gestation

In the domestic horse, the primary corpora lutea (CL) remain functional until about 160–180 days gestation, and accessory CL appear between 40 and 60 days (Stabenfeldt and Hughes 1977). Estrous behaviour has been observed in some pregnant mares, especially early in gestation (Asa *et al.* 1983). Thus, diagnosis of pregnancy or calculations of gestation length based on the absence of estrous behaviour are unreliable. Gestation lengths of 11 to 13 months have been reported for wild equids (Table 10.3).

10.6 Parturition

Equid mares tend to give birth during the night (domestic horse: Rossdale and Short 1967; plains zebra: Wackernagel 1965), with a peak just before midnight in thoroughbreds. Three stages of labour are recognised in the domestic horse (see Ginther 1992, for review). Behavioural signs of the first stage include restlessness, with the appearances of sweat patches on the flanks about four hours before parturition (Arthur 1975). This stage ends with the escape of amniotic fluid, which may stimulate the mare to show flehmen.

Table 10.2. Lengths of the estrous phase and of the ovulatory cycle.

Species	Estrous phase (days)	Ovulatory cycle (days)	Source
<i>Equus zebra</i>			
<i>E. burchellii</i>	6 2–9	19–33	Smuts 1976 Wackernagel 1965
<i>E. grevyi</i>	4–7	28–35	Asa <i>et al.</i> 2001
<i>E. ferus przewalski</i>	6	24	Monfort <i>et al.</i> 1991
<i>E. asinus</i> and <i>E. caballus</i>	2–7	21–28	Rowlands and Weir 1984

Table 10.3. Approximate gestation lengths.

Species	Gestation (months)	Source
<i>Equus zebra</i>	12	Joubert 1974
<i>E. z. hartmannae</i>	12	King 1965
<i>E. burchellii</i>	12	Brown 1936; Wackernagel 1965
<i>E. grevyi</i>	13	Kenneth 1953
<i>E. ferus przewalski</i>	11	Veselovsky and Volf 1965
<i>E. asinus</i> and <i>E. caballus</i>	11	Ali 1946; Kenneth 1953
	>12	Lang 1983
	12	Fraser 1971
<i>E. hemionus</i>	11	Bannikov 1958
<i>E. kiang</i>	12	Kenneth 1953

Table 10.4. Latency to foal heat.

Species	Days	Source
<i>Equus zebra</i>		
<i>E. z. hartmannae</i>		
<i>E. burchellii</i>	8–10	Wackernagel 1965
	7	King 1965; Klingel 1969
<i>E. grevyi</i>	10	King 1965
	7	Read <i>et al.</i> 1988
<i>E. ferus przewalski</i>		
<i>E. asinus</i> and <i>E. caballus</i>	17–18	Rowlands and Weir 1984
<i>E. hemionus</i>		
<i>E. kiang</i>		

During the second stage, which takes from ten to 70 minutes, abdominal contractions become more prominent and result in expulsion of the foal. Mares are most likely to strain only when recumbent, which may help increase abdominal pressure (Ginther 1992). Delivery typically occurs with the mare on her side with limbs extended. The foal is usually encased in the amnion, with umbilicus still attached; both are ruptured by the movement of the foal or the mare.

The third stage, characterised by expulsion of the placental membranes, is typically complete within three hours. Mares usually do not ingest the placenta. Although retained placenta is thought to be associated with pathology, this may not be generally true (Provencher *et al.* 1988).

10.7 Post-partum estrus

In species for which there are data (Table 10.4), the first estrus following parturition (foal heat) occurs within one to two weeks. In domestic horses, there is some disagreement regarding the fertility of this estrus (see Ginther 1992). Still, whether this or subsequent periods of estrus are more fertile is less important than to note

that this genus does not experience a lactational anestrus, but will ovulate and copulate during lactation. In cases where another foal is not born the following year, it is not possible to know whether the failure occurred at the time of fertilisation, or if the embryo/fetus was lost. Even for domestic mares not facing limited food supplies, fetal loss can be 10–18% (see Ginther 1992).

10.8 Recommendations for future research

During the last ten to 20 years, advances in anaesthesia and restraint procedures have allowed physiological sampling from many wild species. However, wild equids remain a problem, since they are more difficult to safely restrain than most other species and do not respond as well to current anaesthetics. Recent validation of assays for steroid hormones in the urine and faeces of Grévy's zebras (Asa *et al.* 2001) will allow remote collection of samples for endocrine analysis. Patterns of steroid hormones can then be used to delineate estrous cycles and pregnancy, or to determine stage of cycle or diagnose pregnancy in free-roaming equids.

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The Dynamics of Equid Populations

David Saltz

11.1 Introduction

The dynamics of a species are determined by its characteristics (phylogeny and ontogeny), the environment in which the individual animals exist, and the interaction between the two. By knowing the reproductive, survival, immigration, and emigration rates of a species and the factors that influence them, we can predict future changes in population density, and the rate at which these are expected to occur.

Equids are large herbivores with body mass ranging from 100kg for adult ass to 450kg in adult Grevy zebra and Perzewalski horse (by comparison the adult weight varies between 8kg and 900kg in Cervidae and between 5kg and 900kg in Bovidae). Thus, equid species are, at least allometrically, very similar. Much of their diet, behaviour, and ontogeny is dictated by the fact that they are hindgut fermenters and have large body mass. All equids are bulk feeders living in open habitat. They are all polygynous and highly social. This, in turn, allows us to make some generalisations about their population dynamics, even though data are limited.

11.2 Survival

The data on age-dependent survival in equids are sparse. Based on studbooks, the maximum life expectancy is approximately 25 years. However, most ungulates may survive up to twice as long in captivity than they do in the wild. A survival curve was established for plains zebra based on recovered skulls (Spinage 1972). This curve suggests that annual survival of adult female plains zebra is 0.9–1.0. Ninety percent of females die by the time they are 16, and only 3% are expected to survive to 18 years of age. There is some evidence that survival in other equids is similar. The survival curve derived by Garrott and Taylor (1990) for feral horses was similar in shape to that of plains zebra (Spinage 1972), with a sharp decline beginning at age 16. Eberhardt *et al.* (1982, based on Wolfe 1980) calculated female feral horses annual survival rate to be 0.94 (range 0.89–0.99). Norment and Douglas (1977) observed in a single year a 95% survival of adult feral burros. Garrott and Taylor (1990) found an adult survival rate of 0.89–0.99 in ten years of an 11-year study. During the remaining year, the population crashed due to severe winter conditions, with survival plummeting to 0.49. Mass

mortality such as this or due to the result of diseases is known to occur in equids, but is rare (see below).

In most species, first year survival is reduced; however, in equid populations under favourable conditions it can approach 100% (Seegmiller and Ohmart 1981 – feral burro; Saltz and Rubenstein 1995 – Asiatic wild ass). First-year survival of feral burros were reported between 0.66 (Moehlman 1974) and 0.79 (Mogart 1978), and between 0.50 and 0.70 in feral horses (Wolfe 1980). Based on Spinage (1972), first-year survival rate is approximately 0.80 for both males and females.

11.3 Reproduction

Except in rare cases, all equids are monotocous. Gestation in equids is long, ranging from 330–390 days (as compared with 160–300 and 120–330 days for Cervidae and Bovidae, respectively). Although under good conditions they do reproduce in consecutive years, females may often forgo reproduction in consecutive seasons. Most papers reviewed herein suggest equids usually give birth for the first time between ages three and five. On rare occasions, two-year-olds may give birth. In growing populations, average annual foaling rates per adult female per year are usually 0.6–0.8 (Table 11.1). In a Przewalski horse population reintroduced in 1992, annual birth rate ranged from 0.11–1.0 with an overall average of 0.47 (Bouman 1996).

Peak reproductive success in horses is between the age of 6 and 16, and is 0.8–0.9 (Eberhardt *et al.* 1982; Seal and Plotka 1983; Garrott *et al.* 1991b). Data of Saltz and Rubenstein (1995) suggest an increase in reproductive success of female Asiatic wild asses with age for young and prime-aged females, but they did not have the data to show a decline in older animals. In two species of equids, Grevy zebra and Asiatic wild ass (Hayward 1987 and Saltz and Rubenstein 1995, respectively), the gender of the offspring is influenced by maternal age. In both cases, mid-aged mothers tended to give birth to males.

11.4 Annual growth rates

Existing data suggest that under favourable conditions, equid populations can grow rapidly with a doubling time of four years. Growing populations of Asiatic wild ass

Table 11.1. Reproductive success (proportion of females producing an offspring each year) in various species of equids.

Species	Reproductive Success	Source
Feral horses	0.60	Speelman <i>et al.</i> 1944
Feral horses	0.45 (0.36–0.65)	Garrott and Taylor 1990
Feral horses	0.57–0.81	Wolfe <i>et al.</i> 1989
Feral burros	0.69	Wolfe <i>et al.</i> 1989
Asiatic wild ass	0.45	Saltz 1995
Asiatic wild ass	0.57 (0.50–0.78)	Saltz and Rubenstein 1995
Asiatic wild ass	0.66	Zhirnov and Ilyinski 1986
Feral donkeys	0.75	Choquenot 1990
Feral burros	0.45–0.77	Perryman and Muchlinski 1987
Plains zebra	0.79–0.82	Smuts 1976
Cape mountain zebra	0.32	Penzhorn 1985
Przewalski's horse	0.47	Bouman 1996

Table 11.2. Annual population growth rates recorded in various species of equids.

Species	Annual Growth	Source
Asiatic wild ass	0.19 (0.10–0.38)	Slomatin 1973
Asiatic wild ass	0.17	Saltz and Rubenstein 1995
Asiatic wild ass	0.15–0.38	Zhirnov and Ilyinski 1986, citing Rashek 1973
Feral donkey	0.23–0.28	Choquenot 1990
Feral burro	0.29	Mogart 1978
Feral burro	0.01	White 1980
Feral burro	0.18	Norment and Douglas 1977
Feral horses	0.20	Eberhardt <i>et al.</i> 1982
Feral horses	0.18	Garrott and Taylor 1990
Feral horses	0.17–0.27	Garrott <i>et al.</i> 1991a
Cape mountain zebra	0.07–0.10	Novellie 1995; Novellie <i>et al.</i> 1992
Plains zebra	0.07	Penzhorn 1985

have shown annual increase rates ranging from 0.10–0.38 (Table 11.2). Similarly, feral donkeys, burros, and horses, have exhibited growth rates of 0.20 and above. The limited data on zebra indicate slower annual increase rates of 0.07–0.10. Based on Leslie matrix simulations, Wolfe (1980) expressed doubts concerning the validity of such population growth rates. His simulation suggested that to achieve such rates adult survival must exceed 0.90. The data presented herein suggest that, in fact, these criteria are often met in wild populations.

11.5 Controllers

It is unclear what the natural controllers of equid populations are. There appears to be little data on stable equid populations and their dynamics. Except for a few plain's zebra populations that are listed as stable, most

other equid populations are either declining due to human activities, or increasing following severe decline, reintroduction, or introduction. Most feral equids are constantly controlled through human intervention.

11.5.1 Resource limitations

Because of their size, equids are dependent on processing large quantities of low-quality forage (bulk feeders). Their ability to survive on low-quality forage suggests that poor habitat conditions would have little impact on their survival, making equids relatively insensitive to environmental changes in forage quality. Thus, "normal" seasonal fluctuations in the environment are believed to have minor effects on equid survival. This has led to the belief that equids can overshoot their carrying capacity, degrade their habitat, and bring about mass mortality and possibly the collapse of entire systems due to overgrazing

(Garrott *et al.* 1992; Saltz 2001a). However, there is little empirical data to support this hypothesis.

Their inability to ruminate or recycle urea makes protein content in their diet an important limiting factor. Such limitations should manifest themselves first and foremost in the ability of females to successfully rear offspring, rather than through adult mortality. Thus, Garrott and Taylor (1990) found the highest foaling rates after a 51% reduction in population size.

Animals of this size are dependent on free water. Space-use and movement patterns of many equid species are dependent on the distribution of water (Saltz *et al.* 2000; Scheibe *et al.* 1998). Because water is more of a Boolean situation (that is, either there is free water or there is not), the drying up of water sources would impact entire populations regardless of density. Thus, severe droughts could bring about mass mortality (Berger 1983a; Zhirnov and Ilyinski 1986). Severe winters are known to cause mass mortality and even local extinction in equids. For example, at the end of the 19th century, winter conditions in Central Asia resulted in a thick layer of ice covering the grass, bringing about the demise of entire Asiatic wild ass populations in Kazakhstan (Zhirnov and Ilyinski 1986). Mass winter die-offs are also known in feral horses (Penzhorn 1975; Berger 1983a; Garrott and Taylor 1990). Lactating or pregnant females may be more susceptible to harsh winters due to their increased energetic demands (Berger 1983b).

11.5.2 Social control

In many cases, this type of control is a response to resource limitations. However, the proximate factor is the behavioural interactions between the animals. Although data are limited, findings in several studies suggest social factors may be an important component in the dynamics of equid populations. In most equids, adult sex ratios are female-skewed due to male-male aggression that causes increased male mortality (Berger 1983a). Increased male mortality would have minor effects on population growth rates and reproductive success, but as the male:female ratio increases, the cost of defending a territory or harem increases. Consequently, male turnover may increase (Rowen and Saltz 1996; Saltz *et al.* 2000). This, in turn, may cause increased abortion (Berger 1983a) or, possibly, reduced conception rates.

In a reintroduced population of Asiatic wild ass, although resources were plentiful, the age of primiparity increased as the population grew (Saltz 2001b) suggesting that rank, reproductive success, and population density may be linked. In horses, maternal rank is positively correlated to reproductive success of male offspring (Feh 1990), and females shifting between groups were shown to have reduced reproductive success (Berger 1983a). However, natal dispersal in horses does not appear

to be induced by density or intraspecific competition (Monard *et al.* 1996; Monard and Duncan 1996). In mountain zebra, maternal rank was correlated to condition and survival of foals was positively correlated with maternal rank (Lloyd and Rasa 1989). A relationship between these factors and population density is yet to be demonstrated.

11.5.3 Diseases

Because of their social structure, equids may be sensitive to epizootics. Many wildlife diseases are density dependent, developing into epidemics once the host population has reached a threshold density (Barlow 1996). This is the point at which an animal is expected to infect more than one conspecific. This, in turn, depends on the length of time the animal remains contagious and the density of the population. Although no model exists, equids living in fission/fusion societies (Rubenstein 1986) may have a low threshold density. This may be for two reasons: (1) females within a group remain in close contact with each other, thus maximising the probability of transmission between all members of the group, and (2) fission/fusion behaviour and the rate at which individuals shift between groups enable rapid transmission of the disease. In harem based societies, the threshold density would depend on the probability of contact between different harems. Slomatin (1973) describes several instances of massive epizootic in Asiatic wild ass from pathogenic trypanosomes contracted from domestic equids. Crashes in Indian wild ass populations have been attributed to sleeping sickness (Ali 1986).

11.5.4 Predation

All equid species are subject to predation by various predators, but there are no data to suggest how much of an impact predation inflicts on their dynamics. Such an impact would most likely come about through foal predation. Given the rapid growth of feral equids in the US and Australia, it is safe to assume that, at least in these cases, predators have little or no impact on the population dynamics. On the African continent, several predators are known to prey on equids. Lions are probably the most capable in handling equids and appear to prefer adult males, while hyenas and wild dogs appear to prefer adult female mountain zebra and common zebra (Berger 1983b and citations therein). In the reintroduced Asiatic wild ass population in Israel, wolves have been sighted several times while attempting to take foals, with only one known success. In all cases the wild ass either actively defended themselves or outran the wolves. In the only recorded case of depredation, the foal was several weeks old and its physiological condition when taken is unknown.

11.6 Conclusions

11.6.1 Dynamics

The drying-up of water sources, extreme winters, and epizootics, cause population crashes relatively independent of population density. Under non-extreme environmental conditions and in the absence of epizootics, equid populations exhibit a rapid growth rate. Given the ability to survive on low-quality forage, it is possible that density-dependent population control in the family Equidae comes about through crashes, and that it is characterised by cycles of rapid growth followed by crashes ('boom/bust').

Density-dependent responses in equids are most likely to come about through reduced reproductive success rather than increased mortality. Equids, like other large-bodied mammals, are typically characterised by high adult survival, low reproductive success, and relatively low sensitivity to environmental fluctuations (what we generally term 'K-selected' species). As such, equids are expected to have an abrupt density-dependent response close to carrying capacity (Fowler 1988; Getz 1996). It is unclear whether such responses would be strong enough to stop population growth and prevent population crashes due to 'overshooting' of carrying capacity. Only one study has documented a stable population in equids (feral burros – White 1980), but the study was short term and thus cannot be conclusive with regard to the reasons for this stability. Because equids are highly social, most intraspecific competition should come about through 'contest' rather than 'scramble' competitions, thus favouring a gradual, less abrupt response to density rather than 'boom/bust' type dynamics (Getz 1996). In species exhibiting age-dependent progeny-sex-ratio, the postponement of primiparity, from age three to four (the female producing age groups – Saltz and Rubenstein 1995; Saltz 2001b) to age five to six with increased density, may have a strong impact on population growth rate.

To conclude, although crashes due to 'overshooting' of carrying capacity may occur in equids, available data suggest that such dynamics cannot be considered typical.

11.6.2 Population viability

Four basic stochastic elements determine the viability of small populations (Shaffer 1981): demographic stochasticity, environmental stochasticity, genetic stochasticity, and catastrophes.

In equids, having an annual growth rate of 0.15–0.20, the number of adult females necessary to bring extinction probability due to demographic stochasticity alone to <0.01 over a period of 100 years is roughly 15–30 (depending on age structure and actual growth rate). This

is similar to other large ungulates. However, the clear hierarchies within equid social groups and the strong relationship between dominance and reproductive success suggest that individual animal variation (data that are hard to obtain and are often lacking) would be an important factor in the viability of equid populations.

It is difficult to make any generalisations concerning environmental stochasticity. It is very much species specific and dependent on the specific environment within which each population exists. However, generally speaking, because normal environmental fluctuation would have minor effects on adult survival and would mostly impact reproductive success, the estimated minimum viable population is not expected to increase dramatically (relative to 'r-selected' species) as a result of stochastic environmental events.

The greatest impact on population viability of equids is possibly catastrophes, i.e. mass mortality episodes due to disease, drought, or frost. Data suggest such catastrophes are not uncommon in equids.

Given a relatively stable positive growth rate, small equid populations have good potential for recovery if threatening agents, such as interspecific competition with domestic stock or hunting, are removed. However, because equids are large bodied, they require large tracts of land in order to sustain a viable population. Furthermore, their sensitivity to site specific extreme conditions (catastrophes) is an important component of their extinction risk. Thus, threatening agents such as loss of habitat and fragmentation (i.e. reduced range and isolation) are the greatest threat to the existence of equid species.

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Disease Concerns for Wild Equids

Rolfe M. Radcliffe and Steven A. Osofsky

12.1 Introduction

12.1.1 Why are diseases a concern?

The translocation of mammals and birds from one region to another for the reinforcement of a population or for reintroduction of a species has become a popular wildlife management technique (Woodford 1993; IUCN 1998). Wild animals are also frequently moved to areas outside of their natural range, for example, for captive breeding or exhibition. Why is an understanding of epidemiology and disease important when considering the movement of wildlife?

When animals are translocated they may “import” new diseases, which can adversely affect the managed species (either the translocated animals or resident animals of the same species), other resident species at the translocation site, or both (Cunningham 1996). The introduction of African horse sickness into Spain in 1987 when several zebra were moved there from Namibia was laden with disastrous results (Rodriguez *et al.* 1992), and symbolises the need for full consideration of diseases and their control when moving wild animals (DeVos 1973; Meltzer 1993; IUCN 1998). Finally, most diseases of domestic equids can be transmitted to wild equids and vice-versa; thus, disease surveillance for conservation programs must be comprehensive (Wemmer *et al.* 1996).

Veterinary involvement in conservation projects can augment problem-solving abilities through an enhanced interdisciplinary approach incorporating clinical disease management, pathology, epidemiology, nutrition, genetics, toxicology, and reproduction (Karesh and Cook 1995). The health of wild populations is more likely to be secure if the conservation team has the ability to identify critical health factors, assess and monitor health status, intervene in crisis situations, develop and apply new technologies, address animal handling and welfare concerns, and provide training (Karesh and Cook 1995).

12.1.2 Summary and objectives

To improve success rates of endangered species conservation efforts, population management requires a multidisciplinary approach. Diseases can have as great an influence on populations as predation, competition, or environmental degradation (Lyles and Dobson 1993). “Disease, because it has profound influences on

individual fitness, is a major evolutionary force and an important factor in the maintenance of biodiversity” (Cunningham 1996). Awareness of diseases affecting both wild animals and their domestic relatives will be an important component in the design of successful conservation measures, with precautions needing to be taken to preclude disease transmission in either direction (Lyles and Dobson 1993; Daszak *et al.* 2000).

Here we present information on diseases reported to affect or to be carried by wild equids, both in their natural environment and in captivity. The tables in this chapter are designed to be tools for managers of wild equid populations, providing a historical perspective on the types and distribution of diseases reported in non-domestic equids. The tables are not, however, an attempt to cover all aspects of the veterinary medicine and management of wild equids, but rather are meant to give wildlife managers an appreciation for the need to include “veterinary tools” in their “conservation toolbox.” Locally available information on the health status of *domestic equids* in an area of interest should always be sought from veterinary authorities and local animal owners (Woodford and Rossiter 1993).

Viral and bacterial diseases of wild equids are emphasised here, based on available literature. A bibliography on parasitic diseases can be found in Appendix 4. Other medical and surgical conditions are mentioned. The authors acknowledge that, overall, there is still inadequate information on the incidence, distribution, and risks of disease in both captive and wild equid populations (Wolff and Seal 1993). Poisonous plants are not covered in this chapter, and other references should be consulted on this important topic (for example, Vahrmeijer 1981).

Acquisition of data on the infectious diseases of threatened and endangered species can be expedited through cooperative disease surveys of captive and free-ranging animals (Munson and Cook 1993). A minimum information base for this profile, compiled largely from pathology data, would include an inventory of all diseases known to have affected the species, the indigenous microflora (bacterial, viral, and parasitic) of the species, and the immunoserologic profile of pathogens known to affect this and related species (Munson 1991).

The reported diseases of non-domestic equids, both free-ranging and captive, are summarised in Table 12.1 and Table 12.2, respectively. A comprehensive bibliography

Table 12.1. Reported diseases of free-ranging wild equids.**A. MOUNTAIN ZEBRAS** Continent of origin: Africa

Hartmann's Mountain Zebra

Equus zebra hartmannae

Country and specific location: Namibia, Khomas Hochland population Study period/Date reported: 1973–1974 Reference: Joubert 1974

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Tested negative for Anthrax (<i>Bacillus anthracis</i>) _M			Drought, accidents, predation _N	Spore ingestion, Insect vectors

E. z. hartmannae

Country and specific location: South Africa Study period/Date reported: 1974 Reference: Penzhorn 1984

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Severe drought _N	N/A

E. z. hartmannae

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1974–1992 Reference: Lindeque and Turnbull 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C}				Spore ingestion, Insect vectors

E. z. hartmannae

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1975–1990 Reference: Berry 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C}				Spore ingestion, Insect vectors

*E. z. hartmannae*Country and specific location: Namibia Study period/Date reported: 1983 Reference: Daly *et al.* 1983

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Sarcocystosis (<i>Sarcocystis</i> spp.) _p		Sporocyst ingestion, Sporocyst dispersal by insects possible, N/V

^A*E. z. hartmannae*

Country and specific location: Namibia Study period/Date reported: 1992 Reference: Borchers and Frolich 1997

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Equine herpes viruses EHV-1 _s , EHV-4 _s , EHV-2 _s					Virus inhalation, Direct contact, N/V

E. z. hartmannae

Country and specific location: Namibia, Etosha National Park and South Africa, Kruger National Park Study period/Date reported: 1994 Reference: De Vos 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C} Rare occurrence				Spore ingestion, Insect vectors

Cape Mountain Zebra

Equus zebra zebra

Country and specific location: South Africa, Mountain Zebra National Park Study period/Date reported: 1970–1984 Reference: Penzhorn 1984

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Severe winter weather _N	N/A

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

A. MOUNTAIN ZEBRAS ... continued

E. z. zebra

Country and specific location: South Africa, Mountain Zebra National Park Study period/Date reported: 1972–1976 Reference: Bath 1979

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Nephritis (<i>Actinobacillus equuli</i>) _{N,C}				Direct contact with infected genital tracts of mares, N/V

E. z. zebra

Country and specific location: South Africa, Mountain Zebra National Park Study period/Date reported: 1973 Reference: Young *et al.* 1973

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
^a African Horse Sickness (AHS) _S ^a EHV-1 _S			Babesiosis (<i>Babesia equi</i>) _M		AHS= <i>Culicoides imicola</i> EHV-1=Inhalation Babesiosis= <i>Rhipicephalus evertsi evertsi</i>

E. z. zebra

Country and specific location: South Africa, Mountain Zebra National Park Study period/Date reported: 1982 Reference: Barnard 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
EHV-1 _S Equine Encephalosis Virus (EEV) _S Tested negative for AHS _S					EHV-1=Inhalation, Direct contact, N/V EEV= <i>Culicoides</i> vectors likely

E. z. zebra

Country and specific location: South Africa Study period/Date reported: 1991–1992 Reference: Barnard 1997

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative for AHS _S					AHS= <i>Culicoides imicola</i>

E. z. zebra

Country and specific location: South Africa, Mountain Zebra National Park Study period/Date reported: 1996 Reference: Barnard 1997

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative _S for EEV and AHS					EEV= <i>Culicoides</i> , AHS= <i>Culicoides imicola</i>

B. GRÉVY'S ZEBRAS Continent of origin: Africa

Grévy's zebras

Equus grevyi

Country and specific location: East Africa Study period/Date reported: 1973 Reference: Pipano and Tadmor 1978

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Babesiosis (<i>Babesia equi</i>) _M		Tick vectors: <i>Rhipicephalus evertsi</i>

E. grevyi

Country and specific location: North-eastern Kenya Study period/Date reported: 1982 Reference: Ogaa 1983

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Capture-stress related abortion _H	N/A

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

C. PLAINS ZEBRAS Continent of origin: Africa

Plains zebras

^A*Equus burchellii crawshayi*

Country and specific location: Zambia, Lumbwe Game Reserve Study period/Date reported: 1922 Reference: Tuchili *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C}				Spore ingestion, Insect vectors

E. b. subspecies

Country and specific location: South Africa Study period/Date reported: 1928–1991 Reference: Swanepoel 1994b

Country and specific location: South Africa, Namibia Study period/Date reported: 1967–1976 Reference: Barnard 1979

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Rabies					Saliva infective, N/V Urban - dog Wildlife - mongoose

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park Study period/Date reported: 1960 Reference: Pienaar 1961

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _M				Spore ingestion, Insect vectors

^A*E. b. antiquorum*

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1960–1994 Reference: Gasaway *et al.* 1996

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Predation and Anthrax may limit population growth	Spore ingestion, Insect vectors

^A*E. b. boehmi*

Country and specific location: Tanzania, Serengeti Study period/Date reported: 1961–1980 Reference: Sinclair and Norton-Griffiths 1982

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Predation or disease may regulate populations	N/R

E. b. subspecies

Country and specific location: Zimbabwe, Zambia, South Africa Study period/Date reported: 1963–1978 Reference: Hamblin and Hedger 1979

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative for BVD _s					N/V

E. b. subspecies

Country and specific location: Zimbabwe, South Africa, Zambia Study period/Date reported: 1963–1983 Reference: Al-Busaidy *et al.* 1987

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative for AKA _s					Insect vectors likely

^A*E. b. boehmi*

Country and specific location: Northern Tanzania Study period/Date reported: 1964–1970 Reference: Kaliner *et al.* 1974

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Sarcocystosis (<i>Sarcocystis</i> spp.) _p		Sporocyst ingestion, Sporocyst dispersal by insects possible, NV

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

C. PLAINS ZEBRAS ... continued

^A*E. b. antiquorum*; *E. b. crawshayi*-*E. b. chapmani* "hybrids"

Country and specific location: South Africa, Zimbabwe Study period/Date reported: 1964–1985 Reference: Shepherd *et al.* 1987

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
CCHF _s					Tick vectors of the genus <i>Hyalomma</i>

^A*E. b. antiquorum*

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1964–1992 Reference: Lindeque and Turnbull 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C} Blue wildebeest, elephant, springbok also affected				Spore ingestion, Insect vectors

^A*E. b. boehmi*

Country and specific location: Tanzania, Kirawira Study period/Date reported: 1965–1968 Reference: Marek *et al.* 1973

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Tested negative for <i>Salmonella</i> _C				Oral route via feces, contaminated feed and water, N/V

^A*E. b. crawshayi*-*E. b. chapmani* "hybrids"

Country and specific location: Zimbabwe Study period/Date reported: 1966–1972 Reference: Condry and Vickers 1972

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Brucellosis (<i>Brucella abortus</i>) _S				Oral route, inhalation, in utero, N/V

^A*E. b. antiquorum*

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1966–1974 Reference: Ebedes 1977

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _M				Spore ingestion, Insect vectors

^A*E. b. boehmi*

Country and specific location: Tanzania, Loliondo Study period/Date reported: 1968 Reference: Young and Purnell 1973

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Babesiosis (<i>Babesia equi</i>) _M		Tick vectors: <i>Rhipicephalus everts</i>

^A*E. b. boehmi*

Country and specific location: Northern Tanzania and Kenya Study period/Date reported: 1971–1973 Reference: Kaliner *et al.* 1974

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Sarcocystosis (<i>Sarcocystis</i> spp.) _P		Sporocyst ingestion, Sporocyst dispersal by insects possible, NV

E. b. subspecies

Country and specific location: East Africa Study period/Date reported: 1973 Reference: Pipano and Tadmor 1978

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Babesiosis (<i>Babesia equi</i>) _M		Tick vectors: <i>Rhipicephalus everts</i>

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

C. PLAINS ZEBRAS ... continued

^A*E. b. boehmi*

Country and specific location: Kenya Study period/Date reported: 1974 Reference: Davies and Lund 1974; Davies *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s					<i>Culicoides imicola</i> midge vector

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park Study period/Date reported: 1975 Reference: Harthoorn and Young 1976

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Capture related pulmonary hypertension _H	N/A

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park Study period/Date reported: 1975 Reference: Erasmus *et al.* 1978a

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Reovirus _s , (Type 3)					Arthropod vector

^A*E. b. boehmi*

Country and specific location: Tanzania, Loliondo Study period/Date reported: 1975 Reference: Riemann *et al.* 1975

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Toxoplasmosis (<i>Toxoplasma gondii</i>) _s		Fecal contamination of feed and water by wild felids, N/V

^A*E. b. antiquorum*

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1975–1978 Reference: Berry 1981

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _M			Predation _H	Spore ingestion, Insect vectors

^A*E. b. antiquorum*

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1975–1984;
1975–1990 Reference: Turnbull *et al.* 1986; Berry 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C}				Spore ingestion, Insect vectors

^A*E. b. boehmi*

Country and specific location: Northern Tanzania Study period/Date reported: 1977 Reference: Davies and Otieno 1977

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotype 1 Elephants tested positive for AHS _s					<i>Culicoides imicola</i> midge vector

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park Study period/Date reported: 1979 Reference: Erasmus *et al.* 1978b, 1979

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotype 3					<i>Culicoides imicola</i> midge vector

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

C. PLAINS ZEBRAS ... continued

^A*E. b. boehmi*

Country and specific location: Kenya Study period/Date reported: 1981 Reference: Nyaga et al. 1981

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative for PI-3 _s					Aerosol, NV

^A*E. b. antiquorum*

Country and specific location: Namibia Study period/Date reported: 1983 Reference: Daly et al. 1983

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Sarcocystosis (<i>Sarcocystis</i> spp.) _p		Sporocyst ingestion, Sporocyst dispersal by insects possible, NV

^A*E. b. boehmi*

Country and specific location: Kenya, Semi-arid zones Study period/Date reported: 1984 Reference: Davies and Jessett 1985

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AKA _s					Insect vectors likely

^A*E. b. antiquorum*

Country and specific location: Namibia, Etosha National Park Study period/Date reported: 1984–1987 Reference: Turnbull et al. 1989

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C} (Also high prevalence in carnivores)				Spore ingestion, Insect vectors

^A*E. b. crawshayi*

Country and specific location: Zambia, Luangwa Valley Study period/Date reported: 1987 Reference: Mulla and Rickman 1988

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Trypanosomiasis (<i>Trypanosoma brucei</i> <i>rhodesiense</i>) _M		Tsetse fly vector, Zebra can be a natural host for human Trypanosomiasis

^A*E. b. crawshayi*

Country and specific location: Zambia, South Luangwa National Park Study period/Date reported: 1987–1991 Reference: Tuchili et al. 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C,S}				Spore ingestion, Insect vectors

^A*E. b. boehmi*

Country and specific location: Tanzania, Tarangire National Park Study period/Date reported: 1988 Reference: Mbise et al. 1991

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C}				Spore ingestion, Insect vectors

^A*E. b. boehmi*

Country and specific location: Tanzania Study period/Date reported: 1989 Reference: Hamblin et al. 1990

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotypes 1–9; Tested negative _s for FMD, BHV-1, BHV-2, LSD, AKA, BEF, BT					AHS= <i>Culicoides imicola</i> ; Ruminant viruses

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

C. PLAINS ZEBRAS ... continued

E. b. subspecies

Country and specific location: South Africa, Namibia **Study period/Date reported:** 1990 **Reference:** Coetzer and Erasmus 1994b

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
EEV _s (Bryantson, Kyalami Serotypes)					<i>Culicoides</i> vectors likely

^A*E. b. antiquorum*

Country and specific location: Namibia, Etosha National Park **Study period/Date reported:** 1991 **Reference:** Turnbull *et al.* 1992

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Tested negative for Anthrax toxin components (<i>Bacillus anthracis</i>) _s				Spore ingestion, Insect vectors

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park **Study period/Date reported:** 1991–1992 **Reference:** Barnard and Paweska 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
EEV _s , Serotypes 1–7 EHV-1 _s , EHV-4 _s Tested negative _s for EI, EAV					EEV= <i>Culicoides</i> EHV=Inhalation, Direct contact, N/V

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park **Study period/Date reported:** 1991–1992; 1994

Reference: Barnard 1993; Lord *et al.* 1997; Barnard *et al.* 1994a

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _{s/v} Serotypes 1–9					<i>Culicoides imicola</i> midge vector

^A*E. b. boehmi*

Country and specific location: Kenya, Nairobi **Study period/Date reported:** 1992 **Reference:** Binepal *et al.* 1992

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotypes 1–9					<i>Culicoides imicola</i> midge vector

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park **Study period/Date reported:** 1992 **Reference:** Barnard *et al.* 1995

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotypes 1–9 (Low level antibodies against AHS also found in elephants)					<i>Culicoides imicola</i> midge vector

^A*E. b. antiquorum*-*E. b. chapmani* “hybrids”

Country and specific location: Botswana, Chobe ecosystem **Study period/Date reported:** 1992–1994

Reference: Barnard 1997; Osofsky, pers. comm., 1997

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotypes 1–9 EHV-1 _s , EEV _s , WSL _s , AKA _s Tested negative _s for EI, EIA, EAV and BHV-1, BHV-2, MCF, PI-3, LSD, BEF, BT, RVF					AHS= <i>Culicoides imicola</i> EHV-1=Inhalation EEV= <i>Culicoides</i> WSL=Mosquitoes AKA=Insect vectors

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

C. PLAINS ZEBRAS ... continued

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park Study period/Date reported: 1993 Reference: Williams *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s EEV _s					AHS= <i>Culicoides imicola</i> EEV= <i>Culicoides</i> likely

Zebra (*E. b.* subspecies likely)

Country and specific location: South Africa, Kenya, Zimbabwe, Botswana Study period/Date reported: 1993 Reference: Paweska *et al.* 1997

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative for EAV _s (Horses, donkeys, mules positive for EAV _s)					Aerosol, fomites, N/V

^A*E. b. antiquorum*

Country and specific location: South Africa (Ecosystem zones: Woodland; Forest transition; Semi-desert; Cape scrubland)

Study period/Date reported: 1993–1995 Reference: Barnard 1997

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotypes present varied with ecosystems; EHV-1 _s , EEV _s all zones; WSL _s , AKA _s zones N/R; Tested negative _s for EI, EIA, EAV and BHV-1, BHV-2, MCF, PI-3, LSD, BEF, BT, RVF					AHS= <i>Culicoides imicola</i> ; EHV-1=Inhalation EEV= <i>Culicoides</i> WSL=Mosquitoes AKA=Insect vectors EI/EAV=Aerosol, fomites EIA=Insect vectors

E. b. subspecies

Country and specific location: South Africa Study period/Date reported: 1994 Reference: Barnard *et al.* 1994b

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative for WD MCF (AHV-1) _s					Aerosol, ?Vectors

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park (KNP); Namibia, Etosha National Park (ENP) Study period/Date reported: 1994
Reference: De Vos 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Anthrax (<i>Bacillus anthracis</i>) _{M,C} KNP-Epizootic ENP-Sporadic				Spore ingestion, Insect vectors

E. b. subspecies

Country and specific location: Africa (southern) Study period/Date reported: 1994 Reference: Bigalke 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Brucellosis (<i>Brucella abortus</i> , <i>Brucella melitensis</i>) _s				Oral route, Inhalation, In utero, N/V

E. b. antiquorum

Country and specific location: South Africa Study period/Date reported: 1994 Reference: Bigalke and Prozesky 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Besnoitiosis (<i>Besnoitia bennetti</i>) _M		?Vectors Transmission unknown

Table 12.1 ... continued. Reported diseases of free-ranging wild equids.

C. PLAINS ZEBRAS ... continued

Zebra (*E. b.* subspecies likely)

Country and specific location: West, Central and East Africa Study period/Date reported: 1994 Reference: Bigalke 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Trypanosomiasis		Tsetse fly vectors
			(<i>Trypanosoma</i> spp.) _M		

D. PRZEWALSKI'S HORSES Continent of origin: Asia (Extirpated in the wild, currently being reintroduced)

Przewalski's horse

Equus ferus przewalskii

Country and specific location: Mongolia (SW), Tachin Tal Study period/Date reported: 1999–2000 Reference: Walzer *et al.* 2000; Walzer, pers. comm. 2001; Stuewe, pers. comm. 2001

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Possible strangles	(<i>Streptococcus equi</i>)		Babesiosis (<i>Babesia caballi</i>) _{P,S} <i>Babesia equi</i>) _{P,S}		Babesia: Tick vectors: <i>Dermacentor nutalli</i>

E. ASIATIC AND AFRICAN WILD ASSES

Asiatic wild asses **Continent of origin: Asia**

Equus hemionus subspecies (*E. h. hemionus*, *E. h. luteus*, *E. h. kulan*, *E. h. onager*, *E. h. khur*)

E. h. khur

Country and specific location: India Study period/Date reported: 1959 Reference: Caughley and Gunn 1996

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
			Surra (<i>Trypanosoma evansi</i>) _M		Biting flies (Horseflies)

E. h. khur

Country and specific location: India Study period/Date reported: 1960 Reference: Caughley and Gunn 1996

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _S					<i>Culicoides</i> spp. midge vector

Equus kiang subspecies (*E. k. kiang*, *E. k. holdereri*, *E. k. polyodon*)

Information lacking

African wild asses **Continent of origin: Africa**

Equus africanus

Information lacking

Key to disease diagnosis:

Diagnostic test:

C= Culture Results

N= Gross Necropsy Results

M= Microscopic Exam of Blood Smears

S= Serology

V= Virus Isolation

H= History and Clinical Signs

P= Histopathology

E= Exploratory Surgery

^A Equid subspecies surmised from Duncan (1992), based on country and specific location reported.

^B Results not conclusive

Reported vector:

? Vectors= Vectors Unknown

N/V= No Vector

N/A= Not Applicable

N/R= Not Reported

The ruminant diseases listed above have been included because these infectious agents have been tested for in some equid populations.

The significance of positive test results is generally unknown.

1° Equine viral diseases:

AHS= African horse sickness

EEV= Equine Encephalosis Virus

EHV= Equine Herpesvirus

EI= Equine Influenza

EIA= Equine Infectious Anemia

EAV= Equine Arteritis Virus

1° Ruminant viral diseases:

AKA= Akabane Disease

BHV-1= Bovine Herpesvirus 1

BHV-2= Bovine Herpesvirus 2

BEF= Bovine Ephemeral Fever

BT= Bluetongue

RVF= Rift Valley Fever (zoonotic)

LSD= Lumpy Skin Disease

WD MCF= Wildebeest Derived

Malignant Catarrhal Fever

AHV-1= Alcelaphine Herpesvirus 1

(same as WD MCF)

WSL= Wesselsbron Disease

FMD= Foot and Mouth Disease

PI-3= Parainfluenza

BVD= Bovine Viral Diarrhea

1° Human viral diseases:

CCHF= Crimean-Congo Hemorrhagic Fever Virus (zoonotic)

Table 12.2. Reported diseases of captive wild equids.

A. MOUNTAIN ZEBRAS Continent of origin: Africa

Hartmann's mountain zebra

^A*Equus zebra hartmannae*

Country and specific location: England, London Zoo Study period/Date reported: 1956-1976 Reference: Jones 1976

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Colic, Respiratory and Metabolic diseases, Capture myopathy _N	N/R

E. z. hartmannae

Country and specific location: California, San Diego Zoo and Wild Animal Park Study period/Date reported: 1964-1977 Reference: Griner 1978

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Capture myopathy _N	N/A

E. z. hartmannae

Country and specific location: Wisconsin, Vilas Park Zoo Study period/Date reported: 1973 Reference: Decker *et al.* 1975

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Enterolithiasis _N	N/V

E. z. hartmannae

Country and specific location: Czechoslovakia, Zoo of Dvur Kralove Study period/Date reported: 1980 Reference: Mikulicova and Mikulica 1981

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Listeriosis (<i>Listeria monocytogenes</i>) _S				Contaminated feed and water, N/V

^A*E. z. hartmannae*

Country and specific location: Guwahati, Assam State Zoo Study period/Date reported: 1985-1989 Reference: Chakraborty and Chaudhury 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Bacterial Pseudomycosis (<i>Staphylococcus aureus</i>) _C				Wound infections, N/V

^A*E. z. hartmannae*

Country and specific location: Guwahati, Assam State Zoo Study period/Date reported: 1988-1991 Reference: Chakraborty and Sarma 1995

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Enteritis (<i>Escherichia coli</i>) _C				Fecal-oral route, N/V

B. GRÉVY'S ZEBRAS Continent of origin: Africa

Grévy's zebras

Equus grevyi

Country and specific location: England, London Zoo Study period/Date reported: 1956-1976 Reference: Jones 1976

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Injury, Colic, Respiratory and Metabolic diseases, Capture myopathy _N	N/R

E. grevyi

Country and specific location: California, San Diego Zoo and Wild Animal Park Study period/Date reported: 1964-1977 Reference: Griner 1978

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Capture myopathy _N	N/A

Table 12.2 ... continued. Reported diseases of captive wild equids.

B. GRÉVY'S ZEBRAS ... continued

E. grevyi

Country and specific location: Germany, Leipzig Zoo Study period/Date reported: 1974 Reference: Eulenberger *et al.* 1975

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Capture myopathy _p	N/A

E. grevyi

Country and specific location: Czechoslovakia, Zoo of Dvur Kralove Study period/Date reported: 1978 Reference: Koci 1982

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				White muscle disease _{N,P}	N/A

E. grevyi

Country and specific location: Ontario, Canada, Metropolitan Toronto Zoo Study period/Date reported: 1978-1979 Reference: Petric *et al.* 1981

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Rotavirus _s					Fecal-oral route, N/V

E. grevyi

Country and specific location: Czechoslovakia, Zoo of Dvur Kralove Study period/Date reported: 1979-1980 Reference: Mikulicova and Mikulica 1981

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Listeriosis (<i>Listeria monocytogenes</i>) _{C,S}				Contaminated feed and water, N/V

E. grevyi

Country and specific location: Czechoslovakia, Zoo of Dvur Kralove Study period/Date reported: 1981 Reference: Mikulicova *et al.* 1982

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Septicemia and Pneumonia (<i>Klebsiella pneumoniae</i>) _{N,P}				Mares-Venereal Foals-In utero, N/V

E. grevyi

Country and specific location: Illinois, Lincoln Park Zoo Study period/Date reported: 1984 Reference: Wolff *et al.* 1986

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Herpes virus infection and abortion (EHV-1) _{H,N,V}					Virus inhalation, Direct contact, N/V

E. grevyi

Country and specific location: Georgia, Atlanta Zoo Study period/Date reported: 1991 Reference: Dillehay and Silberman 1991

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
		Systemic Phaeohyphomycosis _M			Fungus inhalation, Direct contact, N/V

C. PLAINS ZEBRAS Continent of origin: Africa

Plains zebras

Equus burchellii subspecies

Country and specific location: England, London Zoo Study period/Date reported: 1956-1976 Reference: Jones 1976

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Injury, Metabolic and Respiratory diseases, Colic, Abortion, Dystocia _N	N/R

Table 12.2 ... continued. Reported diseases of captive wild equids.

C. PLAINS ZEBRAS ... continued

E. b. boehmi

Country and specific location: Washington, D.C., National Zoo Study period/Date reported: 1961-1971 Reference: Montali *et al.* 1974

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Neurologic disease: Degenerative Myelopathy _p	N/V

E. b. boehmi

Country and specific location: California, San Diego Zoo and Wild Animal Park Study period/Date reported: 1964-1977 Reference: Griner 1978

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Capture Myopathy _N	N/A

E. b. boehmi

Country and specific location: Canada, Ontario Study period/Date reported: 1972 Reference: Higginson *et al.* 1973

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				White Muscle Disease _p	N/A

E. b. boehmi

Country and specific location: Germany, Leipzig Zoo Study period/Date reported: 1974 Reference: Eulenberger *et al.* 1975

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Capture Myopathy _p	N/A

E. b. subspecies

Country and specific location: New Jersey Study period/Date reported: 1974 Reference: Mayhew *et al.* 1977

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Neurological disease: Degenerative Myeloencephalopathy _p	N/V

^A*E. b. antiquorum*

Country and specific location: South Africa, Kruger National Park Study period/Date reported: 1975 Reference: Erasmus *et al.* 1978a

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Reovirus _s (Type 2)					Arthropod vector

E. b. antiquorum

Country and specific location: Germany, West Berlin Zoo Study period/Date reported: 1975-1976 Reference: Goltenboth and Klos 1989

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Neurologic disease: Degenerative Myeloencephalopathy _p and Vitamin E deficiency _s	N/V

E. b. antiquorum; *E. b. boehmi*

Country and specific location: Germany, Berlin Zoo Study period/Date reported: 1975-1986 Reference: Kahrman *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
EHV-1 _{p,H} (Neurologic form)					Virus inhalation, Direct contact, N/V

Table 12.2 ... continued. Reported diseases of captive wild equids.

C. PLAINS ZEBRAS ... continued

E. b. subspecies

Country and specific location: England, Whipsnade Park Study period/Date reported: 1976 Reference: Ashton *et al.* 1977

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Equine Grass Sickness _p	Etiology unknown

E. b. boehmi

Country and specific location: Alabama, Auburn Study period/Date reported: 1976 Reference: Higgins *et al.* 1977

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Neurologic disease: Neurofibrillary accumulation and degeneration _p	N/V

E. b. subspecies

Country and specific location: Nigeria, Kano Zoo Study period/Date reported: 1978 Reference: Okoh 1980

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Pasteurellosis (<i>Pasteurella multocida</i>) _{N,C}				Stress related, N/V

E. b. boehmi; E. b. antiquorum

Country and specific location: Ontario, Canada, Metropolitan Toronto Zoo Study period/Date reported: 1978-1979 Reference: Petric *et al.* 1981

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Rotavirus _s					Fecal-oral route, N/V

E. b. boehmi; E. b. antiquorum

Country and specific location: Czechoslovakia, Zoo of Dvur Kralove Study period/Date reported: 1980 Reference: Mikulicova and Mikulica 1981

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Listeriosis (<i>Listeria monocytogenes</i>) _s				Contaminated feed and water, N/V

E. b. boehmi

Country and specific location: Japan, Obihiro Zoo Study period/Date reported: 1981 Reference: Taniyama *et al.* 1985

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Ovarian Papillary Cystadenocarcinoma _{N,p}	N/V

E. b. subspecies

Country and specific location: Washington, D.C., National Zoo Study period/Date reported: 1984 Reference: Montali *et al.* 1984, 1985

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Herpes virus myelitis (EHV-1) _{S,H}					Virus inhalation, Direct contact, N/V

E. b. boehmi

Country and specific location: Ohio, Columbus Zoo Study period/Date reported: 1986 Reference: Gardner *et al.* 1986

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Colic: Large Colon Volvulus _E	N/A

Table 12.2 ... continued. Reported diseases of captive wild equids.

C. PLAINS ZEBRAS ... continued

E. b. subspecies

Country and specific location: Spain, Madrid (Movement in 1987 from Namibia) Study period/Date reported: 1987 Reference: Rodriguez *et al.* 1992a, 1992b

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
AHS _s , Serotype 4					<i>Culicoides imicola</i> midge vector

E. b. chapmani

Country and specific location: Czechoslovakia, Zoo of Liberec Study period/Date reported: 1988 Reference: Jurek 1989

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Uterine Torsion and Prolapse _H	N/A

E. b. boehmi

Country and specific location: California, Oakland Zoo Study period/Date reported: 1991-1992 Reference: McDuffee *et al.* 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Colic: Enterolithiasis _E	N/A

Zebra (*E. b.* subspecies likely)

Country and specific location: Zoos: USA, Canada, Australia, Netherlands, Germany Study period/Date reported: 1993 Reference: Paweska *et al.* 1997

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Tested negative for EAV _s (Horses, donkeys, mules tested positive for EAV _s)					Aerosol, fomites, N/V

Zebra (*E. b.* subspecies likely)

Country and specific location: Switzerland Study period/Date reported: 1994 Reference: Weiss *et al.* 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
EAV _s					Aerosol, fomites, N/V

E. b. subspecies

Country and specific location: Tennessee, Knoxville Zoo Study period/Date reported: 1994 Reference: Kennedy *et al.* 1996

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Zebra EHV-1 _s positive; Nearby Thomson's Gazelle with encephalitis tested EHV-1 _{sV} positive					Virus inhalation, Direct contact, N/V

D. PRZEWALSKI'S HORSES Continent of origin: Asia

Przewalski's horse

Equus ferus przewalskii

Country and specific location: England, London Zoo Study period/Date reported: 1956-1976 Reference: Jones 1976

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Injury, Hereditary condition, Capture myopathy, Abortion _N	N/R

E. f. przewalskii

Country and specific location: Germany, West Berlin Zoo Study period/Date reported: 1975-1976 Reference: Goltenboth and Klos 1989

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Degenerative myeloencephalopathy _P and Vitamin E deficiency _S	N/V

Table 12.2 ... continued. Reported diseases of captive wild equids.

D. PRZEWALSKI'S HORSES ... continued

E. f. przewalskii

Country and specific location: Germany, Berlin Zoo Study period/Date reported: 1976-1985 Reference: Kahrmann *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Neurologic disease (EHV-1) _{p,H}					Virus inhalation, Direct contact, N/V

E. f. przewalskii

Country and specific location: England, Whipsnade Park Study period/Date reported: 1976 Reference: Ashton *et al.* 1977

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Equine grass sickness _p	Etiology unknown

E. f. przewalskii

Country and specific location: New York Study period/Date reported: 1977-1983 Reference: Liu *et al.* 1983

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Degenerative myelopathy _p and Vitamin E deficiency _s	N/V

E. f. przewalskii

Country and specific location: NR Study period/Date reported: 1978 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Wobbler (Cervical vertebral malformation)	N/A

E. f. przewalskii

Country and specific location: Germany, Leipzig Zoo Study period/Date reported: 1979 Reference: Elze and Eulenberger 1980

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Abortion, Septicemia: <i>Streptococcus</i> spp.				Oral, Respiratory, Wounds, Umbilicus, N/V

E. f. przewalskii

Country and specific location: England, London Zoo Study period/Date reported: 1980 Reference: Liu *et al.* 1983

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Degenerative myeloencephalopathy _p	N/V

E. f. przewalskii

Country and specific location: Colorado, Denver Zoo Study period/Date reported: 1980 Reference: Cambre 1986

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Abortion and Uterine prolapse _H	N/R

E. f. przewalskii

Country and specific location: NR Study period/Date reported: 1980 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Bronchopneumonia (<i>Pseudomonas</i>) _N				Contaminated feed, Aerosol, N/V

Table 12.2 ... continued. Reported diseases of captive wild equids.

D. PRZEWALSKI'S HORSES ... continued

E. f. przewalskii

Country and specific location: NR Study period/Date reported: 1980-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Abortion, Stillbirth (EHV-1)	Stillbirth: <i>Aeromonas</i> , <i>Enterobacteria</i> , <i>Streptococcus</i> spp.			Abortion, Stillbirth: Enteritis, Stress, Twinning, Cleft Palate, Vitamin E deficiency	N/R

E. f. przewalskii

Country and specific location: New York Study period/Date reported: 1981 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Equine degenerative myelopathy (EDM) _p	N/V

E. f. przewalskii

Country and specific location: NR Study period/Date reported: 1981-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Equine Influenza (EI)					Aerosol, fomites, N/V

E. f. przewalskii

Country and specific location: NR Study period/Date reported: 1981-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Equine Rhinopneumonitis (EHV-1)					Virus inhalation, Direct contact, N/V

E. f. przewalskii

Country and specific location: Europe Study period/Date reported: 1981-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
	Tetanus (<i>Clostridium tetani</i>)				<i>Clostridium tetani</i> spores in wound, N/V

E. f. przewalskii

Country and specific location: 5 Zoos Study period/Date reported: 1981-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Injury (Trauma, Fractures)	N/A

E. f. przewalskii

Country and specific location: 6 Zoos Study period/Date reported: 1981-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Neonatal deaths: Septicemia, Hypothermia from severe weather, Pneumonia, Enteritis, Stillbirth, Vitamin E deficiency, Injury from other horses	N/R

E. f. przewalskii

Country and specific location: Germany; New York Study period/Date reported: 1981-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Euthanasia for Geriatric problems	N/A

Table 12.2 ... continued. Reported diseases of captive wild equids.

D. PRZEWALSKI'S HORSES ... continued

E. f. przewalskii

Country and specific location: California, San Diego Wild Animal Park Study period/Date reported: 1982-1983 Reference: Ryder and Massena 1988

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Male Infanticide _{H,N}	N/A

E. f. przewalskii

Country and specific location: Washington, D.C., National Zoo Study period/Date reported: 1982-1984 Reference: Montali *et al.* 1985

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Herpes virus infection (EHV-1) _S					Virus inhalation, Direct contact, N/V

E. f. przewalskii

Country and specific location: Minnesota Zoo; New York Study period/Date reported: 1982-1989 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Colic: Intussusception, Torsion, Volvulus _N	N/A

E. f. przewalskii

Country and specific location: NR Study period/Date reported: 1986 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Meningoencephalitis, Enterocolitis _N	N/R

E. f. przewalskii

Country and specific location: California; New York Study period/Date reported: 1986-1988 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Laminitis	N/A

E. f. przewalskii

Country and specific location: California Study period/Date reported: 1987-1988 Reference: Houpt 1994

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
		Coccidiomycosis (Coccidioides immitis) _N			Inhalation of fungal spores, N/V

E. f. przewalskii

Country and specific location: NR Study period/Date reported: 1993 Reference: Anderson *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Degenerative joint disease _N , Subclinical lumbar polyradiculopathy _P	N/A

E. ASIATIC AND AFRICAN WILD ASSES

Asiatic wild asses **Continent of origin: Asia**

Equus hemionus subspecies (*E. h. hemionus*, *E. h. luteus*, *E. h. kulan*, *E. h. onager*, *E. h. khur*)

E. h. onager

Country and specific location: England, London Zoo Study period/Date reported: 1956-1976 Reference: Jones 1976

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Injury, Colic, Respiratory disease, Capture myopathy, Septicemia _N	N/R

Table 12.2 ... continued. Reported diseases of captive wild equids.

E. ASIATIC AND AFRICAN WILD ASSES ... continued

E. h. subspecies

Country and specific location: NR Study period/Date reported: 1972 Reference: Pohle 1978

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Trauma _H (Primary cause of mortality reported from international zoos)	N/A

E. h. onager

Country and specific location: Germany, Berlin Zoo Study period/Date reported: 1981 Reference: Kahrmann *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Neurologic disease: EHV-1 _{P,H}					Virus inhalation, Direct contact, N/V

E. h. onager

Country and specific location: Washington, D.C., National Zoo Study period/Date reported: 1984 Reference: Montali *et al.* 1985

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
Abortion: EHV-1 _{V,S}					Virus inhalation, Direct contact, N/V

E. h. onager

Country and specific location: NR Study period/Date reported: 1993 Reference: Anderson *et al.* 1993

Reported Diseases/Conditions, Vectors and Transmission

Viral	Bacterial	Fungal	Protozoal	Other diseases or conditions	Disease transmission and vector reported
				Trauma _N , Subclinical lumbar polyradiculopathy _P	N/A

Equus kiang subspecies (*E. k. kiang*, *E. k. holdereri*, *E. k. polyodon*)

Information Lacking

African wild asses Continent of origin: Africa

Equus africanus

Information lacking

Key to disease diagnosis:

Diagnostic test:

C= Culture Results
N= Gross Necropsy Results
M= Microscopic Exam of Blood Smears
S= Serology
V= Virus Isolation
H= History and Clinical Signs
P= Histopathology
E= Exploratory Surgery

^A Equid subspecies surmised from Duncan (1992), based on country and specific location reported.

^B Results not conclusive

Reported vector:

? Vectors= Vectors Unknown
N/V= No Vector
N/A= Not Applicable
N/R= Not Reported

The ruminant diseases listed above have been included because these infectious agents have been tested for in some equid populations. The significance of positive test results is generally unknown.

1° Equine viral diseases:

AHS= African horse sickness
EEV= Equine Encephalosis Virus
EHV= Equine Herpesvirus
EI= Equine Influenza
EIA= Equine Infectious Anemia
EAV= Equine Arteritis Virus

1° Ruminant viral diseases:

AKA= Akabane Disease
BHV-1= Bovine Herpesvirus 1
BHV-2= Bovine Herpesvirus 2
BEF= Bovine Ephemeral Fever
BT= Bluetongue
RVF= Rift Valley Fever (zoonotic)
LSD= Lumpy Skin Disease
WD MCF= Wildebeest Derived
Malignant Catarrhal Fever
AHV-1= Alcelaphine Herpesvirus 1
WSL= Wesselsbron Disease
FMD= Foot and Mouth Disease
PI-3= Parainfluenza
BVD= Bovine Viral Diarrhea

1° Human viral diseases:

CCHF= Crimean-Congo Hemorrhagic Fever Virus (zoonotic)

on the diseases affecting wild equids is also provided. In addition, selected references regarding equine medicine, surgery, and reproduction can be found in Appendix 4. Local and/or regional veterinary authorities, the Office International des Epizooties (OIE), as well as the IUCN

Species Survival Commission (SSC) Veterinary Specialist Group (VSG) and the Reintroduction Specialist Group (RSG) should be consulted when specific veterinary questions arise during project design, implementation, or monitoring.

12.2 Wild populations and disease

The fundamental strategy for single-species conservation involves reducing a population's risk of going extinct while minimising the population's loss of genetic diversity. Loss of genetic variation may result in decreased resistance to disease. Disease is one contributor to the financial, genetic, and demographic risks facing conservation programs, and must be considered when conservation strategies are developed (Ballou 1993). Population viability analysis, a form of modelling that assesses the probability of extinction and the loss of genetic diversity over time, can be used to evaluate risks facing small populations. Models can be used to evaluate ecological processes and to assess these risks – including those risks related to infectious disease. Note that the IUCN SSC Conservation Breeding Specialist Group (CBSG) has been investigating novel options for disease risk assessment (Armstrong and Seal 2000). The most important and catastrophic disease risks are epizootics, which can result from the transmission of local agents or from the introduction of novel or emergent diseases (Ballou 1993; Daszak *et al.* 2000). Epizootics and other disease occurrences can affect the long-term viability of a population by reducing survival and reproduction, and/or by increasing susceptibility to predators and various forms of stress (Ballou 1993).

Lyles and Dobson (1993) stressed the importance of host-parasite relationships in the management of wildlife populations:

“Outbreaks of infectious diseases can ruin conservation programs. Biologically diverse parasites will never be entirely eliminated from intensively managed wildlife. Rather, one of the great challenges facing conservation biologists is to learn how to manage the natural and healthy relationship between parasites and their hosts.”

Thus, one must also recognise the value of conserving biodiverse equine-specific parasites. To conserve the remaining equids, their genetic diversity, and their relationship with the diverse array of parasites with which they have evolved, two new approaches offer promise. One involves developing economic, social, and political linkages that encourage local people to participate in and benefit from the conservation of wildlife (Duncan 1992; Osofsky 1997). The second encompasses managing fragmented populations of equids using modern genetic and demographic principles (Duncan 1992). Metapopulation management, where subpopulations exist in geographically distinct areas yet are managed via exchange of individuals, will likely become a critical strategy for wild equid conservation. These subpopulations are managed together as one large genetic unit, thus maintaining genetic diversity (Ballou 1993). However, these subpopulations may be very different with regard to

disease epidemiology and must be managed accordingly. The benefits, thus, have potential costs: the translocation of animals increases the risks of moving diseases among populations. Yet, with a thorough knowledge of disease epidemiology and control, these risks are potentially manageable (Ballou 1993).

12.3 Management implications

12.3.1 Disease testing considerations

Diagnostic testing plays an important role in monitoring the health of captive and free-ranging wildlife populations (Gardner *et al.* 1996). For wild species, a variety of tests is used to identify the agent(s) involved in disease in individuals and populations, as well as to detect exposure to agent(s). Such tests are critical epidemiological tools, providing information on the prevalence of disease, the status of infections in populations, risk factors for disease, and the probability of disease transmission between wildlife and domestic species, as well as between wildlife and humans (Gardner *et al.* 1996).

Serological testing (the measurement of serum antibody against microorganisms) is the most frequently used diagnostic test in wildlife. Serology allows for discrimination between exposed and non-exposed animals, and sometimes for differentiation between actual infection, resolved infection, and vaccine-induced seroconversion (Worley 1993). Several serological tests are available to detect antibodies to African horse sickness (AHS), for example. Serogroup-specific tests for AHS virus isolates include complement fixation (CF), agar-gel immunodiffusion (AGID), direct or indirect immunofluorescence (IFA), and enzyme-linked immunosorbent assay (ELISA), while specific serotypes are identified by virus neutralisation (VN) (Williams *et al.* 1993; Coetzer and Erasmus 1994a). ELISA tests have been developed, for example, to selectively differentiate between two orbiviruses (AHS and equine encephalosis (EEV) viruses) that infect equids (Williams *et al.* 1993). In addition, the ELISA test (as a quantitative serological tool for the detection of antibodies against AHS) has been shown to be superior to the CF test with regards to sensitivity and specificity (Williams 1987). Most serologic tests used in wildlife species have been directly transposed, without validation, from use in domestic species. These tests may not perform identically in wildlife (Gardner *et al.* 1996). Note that most tests do not provide 100% accuracy for disease diagnosis, and thus test interpretation requires knowledge of assay sensitivity and specificity. For many serologic tests, such information is lacking in wildlife veterinary medicine. This information would improve estimates of disease prevalence, would help in assessing the risk of disease transmission, and would

facilitate management decisions regarding animal translocations (Gardner *et al.* 1996).

Isolating pathogens is essential to understanding them. Culture techniques utilising selective media have proven very successful for the detection of most bacterial and fungal organisms in domestic and wild animals (Worley 1993). New advances in molecular biology have led to the development of new diagnostic tests, such as the polymerase chain reaction (PCR), which utilises DNA probes for the rapid detection and identification of infectious agents directly from clinical specimens (Worley 1993; Coetzer and Erasmus 1994a). DNA probes may be the only diagnostic method of detection for viruses that replicate slowly, establish persistent infections, express low levels of antigen, or incorporate into the host genome (Worley 1993).

12.3.2 Disease control recommendations

In this section, we focus on southern Africa for illustrative purposes. Animal disease research in this region has been relatively comprehensive. We use diseases such as African horse sickness and anthrax to illustrate some of the basic epidemiological principles of importance to wildlife managers around the world. These principles are particularly important as pressures at the wildlife/livestock interface continue to balloon.

The control of infectious diseases is based upon an understanding of disease epidemiology (Swanepoel 1994a). Information on disease distribution, hosts, vectors, modes of transmission, carrier states, and pathogenicity is essential for the design, implementation, and monitoring of conservation plans (Swanepoel 1994a). The wild species of southern Africa, for example, have been adapting over millions of years to their environments and to the myriad of infectious agents and parasites of this region. As such, they have acquired natural resistance to these indigenous diseases and often serve as carriers of disease or as readily available maintenance hosts (Bigalke 1994).

Vectors play a key role in the spread and maintenance of many diseases affecting domestic and wildlife species in southern Africa and elsewhere (Norval 1994; Phelps and Lovemore 1994; Nevill 1994; Nevill *et al.* 1994; Meiswinkel *et al.* 1994; Jupp 1994; Bengis 2002a; Bengis 2002b). The control of arthropod-borne viruses (arboviruses), such as AHS, may be directed at the susceptible vertebrate species, the vertebrates that serve as maintenance or intermediate hosts of the virus, and the arthropod vectors (Swanepoel 1994a). As presented in tables 12.1 and 12.2, *Culicoides* midge vectors are important in the transmission of AHS and EEV viruses in equids, for example. The eradication of many vectors, including *Culicoides*, is impossible because adults occur in large numbers and their larval habitats are widespread (Meiswinkel *et al.* 1994). Thus, disease prevention is directed at lowering the chances of domestic

animals becoming infected. Such methods include vaccination of domestic equids at an early age to induce herd immunity, stabling of susceptible animals at night when *Culicoides* species are most active, and avoidance of moist, low-lying areas during times of peak midge activity (Meiswinkel *et al.* 1994).

Other vectors of concern for domestic equids in southern Africa include, for example, ticks (e.g. babesiosis), tsetse flies (trypanosomiasis), and tabanid flies (e.g. equine infectious anaemia, anthrax). Acaricides and vaccines can be used in the control of ticks and tick-borne diseases (Norval 1994). In general, trypanosomiasis control includes vector control or elimination, the use of trypanotolerant livestock, and administration of curative and prophylactic drugs (Phelps and Lovemore 1994). Tabanid control encompasses the use of insect traps or insecticide treatment of animals (Nevill *et al.* 1994). Control of vectors has historically involved selective clearing and drainage of land to reduce survival of hematophagous arthropods (Swanepoel 1994a). In addition, larvicidal treatments have been applied to water where vectors breed. The measures outlined above come from literature describing efforts to control disease in domestic animals. We do not necessarily endorse particular methods in this chapter, and recognise that most wild animals have adapted to living with native parasites. Particularly when the widespread use of insecticides is being considered, environmental consequences should be carefully assessed beforehand, with a “first, do no harm” perspective taken in regards to ecosystem health.

The most practical method for controlling many diseases in domestic and wildlife species, especially diseases caused by arboviruses, is the protection of susceptible vertebrate species through vaccination (Swanepoel 1994a). Vaccines are designed to protect susceptible animals against infectious diseases by stimulating immune responses. Viral vaccines are generally more effective than bacterin or anti-parasite vaccines because the proteins used are smaller. Herd immunity is the immunologically-derived resistance of a population to an infectious agent, either from natural infection or immunisation (Van Dijk *et al.* 1994). Mathematical modelling can be used to determine the level of herd immunity required in a population depending on the primary objective (e.g. protecting individuals, controlling diseases, eradicating diseases) (Van Dijk *et al.* 1994).

Vaccines are commercially available for many of the viral diseases of equids (e.g. AHS, EI, EHV, rabies), as well as for several bacterial diseases (e.g. anthrax, tetanus, botulism) (Van Dijk *et al.* 1994). Except for tetanus and botulism, where immunity is directed at the toxins these bacteria produce, these vaccines are directed against the infectious agent. Several vaccines have inherent problems of efficacy. For example, some AHS vaccines do not stimulate immune responses to all of the serotypes of the

virus (Swanepoel 1994a). Attenuated vaccine containing only serotypes 1 to 6 failed to induce adequate cross-immunity to serotypes 7 to 9 of the virus (Blackburn and Swanepoel 1988a, 1988b). The recommended control measures for many diseases affecting wild equids, as mentioned previously, can be obtained from current literature, local or regional veterinary authorities, IUCN SSC, and the OIE (IUCN 1998; Woodford 2001). To be clear, the authors are not advocating the routine vaccination of wild equids! The IUCN SSC Veterinary Specialist Group (Woodford 2001) states:

“The question of the desirability of vaccination prior to release should be carefully considered and the decision whether or not to immunise the animals to be released should be made by the attending veterinarian after evaluating the immunological status of the animals held in quarantine, and the likely challenge by enzootic and exotic disease agents upon release....

It might be argued that immunisation of translocated animals against enzootic diseases in the release environment is contra-indicated because they would thus be afforded an unfair selective advantage over the resident wildlife. However, this is not necessarily the case, because the resident wildlife would probably have been challenged under natural conditions when young, while under partial protection through colostral immunity, and would presumably have acquired a solid immunity later. In addition, usually only the founder generation of translocated animals would receive vaccine protection.

It is important to remember that some of the potential pathogens...which may occur in a release area are as much a part of the environmental biodiversity as are the animals to be released and have exerted selective pressures on unvaccinated wildlife for a very long time.”

Perhaps the most important viral disease of zebras is African horse sickness – the majority of the literature focusing on common (plains) zebras because of the vector-friendly habitat they often occupy. African horse sickness is an acute to subacute systemic illness of horses and other equidae (Coetzer and Erasmus 1994a). The virus is transmitted biologically by insects of the *Culicoides* genus. Four classic forms of the disease have been described: pulmonary, cardiac, mixed, and mild. The most common form is mixed, with malfunction of the pulmonary and cardiac systems secondary to loss of vascular integrity. Horses are the most susceptible, with mortality rates approaching 100%. Mules and donkeys are less susceptible, and zebras are the most resistant (Coetzer and Erasmus 1994a). Zebras do not develop clinical disease following infection with AHS virus; this resistance to disease

probably resulted from thousands of years of evolution with the virus and the process of natural selection. Other mammals, including camelids, bovids, African elephants, domestic dogs, and many free-ranging African carnivores have been found positive for AHS antibodies or virus, although the role of these non-equid hosts in the epidemiology of the disease is unknown (Alexander *et al.* 1995). Concerns regarding AHS relate to its potentially devastating effects on domestic horses. Following the outbreak of a viral disease, such as AHS, strong preventive measures must be enforced to limit further transmission of the virus. The specific control measures for AHS, for example, include:

- Establishing a complete ban on the movements of all susceptible animals, especially equids. According to OIE rules, no equids should be allowed to leave the region for a period of two years;
- Protecting equids against vectors by stabling the equids under fine mesh at night, eliminating vector breeding sites, using insecticides and insect repellents;
- Euthanising or immediately isolating all sick animals that may act as a source of virus for transmission of the disease;
- Providing mandatory, immediate vaccination of all domestic equids. In the event of an epizootic, begin vaccinating with an attenuated polyvalent AHS vaccine;
- Identifying the virus serotype(s) responsible for the outbreak, and administering the appropriate monovalent vaccine(s) to induce solid, durable immunity; and
- Notifying the OIE immediately of all cases of the disease.

(Sources: Rodriguez *et al.* 1992a; Rodriguez *et al.* 1992b; Bosman 1994; Coetzer and Erasmus 1994a; Bosman *et al.* 1995.)

Importantly, since the duration of viremia in zebras infected with AHS virus ranges from 11–30 days, the importation of zebras into countries free of AHS should be considered cautiously, and preferably be restricted to serologically negative zebra (Barnard 1994; Barnard *et al.* 1994a). Note that the incubation period between vector bite and sero-conversion can be over two weeks (4–17 days) in zebras, a serious consideration when establishing the duration of quarantine periods.

The control of bacterial diseases of domestic and wild equids is equally crucial. The most important bacterial disease actually affecting wild zebra populations, for example, is anthrax (*Bacillus anthracis*). Anthrax is an acute, febrile disease of most warm-blooded animals characterised by severe vascular damage, usually with a rapidly fatal course (De Vos 1994). The bacteria form spores when exposed to air and can persist in an organism-spore-organism cycle for years. Transmission is via contact with infective spores, and in horses the most prominent

clinical feature of the disease is often colic (De Vos 1994). A summary of the several control measures for anthrax follows for illustrative purposes. A live, avirulent spore vaccine developed in South Africa provides the major method of anthrax control throughout the world (De Vos 1994). The Sterne vaccine is non-pathogenic in domestic and many wild animal species, providing effective immunity within one week of vaccination in some species (it may take up to four weeks or more in horses) that generally lasts for nine months in domestic animals. However, the yearly inoculation of susceptible wildlife populations against anthrax is generally prohibitively expensive, time-consuming, and impractical (Berry 1993).

When an anthrax carcass is opened, the bacteria that are exposed to air form spores that are resistant to the extremes of temperature, chemical disinfection and desiccation. Thus, to prevent sporulation of *Bacillus anthracis*, carcasses should not be opened. The recommended procedure for disposal is burning, or burial of the carcass to a depth of two metres and then covering it with a specific mixture of chloride of lime (De Vos 1994). High concentrations of chemicals such as formaldehyde, glutaraldehyde, hydrogen peroxide, or peracetic acid are useful to inactivate spores; the World Health Organisation (WHO) has established guidelines for the disinfection of *Bacillus anthracis* material (De Vos 1994).

In the event of an outbreak of anthrax in domestic animals, the following control measures are indicated (De Vos 1994):

- Vaccinate all livestock and game animals on the premises (when possible);
- Isolate exposed animals under authorised veterinary supervision for two weeks after vaccination;
- Euthanise and dispose of infected animals under supervision. Treatment of valuable animals in the early stages of infection can be attempted with appropriate antibiotics.

Anthrax has almost been eliminated from domestic animals in South Africa with the above methods, yet the disease is still a major threat to wildlife populations. Disease is often a natural ecological factor that, in many cases, can control populations as predation does. In Namibia's Etosha National Park, for example, anthrax is considered to be a major population-limiting factor in several plains ungulates (Ebedes 1977; Berry 1981, 1993; Turnbull *et al.* 1986, 1989, 1992; Lindeque and Turnbull 1994; Gasaway *et al.* 1996). According to Young (1973) and De Vos (1994), herd animals such as common zebra (*Equus burchellii*), blue wildebeest (*Connochaetes taurinus*), and African buffalo (*Syncerus caffer*) can be boma-captured and vaccinated (with some difficulty) from the sides of a crush. De Vos *et al.* (1973) developed an aerial method of immunising free-ranging roan antelope (*Hippotragus equinus*) against anthrax in the Kruger National Park,

South Africa that may be applicable to wild equids. Introducing avirulent spores into water supplies as a method of oral vaccination has been investigated as another alternative for mass inoculation, although the immunity is short-lived (Ebedes 1977).

In addition to immunisation, anthrax control in wildlife depends upon the elimination of sources of infection through application of the following management practices (De Vos 1994):

- Fencing-off known anthrax hot-spots;
- Instituting a continuous surveillance system to detect outbreaks early;
- Locating and incinerating carcasses immediately to prevent their destruction by scavengers, and subsequent dispersal of spores;
- Replacing natural waterholes with concrete drinking troughs if intermittent disinfection is considered a realistic possibility;
- Fencing-off open waters that have been infected by vultures; and
- Preventing contamination of drinking water by vultures by erecting branch barriers.

The anthrax control methods listed above are considered temporary measures that cannot effectively eliminate anthrax permanently. The long-term control of anthrax should be directed at improving management practices. Improving the quality of vegetation and eliminating contaminated artificial water supplies will force migrating animals to move out of enzootic areas, thus preventing overcrowding and reducing disease transmission (Ebedes 1977).

12.3.3 Disease transmission and reintroduction

All wild equids destined for translocations, re-introductions, or other movements should undergo pre-shipment (and often post-shipment) quarantine procedures (Young 1973). When wildlife managers are considering such movements of wild equids, the following advice from Woodford and Rossiter (1993) should be heeded:

“Each case must be separately evaluated, taking into account all biological, ecological, geographical, and epidemiological circumstances. Only then will the inherent risks in moving potential ‘disease packages’ across the world be minimised, and the chances of failing to establish a healthy new wild population significantly reduced.”

Quarantine periods for wild equids should be established for a minimum of 30 days. In addition to visual and physical examination (when possible) and evaluation of any observed abnormalities, disease screening for wild equids in quarantine should include a protocol similar to

the following, based on recommendations for domestic equids (Woodford and Rossiter 1993; Phillips 1999; Woodford 2001). Note that movement of non-domestic equids from *ex situ* captivity (for example – in a North American zoo) back to an area within their natural range would mandate screening for diseases known to occur in the region of captivity (Wolff and Seal, 1993). Such diseases (such as the equine encephalitides of the family Togaviridae) are not necessarily discussed in this chapter.

Recommended biomedical precautions to be taken:

- Clinical haematology testing (complete blood count, serum chemistry profile, haematocrit);
- Bacterial cultures as indicated, such as for contagious equine metritis (*Tylorella equigenitalis*);
- Urinalysis, if feasible;
- Fecal examination for endoparasites;
- Fecal larval culture (especially for lungworm);
- Baermann tests for lungworm larvae (especially for wild asses);
- Serological tests: for example-African horse sickness (VN), equine encephalosis virus (VN), equine infectious anaemia (AGID), equine arteritis virus (VN), equine herpes viruses (CF), equine influenza (hemagglutination inhibition) (HI), glanders (*Pseudomonas mallei*) (CF), dourine (*Trypanosoma equiperdum*) (CF); West Nile virus (consult relevant authorities);
- Viral isolation, as indicated;
- Blood smears for haemoparasites (*Babesia* spp., *Besnoitia bennetti*) (Perform serology on animals with negative blood smears);
- Buffy coat smears for trypanosomes (*Trypanosoma brucei*, *Trypanosoma evansi*) (Perform ELISA test for negative samples);
- Ectoparasite checks (treat if necessary);
- Treatment for endoparasites;
- Vaccination of equids based on local and regional disease concerns, (such immunisations may include, but are not limited to: African horse sickness, rabies, tetanus, anthrax, equine influenza, equine herpes viruses, equine encephalomyelitis, strangles, and botulism). Killed vaccines are generally safer than modified-live vaccines, given that commercial vaccines are tested and approved for domestic equids;
- Collection and freezing of labelled serum and tissue samples; and
- Permanent identification of animals by ear tag, tattoo, and/or microchip.

For an example of a “real world” approach to equid disease screening and monitoring, see Walzer *et al.* (2000): the authors present a summary of current veterinary issues surrounding Przewalski’s horse reintroduction to Mongolia.

12.3.4 Summary and future conservation priorities

As wild animal populations diminish and the urgent need to conserve them intensifies, the importance of disease in wildlife populations becomes more obvious (Pastoret *et al.* 1988; Hutchins *et al.* 1991; Ballou 1993; Kirkwood 1993; Lyles and Dobson 1993; Meltzer 1993; Woodford 1993; Woodford and Rossiter 1993; Wolff and Seal 1993; Gull and 1995; Cunningham 1996; Daszak *et al.* 2000; Bengis 2002a; Bengis 2002b). Infectious agents can exert important effects on host population dynamics. Before control of diseases in wildlife is possible, there is a need for increased understanding of the dynamics of infections in wild and domestic animal populations. Detailed field studies are required if one hopes to determine the distribution of diseases in wild animal populations and to elucidate interactions between the environment, host genetics, and immune responses (Gulland 1995). Collaboration between domestic animal health authorities and wildlife management agencies can only enhance surveillance efficiency. Thorough postmortem examination and sample collection protocols (Woodford 2000) must be part of any endangered species recovery project. If nothing else, readers of this chapter’s text and tables should note how much our current understanding of animal disease depends on thorough necropsy efforts (and pathologists). The involvement of veterinarians and other wildlife disease experts in field investigations of disease outbreaks and/or mortality events is therefore paramount.

Securing solutions to conservation problems facing wild animals and their habitats will require careful multidisciplinary work (Karesh *et al.* 2002). With the remaining populations of most wild equids under threat, their survival will certainly depend on careful management, and the veterinary implications of this reality will be enormous (Hutchins *et al.* 1991).

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Ecosystem Modelling in Support of the Conservation of Wild Equids – the Example of the Pryor Mountain Wild Horse Range¹

Michael B. Coughenour

13.1 Introduction

It is widely recognised that individual species cannot be conserved without also conserving ecosystems (Samson and Knopf 1996). The concept of ecosystem management embodies this principle, as well as recognising the importance of sustainability, ecological change, spatial and temporal scale, interconnectedness, humans as components of ecosystems, and appropriate ecological models (Christensen *et al.* 1996). The conservation of wild equids, in particular, depends on the principles of ecosystem management. Three of the seven surviving species of equids are threatened with extinction – one is vulnerable, and one is extinct in the wild (IUCN 1996). Their conservation requires careful management to increase remaining populations, and reintroductions into ancestral habitats where viable habitats still exist (Duncan 1992). There is a pressing need for an assessment methodology that explicitly considers the role of horses in ecosystems and the ecological processes necessary for ecosystem viability.

According to an Ecological Society of America report, “ecosystem management should be rooted in the best current models of ecosystem function” (Christensen *et al.* 1996). It has long been recognised that grazing ecosystems function and change as a result of complex interacting processes of plant growth, nutrient cycling, herbivory, and the site water balance (e.g. McNaughton *et al.* 1982; Archer and Smeins 1991; Frank 1998). Simulation models have been constructed to represent these processes and their interactions for nearly three decades. Until relatively recently, however, ecosystem models have been aspatial, representing a mean or aggregate ecosystem response. This has severely limited their application to ecosystems comprised of expansive and heterogeneous landscapes and mobile populations of herbivores – typical characteristics of free-ranging equid ecosystems. Now, however, we have the capability to construct spatially explicit models of ecosystems, which represent many points in space and the movements of organisms among those points (Coughenour 1991). These models can be used to assess the role of equids

in ecosystems, the potential of ecosystems to support equids, and the effects of human-induced changes to ecosystems on the viability of equid populations.

This chapter demonstrates how a spatial ecosystem model can be used to assess a wild horse population and its habitat. Ecosystem modelling has been used to support the management of wild horses (*Equus caballus*) on the Pryor Mountain Wild Horse Range (PMWHR) in southern Montana (Coughenour 1999, 2000). The PMWHR is the first officially designated wild horse range in the US, established in 1968. The Bureau of Land Management (BLM) is responsible for the maintenance of a “thriving ecological balance” on the PMWHR and has deemed it necessary to conduct periodic management removals of wild horses since 1970 to halt and prevent further range degradation (US BLM 1997). The PMWHR horse herd is not an ordinary band of runaways, but is a unique genetic strain with ancestry likely going back to the first Spanish reintroductions (Gregerson 1973; Ryden 1990; Sponenberg 1997). They have probably inhabited the PMWHR for at least a century, and there is historical evidence that they are descendants of horses used by the Crow or Shoshone tribes of Native Americans (Ryden 1990; Brownell 1999).

13.2 Site description

The PMWHR straddles the border between southern Montana and northern Wyoming. It lies approximately 80km due south of Billings, Montana. The range of the Pryor Mountain wild horses includes lands designated as the PMWHR in the 1968 enactment, and lands used by horses under agreement or lease with other government agencies or private landholders (Figure 13.1). The PMWHR lands include portions of the Bighorn Canyon National Recreation Area (BCNRA), administered by the National Park Service, and lands administered by the BLM. Additional lands used under prior agreement include the Lost Water Canyon allotment of the Custer National Forest (US Forest Service [USFS]), and the Mystic allotment comprised of private and BLM lands. The

1. Some of the material contained in this report is taken from (Coughenour 1999, 2000), and is in journal publications. Please contact the author for further information.

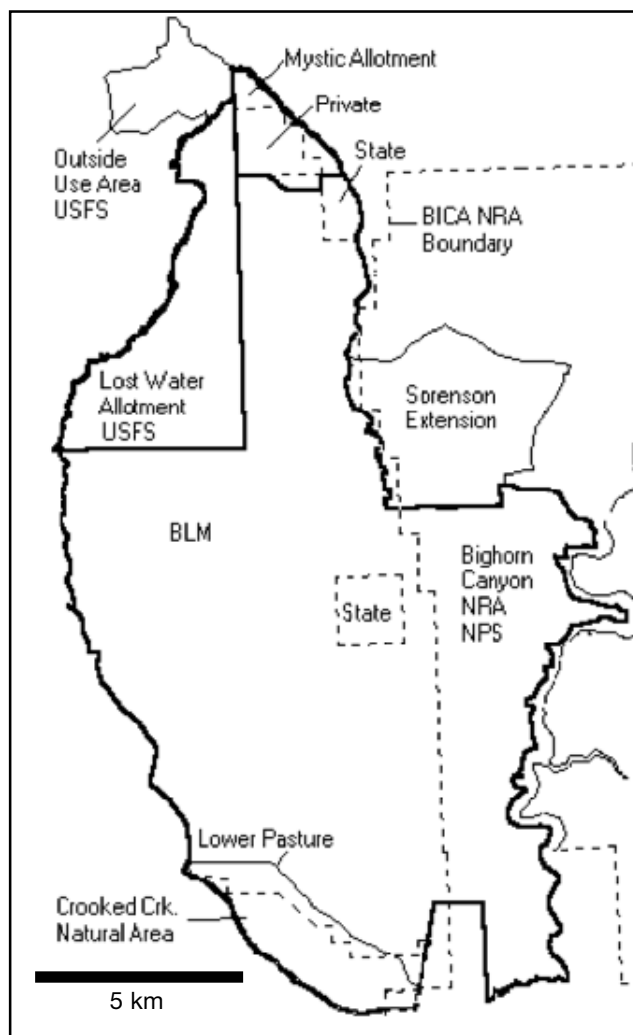


Figure 13.1. Lands used by horses under agreement or lease with other government agencies or private landholders.

Sorenson Extension of the BCNRA has been used by horses in the past under agreement. Additional lands are leased from the state of Montana. The Crooked Creek Natural Area is a Federal protective withdrawal area (BLM), and is not available to horses.

The climate of the PMWHR is temperate continental, with cold winters and warm summers. Mean annual precipitation at Lovell, Wyoming, from 1948 to 1996 was 170mm, with a standard deviation of 37mm. The PMWHR landscape is topographically diverse. Elevations range from 1,200–2,400m. A prominent feature of the landscape is the steep-walled escarpment that runs north and south, rising dramatically above the lower elevation plains and bajadas below. The landscape is characterised by deep, steep-walled canyons, isolated plateaus, and foothill slopes.

The vegetation of the PMWHR is diverse, due to the large elevation and associated climatic gradient, but also due to the wide variety of soils and substrates, and patterns

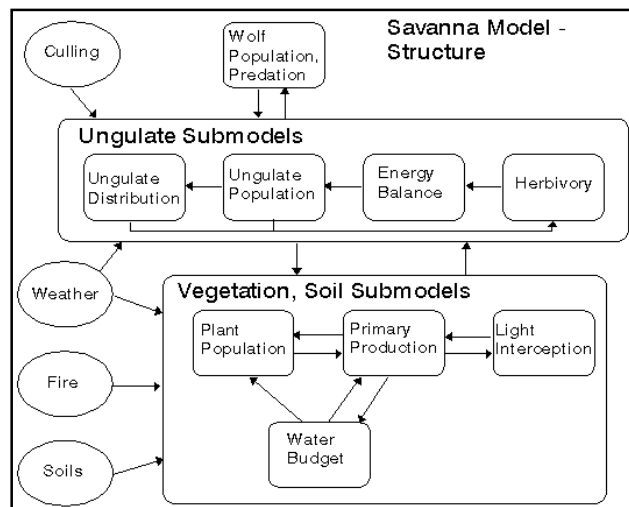
of water redistribution on the landscape. Vegetation types include desert shrublands at lowest elevations, sagebrush grasslands, several grassland types spanning all elevations, juniper and curl-leaf mountain mahogany woodlands at low to mid elevations, and coniferous forests at the higher elevations.

13.3 The ecosystem model

An ecosystem simulation model called SAVANNA (Coughenour 1992, 1993) was used to represent ecosystem dynamics and interactions on the PMWHR landscape. The model is comprised of submodels of site water balance, plant biomass production, plant population dynamics, litter decomposition and nitrogen cycling, ungulate herbivory, ungulate spatial distribution, ungulate energy balance, and ungulate population dynamics (Figure 13.2). Ecosystem simulation models consist of mathematical equations that describe changes and interactions within the ecosystem, while maintaining consistency with fundamental principles such as the conservation of matter and energy and fundamental biological attributes of organisms and populations. The SAVANNA model is capable of simulating grassland, shrubland, savanna, and forested ecosystems. It simulates landscape processes through regional spatial scales over annual to decadal time scales. Typically, the landscape is divided into 5,000–10,000 square grid-cells (Figure 13.3). A grid-cell size of 500×500m was used in the PMWHR simulations. The model simulates ecosystem processes on each of these grid-cells, including water and nutrient balances, plant growth, and herbivory.

SAVANNA uses monthly weather station data as basic input to its hydrological submodel. Precipitation data from the weather stations are spatially interpolated

Figure 13.2. The SAVANNA ecosystem simulation model.



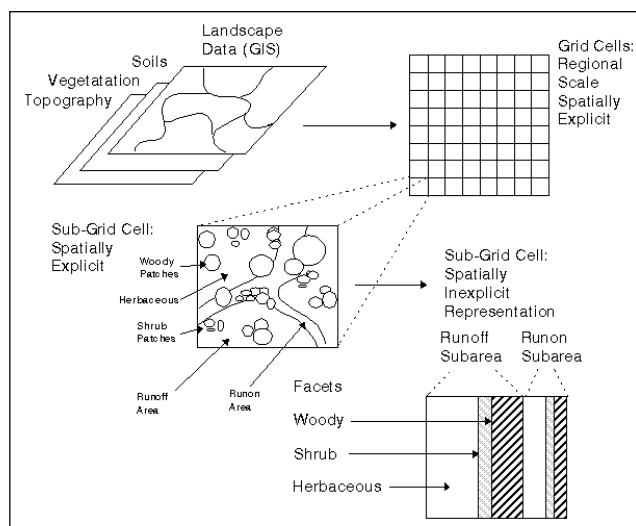


Figure 13.3. In SAVANNA the landscape is divided into 5,000–10,000 square grid-cells.

to create monthly precipitation maps. The interpolation scheme corrects for elevation differences between the weather stations and the grid-cells. The water balance submodel then simulates soil moisture dynamics and use on each grid-cell. A soils map is read into the model upon initialisation. By knowing the water holding capacity of each soil type, the model can use the map to determine soil water-holding capacities of each grid-cell. The water budget for each grid-cell includes terms for precipitation, interception by leaves and detritus, runoff, runon, infiltration to subsurface layers, deep drainage losses, bare soil evaporation, root water uptake, and transpiration losses from leaves.

The net primary production (NPP) submodel simulates plant biomass production and dynamics. Plant biomass production is affected by light, water, temperature, nitrogen, and herbivory. This submodel is explicitly linked to the water budget submodel through transpiration and plant water use. Plants must transpire water in order to manufacture biomass through photosynthesis. The newly produced biomass is allocated to leaves, stems, and roots. Plant tissues die at nominal rates that reflect their maximal longevities, but death rates may be accelerated due to water or temperature stress, or phenological stage.

Nitrogen enters the system dissolved in rainfall or snow. Certain atmospheric forms can be deposited directly on soil and leaf surfaces. Nitrogen gas is also incorporated by symbiotic or free-living nitrogen-fixing microorganisms. A litter decomposition and nitrogen cycling submodel simulates the breakdown of dead plant materials and animal faeces. Nitrogen is released during decomposition to mineral forms that can be taken up by plants. Nitrogen taken up by plants is either transferred to soil detritus due to tissue mortality, or it is lost to herbivory, and recycled from herbivores to soil as urine or faeces. Nitrogen leaves

the system through conversion to gaseous forms during detritus decomposition, or through volatilisation of ammonia from the urea in herbivore urine.

Forage intake by herbivores is influenced by diet selection, forage abundance, forage quality, and snow cover. Animals choose among available plant types and tissues to achieve a preferred diet composition. Diet composition is affected by the relative availability of different forage types as well as preferences or avoidances. As forage biomass increases from zero to a specified level, forage intake rate increases. Forage intake rate is increasingly inhibited by deeper snow.

The animal energy balance submodel simulates average body weight of each population or herd based upon rates of energy intake and energy expenditure. Energy intake rate is derived from forage biomass intake rate and the concentration of digestible energy in the forage. Expenditures depend on body weight, stage of gestation, lactation, activity, and travel patterns. As energy intake increases, animals gain weight. When energy use exceeds intake, animals use energy stored as fat, and thus lose weight. A body condition index is calculated from body weight, with heavier animals being considered to be in better condition. In this way, herbivore body condition declines during times of food shortage. Since food shortage can be brought about by competition with other herbivores, the likelihood of food shortage increases as the number of herbivores increases.

The herbivore population dynamics submodel represents changes in the number of animals in each age class, for each sex. Birth and death rates are affected by animal condition indices. This is the way the model represents population responses to factors affecting forage availability, including plant growth rates, snow depth, and competition for forage by other animals.

The herbivore spatial distribution submodel simulates animal distributions over the landscape or region. Animals are redistributed in relationship to the distribution of a habitat suitability index. The habitat suitability index is affected by slope, temperature, forage biomass, forage intake rate, snow depth, distance to water, and tree cover. Since some of these variables change on a seasonal basis, animal distribution also changes seasonally. Animals can also be forced to occupy a certain area, or be excluded from certain areas by reading maps of these areas into the model.

13.4 Model parameterisation

Six groups of plants were simulated: grasses, forbs, shrubs, mountain mahogany, juniper, and coniferous trees. These groups were chosen to meet the objectives of this modelling analysis, without making the model overly complex. Many of the plant model parameters were taken from the literature, for example, from data on photosynthesis,

biomass allocation, tissue nitrogen concentrations, and plant allometry. Data from Detling and Gerhardt (1996), Gerhardt and Detling (1998), Fahnestock (1998), and Peterson (1999) were used to parameterise the plant growth model, and test its predictions. The objective was to maximise the model's skill in providing realistic simulations by making maximal use of information contained in the field data and literature.

A vegetation map existed for BCNRA (Knight *et al.* 1987), but none existed for the remainder of the PMWHR. A vegetation map for the PMWHR was developed by merging the BCNRA vegetation map with a modelled vegetation map for the remaining area. The modelled vegetation map was based on a map of forest cover from USGS quad sheets, the soils map, and qualitative relationships between major vegetation types, elevation, and soils observed on the Knight *et al.* (1987) map.

There are three relatively distinct herds of horses in the PMWHR, occupying habitats that are separated by distinct topographic barriers (Hall 1972; US BLM 1984, 1997; Singer *et al.* 2000). Each of the three herds was modelled separately and distributions were limited to their respective range areas. Seasonal movements were modelled as dynamic responses to changing forage and snow conditions, with a seasonal avoidance of areas below 1,500m in summer.

The locations of known horse watering points within the horse range were digitised from information provided by BLM personnel (L. Padden, BLM, pers. comm.). A map of distance to water was calculated using GIS. Bighorn sheep were kept within the seasonal ranges observed by Irby *et al.* (1994). Within these ranges, the model redistributed animals in relation to forage biomass and forage energy intake rate. Mule deer winter on the PMWHR, but during summer, most migrate to ranges north of the PMWHR (Irby *et al.* 1994). The model was parameterised so that the entire deer herd was on the PMWHR during December–April, and 10% were on the PMWHR during June–October.

Some model runs used observed animal population data as input, rather than simulating animal population dynamics. In such simulations, the summarised horse population data from USDI/BLM (1997) were used, based on data from Taylor (1990 memo) and Garrott and Taylor (1990). Sheep population data were obtained from Coates and Schemnitz (1989) and Kissell (1996). Mule deer population sizes were based upon information from Kissell (1996).

In model runs where the animal populations were simulated, they were normally culled or hunted at observed rates. Horse culling data from the USDI/BLM (1997) were used in simulations using observed culling data. Deer were culled to maintain the population between 500 and 700. Bighorn sheep have never been culled or hunted.

Population model parameters for horses were obtained from Garrott and Taylor (1990) and Singer *et al.* (1997,

2000), while population model parameters for bighorn sheep were derived from Leslie and Douglas (1986), Kissell (1996), Singer *et al.* (1997, 2000), and Coates and Schemnitz (1989).

Based on information in Lewis (1995), Pilliner (1992), National Research Council (1973, 1978), and others, maintenance and basic activity energy requirements were derived. Gestation and lactation costs were added using the multipliers given in Lewis (1995).

Maximum forage intake rates were based on values reported in the scientific literature. Conventional wisdom is that a horse will eat about 2.5% of body weight per day, although lactating mares and growing foals may eat more (Pilliner 1992). Duncan (1992) argued that breeding or growing equids are capable of much higher intake rates than typically reported in standard feeding trials. Five wild species, studied by Foose (1982), had intake rates that were markedly lower than intake rates of productive domestic animals. However, zebras that had been caught in the wild and that had been recently tamed had very high intake rates – corresponding to 4% per day (Gakahu 1982).

The spatial distribution model was parameterised based upon known habitat preferences. There are three relatively distinct herds of horses in the PMWHR, occupying habitats that are separated by distinct topographic barriers (Hall 1972; US BLM 1984, 1997; Singer *et al.* 2000). Each herd was modelled separately, and each was restricted in the model to their respective range. The Dryhead herd in the east spends the entire year at low elevations below the Sykes Ridge escarpment. The Sykes Ridge herd in the middle moves up and down Sykes Ridge, to high elevations in summer, and low elevations in winter. The Burnt Timber Ridge herd to the west moves similarly up and down a separate ridge. The summer ranges of the herds from Sykes Ridge and Burnt Timber Ridge overlap at the top of the mountain. Sykes Ridge and Burnt Timber Ridge ranges are separated by a steep, deep canyon (Big Coulee). Each of the three herds was modelled separately and limited to their distinct ranges. A small rate of inter-herd exchange was simulated, in accordance with existing data. Seasonal movements were modelled as dynamic responses to changing forage and snow conditions, with a seasonal avoidance of areas below 1,500m in summer.

13.5 Model application

The model performed well in simulating herbaceous plant growth with and without grazing, and it successfully simulated herbaceous biomass dynamics across a wide range of sites and weather years. The biomass dynamics data collected by James Detling and his colleagues proved to be critically important, particularly since they were collected at monthly intervals, over a wide variety of site types. The proportions of grasses and forbs, the rates of

transfers from live to dead, and the rates of transfers of dead tissues to soil all proved to be adequately simulated. More subtly, this suite of tests indicated that the model correctly represented biomass production, as opposed to simple biomass amounts. This is a subtle but important distinction. Biomass amount is usually lower than biomass production because biomass is always being transferred to detritus and herbivores. So, biomass amount is likely to be an underestimate of the actual amount of forage that is being produced.

Without horse grazing, above ground grass biomass varied nearly two-fold inter-annually. Grass biomass generally increased over time. Forb biomass increased less, so the proportion of forbs in total herbaceous biomass decreased. Grass biomass varied two-fold with the observed levels of horse grazing, and forb biomass was similar to grass biomass, whilst the ratio of grass to forbs was similar throughout. With no horse culling, biomass of grasses decreased over time.

The model simulated reasonable population dynamics and distributions of horses, bighorn sheep, and mule deer. These distributions were comparable to the best information available at the time. The rates of forage

offtake per animal, and the compositions of the herbivore's diets, also proved to be realistic, and consistent with the best available data.

Forage intake rate by horses varied seasonally from <0.5% of body weight per day to the maximum of 3.5% per day. Minimum values varied more among years than maximum values, with especially low minimal intake rates being predicted for 1978 and 1979. Generally, the most stressful years for forage intake were also years with deeper snow depths. Maximum intake rates for the Dryhead herd were consistently lower than for the other two herds, as a result of the lower forage biomass on the Dryhead summer range. Intake rates were markedly reduced when horse herds were not culled. Maxima and minima were both reduced at higher horse densities, as a consequence of intraspecific competition for forage.

Horse condition indices varied primarily between 0.5 and 1.0, indicating that body weight varied from 50% to 100% of its maximum. Years with high minimum forage intake rates were years with high minimum condition indices. Condition indices on the Sykes Ridge and Burnt Timber Ridge ranges often reached lower minimum values than on the Dryhead range, most likely a result of deeper

Figure 13.4. Herbaceous ANPP (annual net primary production) in Pryor Mountain Wild Horse Range.

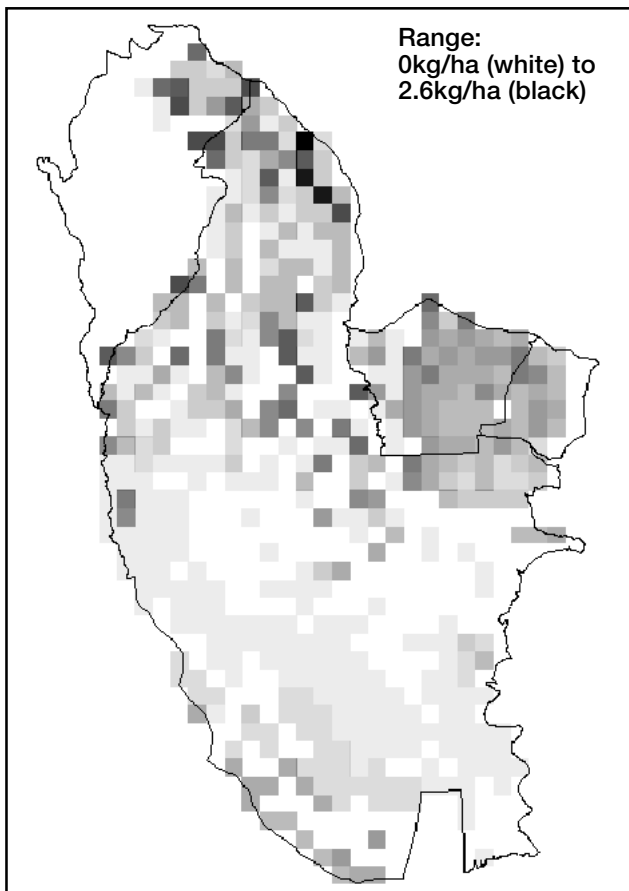
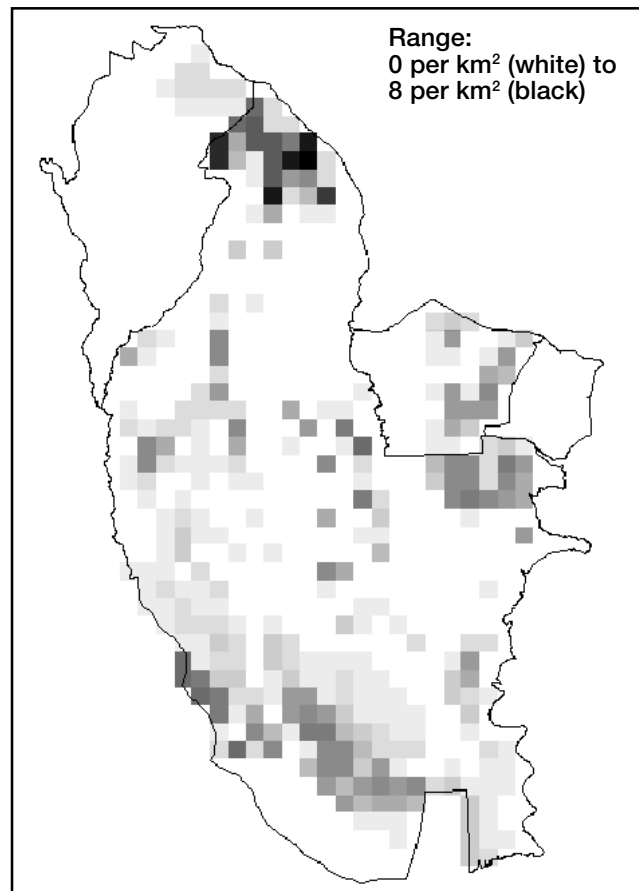


Figure 13.5. Horse densities (year-long) in Pryor Mountain Wild Horse Range.



snow cover at the higher elevations. When horse herds were not culled, horse condition indices decreased. Both maximal and minimal values decreased on the Dryhead range, while on the higher elevation ranges, only the minimum values decreased.

Gradients of herbaceous ANPP (annual net primary production) across the landscape were partly due to precipitation gradients and partly due to soil differences (Figure 13.4). Lands within the Sorenson Extension, and just south of it were more productive for a similar amount of precipitation than areas further south on the Dryhead horse range. The difference was clearly related to the distribution of deeper and shallower soils, and their associated water-holding capacities.

Horse densities were heterogeneously distributed on the landscape (Figure 13.5). With observed horse numbers, highest use areas at low elevations were 2–5 head per km² year-long. Heavy use areas at the top of the mountain were higher, reaching 6–8 head per km² year-long.

Between 1970 and 1996, 40–70% of the landscape experienced light herbivory of grasses (using observed horse numbers). However, 5–20% of the landscape received >80% herbivory and 5–15% experienced herbivory in the 50–80% range. The fraction of the landscape receiving >80% herbivory varied markedly from year to year.

The effects of grazing on ANPP can be displayed as a map of the differences between ANPP with and without horses. There were smaller decreases in ANPP on portions of the landscape, and there were no differences, or even increases in ANPP in some areas due to herbivory. Grass ANPP was diminished by herbivory more than forb ANPP, most likely due to higher dietary preferences for grasses. With observed horse numbers, grass ANPP was 60–80% lower in some areas than without horses. With no horse culling, there were areas where grass ANPP was reduced by 80–90% and forb ANPP was reduced by 50–70%.

As horse numbers increased, herbaceous ANPP on the primary horse range decreased by 10–13% for each additional 50 horses. There was approximately 75% as much herbaceous production with 200 horses as with 50 horses. With 350 horses, ANPP was about 60% of that with 50 horses.

Mean horse condition index declined with increases in horse numbers, indicating increased competition for food. Indeed, forage intake rate declined with increasing horse number.

In addition to the results just described, the model also produced the following results that are relevant to ecosystem management:

1. Grazers generally decreased above-ground herbaceous plant biomass, with potential implications for site water balance, and habitats for other species.
2. As herbivory pressure increased, forbs increase in relative abundance compared to grasses. An increase

in the ratio of forbs to grasses is often taken as a sign of decreased range condition.

3. Basal cover and root biomass decreased under increased herbivory due to decreases in above and below-ground primary production relative to root turnover.
4. The percentage of the landscape where grasses were grazed in excess of 80% increased from 16% at 125 horses to 25% at 225 horses. This level of grazing is negatively perceived by most. Importantly, the response was a smooth transition, rather than a discontinuous threshold response to increasing horse numbers.
5. The mean proportion of herbaceous plant growth consumed on the entire landscape varied from a mean of 15% at 125 horses to a mean of 23% at 225 horses. Thus, the mean offtake level on the landscape was well below the 50% level often used by range managers, despite the fact that much of the landscape was grazed quite heavily.
6. Horses had little effect on bighorn sheep populations due to a high degree of spatial segregation, dietary separation, and the fact that sheep are strongly influenced by their own density within their own range.
7. Horses increased to over 300 in many weather scenarios, and even to over 450, if they were not culled. This could be regarded as the ecological or food-limited carrying capacity of the population. However at ecological carrying capacity, plant biomass and horse condition would be unacceptably low, and horse mortality would be unacceptably high.

13.6 Using ecosystem models for the management of wild equids

The feasibility of using modelling to assess equid-ecosystem interactions was demonstrated. The model performed in a realistic way to soil properties, climate, grazing pressure, and their interactions. Predictions of plant biomass dynamics were consistent with data over a wide range of soils and climatic conditions. Plant production and biomass generally declined under increasing levels of herbivory, as expected. Horse distributions were generally consistent with available data, as were herbivore forage intake rates and energy use rates. Animal condition varied in response to the balance between forage intake and energy expenditure, as expected. Simulated and observed horse population dynamics were in general agreement over a 27-year period.

Horse grazing affected plants and soils as expected. Above and below-ground biomass declined as horse number increased, as did litter, plant cover, and total net primary production. The significant point here is that these plant and soil responses could be quantified, and embodied into a dynamic model that could be used to explain observed responses, and furthermore, predict

responses to alternative scenarios of climate, land use, and herd management.

The approach taken here for assessing carrying capacity was to construct a process-based ecosystem model, run it under different management and climate scenarios, and judge which scenario among a full spectrum of possibilities is most desirable. This approach is not as 'cut and dried' as traditional approaches, but the benefits are as follows: 1) It shows the range of possible outcomes. Responses may be continuous, taking the form of many shades of grey, rather than discreet categories that can more easily be deemed to be good or bad. 2) It does not make simplifying assumptions about ecosystem processes (e.g. that plant-herbivore systems come into an equilibrium, that if herbivores consume more than 50% of plant production the plants will die, that the herbivores are food or predator limited, or that herbivory is uniformly distributed over space and time). 3) It does not make implicit assumptions about what is acceptable or proper. Instead, that decision is deferred until the alternative results are presented and explained. This forces scientists and decision-makers to tackle the judgement of appropriateness head-on, rather than relying on an aprior criteria that may or may not be relevant to the situation at hand.

The ecosystem approach unifies the formerly disparate, nutrition-based and population-based methods for estimating carrying capacity without making simplifying assumptions characteristic of each one alone. The nutritional approach, which calculates how many animals can be supported by the forage base, operates under the assumption that herbivores are food-limited, and that population growth rate will decline to zero when food becomes limiting. On the other hand, the population response is not simulated – the population approach operates under the assumption that if population growth has declined to zero, the population must be at nutritional carrying capacity. Instead of making such assumptions, the ecosystem modelling approach represents the actual linkage between forage abundance and population growth rate.

The responses of plants and soils to herbivory are modelled explicitly, by modelling plant growth responses to the loss of photosynthetic tissue, reallocation of carbon by the plant, and the recycling of nutrients from the herbivore to the soil. Since plant growth responds to moisture and temperature, the model can be used to examine changes in the plant-herbivore system and carrying capacity that might occur under climatic change. This is particularly useful since responses to potential global warming are becoming an increasingly prevalent concern. In the shorter term, this feature of the model is useful for looking at the range of variability in forage supply and herbivore responses among different weather years, and sequences of weather years such as droughts.

The spatial component of the model proved to be essential for several reasons. First, forage biomass and

vegetation types varied considerably over the landscape due to large elevation, precipitation, and soil differences. Second, horse distributions were not at all uniform, resulting in uneven distribution of grazing intensity. Third, it was critical to distinguish the spatial habitats of horses and bighorn sheep in order to accurately portray the interaction between these two populations. The uneven distribution of grazing pressure precluded the use of a single proper use factor when estimating the appropriate numbers of horses. Instead, a proper use factor must be two-tiered, specifying both the spatial stratification of grazing intensity, and the acceptable grazing pressure within strata. An example of this would be to state that no more than X% of the landscape should experience a utilisation level of greater Y%.

The PMWHR case is interesting because the designated horse range involves multiple land use agencies – the BLM, the National Park Service, the US Forest Service, and private landowners. Additionally, there are several important groups of stakeholders with often conflicting points of view, ranging from wild horse enthusiasts, to wildlife protectionists, to recreational users. This is probably not an uncommon situation, and is likely to become even more common as human populations expand and human land use intensifies. The utility of an objective, or neutral model as an object of discussion becomes evident in situations involving multiple use, since it provides a statement of the way things are, or would be, under different management scenarios. It is also an instrument that can be used to find alternative solutions, which are palpable to multiple stakeholders. This is the idea behind our current efforts to incorporate the model into an Integrated Modelling and Assessment System (IMAS) in order to assess interactions between wildlife and livestock in East Africa (using funding from the USAID Global Livestock Collaborative Research Support Program).

Ecosystem model-based assessments could be very useful for projecting potential successes of wild horse reintroductions, and in guiding management after initial reintroductions have been made. Laudably, efforts are being made to assess carrying capacities of potential reintroduction sites. However, the efforts are often based on the traditional approaches. There is a need, and a capability to conduct even more thorough assessments that address the importances of temporal and spatial heterogeneities.

To conclude, the ecosystem model provides a broader and more explanatory foundation upon which to base management decisions than traditional approaches to habitat carrying capacity or population viability, including assessments of threatened and endangered species. The ecosystem modelling approach, while more difficult to implement, has greater explanatory and predictive power than the traditional methodologies. Ecosystem modelling is a critical component of ecosystem management (Christensen *et al.* 1997). As part of an adaptive

management process, an ecosystem model should be revisited periodically, to check the consistency of its predictions with actual results. Ecosystem monitoring should be established to corroborate or refute key model predictions. The model should then be revised, based upon the new information, and a new assessment should be carried out. In this way, resource management and the basis for it, can be improved over the long term.

The opportunity to conduct an ecosystem modelling assessment of a wild horse range appears to be unprecedented. The Pryor Mountain horses have remarkable historical and ecological attributes that merit special attention. The approach of combining ecological field studies and ecosystem modelling, as has been carried out in the PMWHR, should prove equally useful for the scientific management and conservation of wild equids worldwide.

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Appendix 1

List of Equids on the 2002 *IUCN Red List of Threatened Species*

Assessments were made in 1996 using the 1994 Categories and Criteria (version 2.3), and in 2001 using the 2001 Red List Categories and Criteria (version 3.1), which can be found in Appendix 2.

Taxon	Assessment	Assessment date	Categories and criteria version
<i>Equus africanus africanus</i>	CR A1b	1996	Ver. 2.3, 1994
<i>Equus africanus somaliensis</i>	CR A1b	1996	Ver. 2.3, 1994
<i>Equus africanus</i>	CR A1b	1996	Ver. 2.3, 1994
<i>Equus burchellii</i>	LC	2001	Ver. 3.1, 2001
<i>Equus burchellii antiquorum</i>	LC	2001	Ver. 3.1, 2001
<i>Equus burchellii boehmi</i>	LC	2001	Ver. 3.1, 2001
<i>Equus burchellii burchellii</i>	EX	1996	Ver. 2.3, 1994
<i>Equus burchellii chapmani</i>	DD	1996	Ver. 2.3, 1994
<i>Equus burchellii crawshayi</i>	DD	1996	Ver. 2.3, 1994
<i>Equus burchellii zambeziensis</i>	DD	1996	Ver. 2.3, 1994
<i>Equus ferus przewalskii</i>	EW	1996	Ver. 2.3, 1994
<i>Equus grevyi</i>	EN A1a+2c	1996	Ver. 2.3, 1994
<i>Equus hemionus hemippus</i>	EX	2001	Ver. 3.1, 2001
<i>Equus hemionus hemionus</i>	VU C1	2001	Ver. 3.1, 2001
<i>Equus hemionus khur</i>	EN B1ab(iii,v); C2a(ii)	2001	Ver. 3.1, 2001
<i>Equus hemionus kulan</i>	CR A2bcd+4bcd	2001	Ver. 3.1, 2001
<i>Equus hemionus luteus</i>	VU C1	2001	Ver. 3.1, 2001
<i>Equus hemionus onager</i>	CR C1	2001	Ver. 3.1, 2001
<i>Equus hemionus</i>	VU A3bcd; C1	2001	Ver. 3.1, 2001
<i>Equus kiang</i>	LR/lc	1996	Ver. 2.3, 1994
<i>Equus kiang holdereri</i>	LR/lc	1996	Ver. 2.3, 1994
<i>Equus kiang kiang</i>	DD	1996	Ver. 2.3, 1994
<i>Equus kiang polyodon</i>	DD	1996	Ver. 2.3, 1994
<i>Equus quagga</i>	EX	2001	Ver. 3.1, 2001
<i>Equus zebra zebra</i>	EN C2a	1996	Ver. 2.3, 1994
<i>Equus zebra</i>	EN A1b	1996	Ver. 2.3, 1994
<i>Equus zebra hartmannae</i>	EN A1a	1996	Ver. 2.3, 1994

IUCN Red List Categories and Criteria

Version 3.1

Prepared by the IUCN Species Survival Commission

As approved by the 51st meeting of the IUCN Council, Gland, Switzerland, 9 February 2000

I. Introduction

1. The IUCN Red List Categories and Criteria are intended to be an easily and widely understood system for classifying species at high risk of global extinction. The general aim of the system is to provide an explicit, objective framework for the classification of the broadest range of species according to their extinction risk. However, while the Red List may focus attention on those taxa at the highest risk, it is not the sole means of setting priorities for conservation measures for their protection.

Extensive consultation and testing in the development of the system strongly suggest that it is robust across most organisms. However, it should be noted that although the system places species into the threatened categories with a high degree of consistency, the criteria do not take into account the life histories of every species. Hence, in certain individual cases, the risk of extinction may be under- or over-estimated.

2. Before 1994 the more subjective threatened species categories used in IUCN Red Data Books and Red Lists had been in place, with some modification, for almost 30 years. Although the need to revise the categories had long been recognised (Fitter and Fitter 1987), the current phase of development only began in 1989 following a request from the IUCN Species Survival Commission (SSC) Steering Committee to develop a more objective approach. The IUCN Council adopted the new Red List system in 1994.

The IUCN Red List Categories and Criteria have several specific aims:

- to provide a system that can be applied consistently by different people;
- to improve objectivity by providing users with clear guidance on how to evaluate different factors which affect the risk of extinction;
- to provide a system which will facilitate comparisons across widely different taxa;
- to give people using threatened species lists a better understanding of how individual species were classified.

3. Since their adoption by IUCN Council in 1994, the IUCN Red List Categories have become widely recognised

internationally, and they are now used in a range of publications and listings produced by IUCN, as well as by numerous governmental and non-governmental organisations. Such broad and extensive use revealed the need for a number of improvements, and SSC was mandated by the 1996 World Conservation Congress (WCC Res. 1.4) to conduct a review of the system (IUCN 1996). This document presents the revisions accepted by the IUCN Council.

The proposals presented in this document result from a continuing process of drafting, consultation and validation. The production of a large number of draft proposals has led to some confusion, especially as each draft has been used for classifying some set of species for conservation purposes. To clarify matters, and to open the way for modifications as and when they become necessary, a system for version numbering has been adopted as follows:

Version 1.0: Mace and Lande (1991)

The first paper discussing a new basis for the categories, and presenting numerical criteria especially relevant for large vertebrates.

Version 2.0: Mace *et al.* (1992)

A major revision of Version 1.0, including numerical criteria appropriate to all organisms and introducing the non-threatened categories.

Version 2.1: IUCN (1993)

Following an extensive consultation process within SSC, a number of changes were made to the details of the criteria, and fuller explanation of basic principles was included. A more explicit structure clarified the significance of the non-threatened categories.

Version 2.2: Mace and Stuart (1994)

Following further comments received and additional validation exercises, some minor changes to the criteria were made. In addition, the Susceptible category present in Versions 2.0 and 2.1 was subsumed into the Vulnerable category. A precautionary application of the system was emphasised.

Version 2.3: IUCN (1994)

IUCN Council adopted this version, which incorporated

changes as a result of comments from IUCN members, in December 1994. The initial version of this document was published without the necessary bibliographic details, such as date of publication and ISBN number, but these were included in the subsequent reprints in 1998 and 1999. This version was used for the 1996 *IUCN Red List of Threatened Animals* (Baillie and Groombridge 1996), *The World List of Threatened Trees* (Oldfield *et al.* 1998) and the 2000 *IUCN Red List of Threatened Species* (Hilton-Taylor 2000).

Version 3.0: IUCN/SSC Criteria Review Working Group (1999)

Following comments received, a series of workshops were convened to look at the IUCN Red List Criteria following which, changes were proposed affecting the criteria, the definitions of some key terms and the handling of uncertainty.

Version 3.1: IUCN (2001)

The IUCN Council adopted this latest version, which incorporated changes as a result of comments from the IUCN and SSC memberships and from a final meeting of the Criteria Review Working Group, in February 2000.

All new assessments from January 2001 should use the latest adopted version and cite the year of publication and version number.

4. In the rest of this document, the proposed system is outlined in several sections. Section II, the Preamble, presents basic information about the context and structure of the system, and the procedures that are to be followed in applying the criteria to species. Section III provides definitions of key terms used. Section IV presents the categories, while Section V details the quantitative criteria used for classification within the threatened categories. Annex I provides guidance on how to deal with uncertainty when applying the criteria; Annex II suggests a standard format for citing the Red List Categories and Criteria; and Annex III outlines the documentation requirements for taxa to be included on IUCN's global Red Lists. It is important for the effective functioning of the system that all sections are read and understood to ensure that the definitions and rules are followed. (**Note:** Annexes I, II and III will be updated on a regular basis.)

II. Preamble

The information in this section is intended to direct and facilitate the use and interpretation of the categories (Critically Endangered, Endangered, etc.), criteria (A to E), and subcriteria (1, 2, etc.; a, b, etc.; i, ii, etc.).

1. Taxonomic level and scope of the categorisation process

The criteria can be applied to any taxonomic unit at or below the species level. In the following information, definitions and criteria the term 'taxon' is used for convenience, and may represent species or lower taxonomic levels, including forms that are not yet formally described. There is sufficient range among the different criteria to enable the appropriate listing of taxa from the complete taxonomic spectrum, with the exception of micro-organisms. The criteria may also be applied within any specified geographical or political area, although in such cases special notice should be taken of point 14. In presenting the results of applying the criteria, the taxonomic unit and area under consideration should be specified in accordance with the documentation guidelines (see Annex 3). The categorisation process should only be applied to wild populations inside their natural range, and to populations resulting from benign introductions. The latter are defined in the *IUCN Guidelines for Re-introductions* (IUCN 1998) as '... an attempt to establish a species, for the purpose of conservation, outside its recorded distribution, but within an appropriate habitat and eco-geographical area. This is a feasible conservation tool only when there is no remaining area left within a species' historic range'.

2. Nature of the categories

Extinction is a chance process. Thus, a listing in a higher extinction risk category implies a higher expectation of extinction, and over the time-frames specified more taxa listed in a higher category are expected to go extinct than those in a lower one (without effective conservation action). However, the persistence of some taxa in high-risk categories does not necessarily mean their initial assessment was inaccurate.

All taxa listed as Critically Endangered qualify for Vulnerable and Endangered, and all listed as Endangered qualify for Vulnerable. Together these categories are described as 'threatened'. The threatened categories form a part of the overall scheme. It will be possible to place all taxa into one of the categories (see Figure 1).

3. Role of the different criteria

For listing as Critically Endangered, Endangered or Vulnerable there is a range of quantitative criteria; meeting any one of these criteria qualifies a taxon for listing at that level of threat. Each taxon should be evaluated against all the criteria. Even though some criteria will be inappropriate for certain taxa (some taxa will never qualify under these however close to extinction they come), there should be criteria appropriate for assessing threat levels for any taxon. The relevant factor is whether *any one* criterion is met, not whether all are appropriate or all are met. Because it will never be clear in advance which criteria are

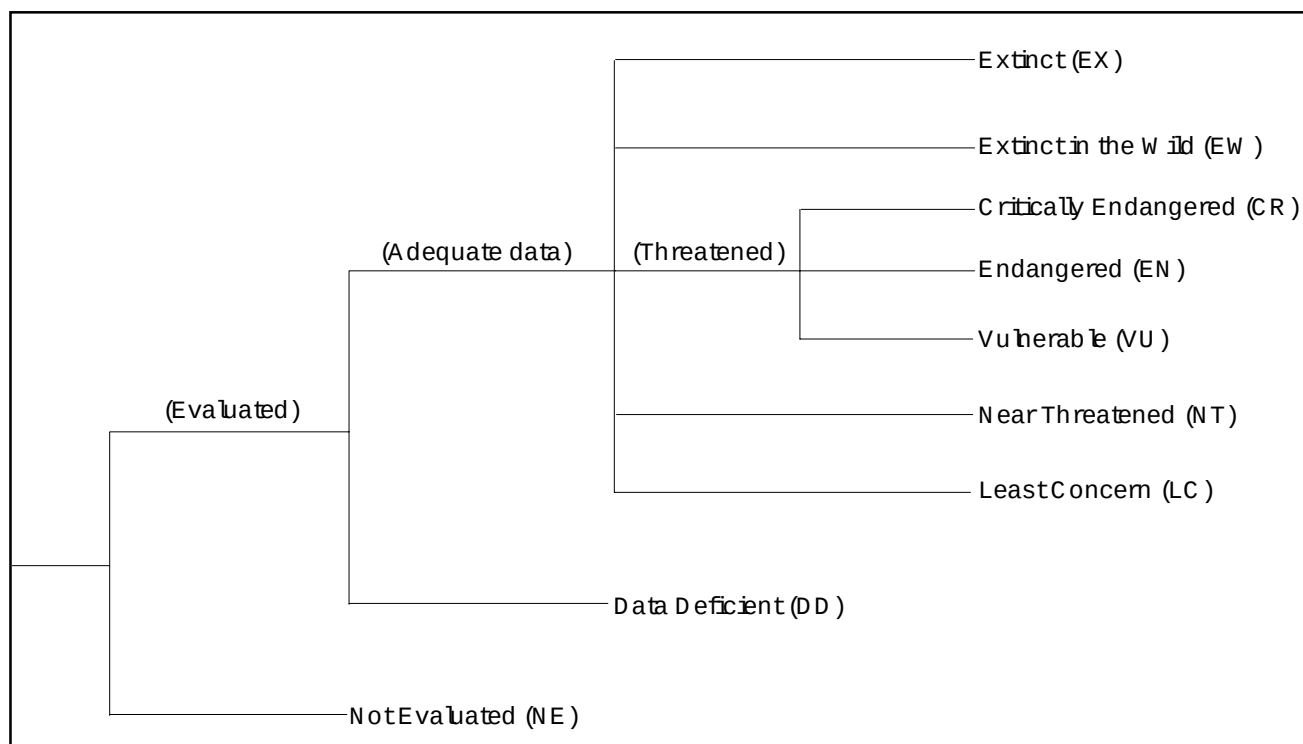


Figure 1. Structure of the categories.

appropriate for a particular taxon, each taxon should be evaluated against all the criteria, and *all* criteria met at the highest threat category must be listed.

4. Derivation of quantitative criteria

The different criteria (A–E) are derived from a wide review aimed at detecting risk factors across the broad range of organisms and the diverse life histories they exhibit. The quantitative values presented in the various criteria associated with threatened categories were developed through wide consultation, and they are set at what are generally judged to be appropriate levels, even if no formal justification for these values exists. The levels for different criteria within categories were set independently but against a common standard. Broad consistency between them was sought.

5. Conservation actions in the listing process

The criteria for the threatened categories are to be applied to a taxon whatever the level of conservation action affecting it. It is important to emphasise here that a taxon may require conservation action even if it is not listed as threatened. Conservation actions which may benefit the taxon are included as part of the documentation requirements (see Annex 3).

6. Data quality and the importance of inference and projection

The criteria are clearly quantitative in nature. However, the absence of high-quality data should not deter attempts

at applying the criteria, as methods involving estimation, inference and projection are emphasised as being acceptable throughout. Inference and projection may be based on extrapolation of current or potential threats into the future (including their rate of change), or of factors related to population abundance or distribution (including dependence on other taxa), so long as these can reasonably be supported. Suspected or inferred patterns in the recent past, present or near future can be based on any of a series of related factors, and these factors should be specified as part of the documentation.

Taxa at risk from threats posed by future events of low probability but with severe consequences (catastrophes) should be identified by the criteria (e.g. small distributions, few locations). Some threats need to be identified particularly early, and appropriate actions taken, because their effects are irreversible or nearly so (e.g. pathogens, invasive organisms, hybridisation).

7. Problems of scale

Classification based on the sizes of geographic ranges or the patterns of habitat occupancy is complicated by problems of spatial scale. The finer the scale at which the distributions or habitats of taxa are mapped, the smaller the area will be that they are found to occupy, and the less likely it will be that range estimates (at least for ‘area of occupancy’: see Definitions, point 10) exceed the thresholds specified in the criteria. Mapping at finer scales reveals more areas in which the taxon is unrecorded. Conversely, coarse-scale mapping reveals fewer unoccupied areas,

resulting in range estimates that are more likely to exceed the thresholds for the threatened categories. The choice of scale at which range is estimated may thus, itself, influence the outcome of Red List assessments and could be a source of inconsistency and bias. It is impossible to provide any strict but general rules for mapping taxa or habitats; the most appropriate scale will depend on the taxon in question, and the origin and comprehensiveness of the distribution data.

8. Uncertainty

The data used to evaluate taxa against the criteria are often estimated with considerable uncertainty. Such uncertainty can arise from any one or all of the following three factors: natural variation, vagueness in the terms and definitions used, and measurement error. The way in which this uncertainty is handled can have a strong influence on the results of an evaluation. Details of methods recommended for handling uncertainty are included in Annex 1, and assessors are encouraged to read and follow these principles.

In general, when uncertainty leads to wide variation in the results of assessments, the range of possible outcomes should be specified. A single category must be chosen and the basis for the decision should be documented; it should be both precautionary and credible.

When data are very uncertain, the category of 'Data Deficient' may be assigned. However, in this case the assessor must provide documentation showing that this category has been assigned because data are inadequate to determine a threat category. It is important to recognise that taxa that are poorly known can often be assigned a threat category on the basis of background information concerning the deterioration of their habitat and/or other causal factors; therefore the liberal use of 'Data Deficient' is discouraged.

9. Implications of listing

Listing in the categories of Not Evaluated and Data Deficient indicates that no assessment of extinction risk has been made, though for different reasons. Until such time as an assessment is made, taxa listed in these categories should not be treated as if they were non-threatened. It may be appropriate (especially for Data Deficient forms) to give them the same degree of attention as threatened taxa, at least until their status can be assessed.

10. Documentation

All assessments should be documented. Threatened classifications should state the criteria and subcriteria that were met. No assessment can be accepted for the IUCN Red List as valid unless at least one criterion is given. If more than one criterion or subcriterion is met, then each should be listed. If a re-evaluation indicates that the documented criterion is no longer met, this should not result in automatic reassignment to a lower category of

threat (downlisting). Instead, the taxon should be re-evaluated against all the criteria to clarify its status. The factors responsible for qualifying the taxon against the criteria, especially where inference and projection are used, should be documented (see Annexes 2 and 3). The documentation requirements for other categories are also specified in Annex 3.

11. Threats and priorities

The category of threat is not necessarily sufficient to determine priorities for conservation action. The category of threat simply provides an assessment of the extinction risk under current circumstances, whereas a system for assessing priorities for action will include numerous other factors concerning conservation action such as costs, logistics, chances of success, and other biological characteristics of the subject.

12. Re-evaluation

Re-evaluation of taxa against the criteria should be carried out at appropriate intervals. This is especially important for taxa listed under Near Threatened, Data Deficient and for threatened taxa whose status is known or suspected to be deteriorating.

13. Transfer between categories

The following rules govern the movement of taxa between categories:

- A. A taxon may be moved from a category of higher threat to a category of lower threat if none of the criteria of the higher category has been met for five years or more.
- B. If the original classification is found to have been erroneous, the taxon may be transferred to the appropriate category or removed from the threatened categories altogether, without delay (but see Point 10 above).
- C. Transfer from categories of lower to higher risk should be made without delay.

14. Use at regional level

The IUCN Red List Categories and Criteria were designed for global taxon assessments. However, many people are interested in applying them to subsets of global data, especially at regional, national or local levels. To do this it is important to refer to guidelines prepared by the IUCN/SSC Regional Applications Working Group (e.g. Gärdenfors *et al.* 2001). When applied at national or regional levels it must be recognised that a global category may not be the same as a national or regional category for a particular taxon. For example, taxa classified as Least Concern globally might be Critically Endangered within a particular region where numbers are very small or declining, perhaps only because they are at the margins of their global range. Conversely, taxa classified as Vulnerable on

the basis of their global declines in numbers or range might be Least Concern within a particular region where their populations are stable. It is also important to note that taxa endemic to regions or nations will be assessed globally in any regional or national applications of the criteria, and in these cases great care must be taken to check that an assessment has not already been undertaken by a Red List Authority (RLA), and that the categorisation is agreed with the relevant RLA (e.g. an SSC Specialist Group known to cover the taxon).

III. Definitions

1. Population and Population Size (Criteria A, C and D)

The term 'population' is used in a specific sense in the Red List Criteria that is different to its common biological usage. Population is here defined as the total number of individuals of the taxon. For functional reasons, primarily owing to differences between life forms, population size is measured as numbers of mature individuals only. In the case of taxa obligately dependent on other taxa for all or part of their life cycles, biologically appropriate values for the host taxon should be used.

2. Subpopulations (Criteria B and C)

Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less).

3. Mature individuals (Criteria A, B, C and D)

The number of mature individuals is the number of individuals known, estimated or inferred to be capable of reproduction. When estimating this quantity, the following points should be borne in mind:

- Mature individuals that will never produce new recruits should not be counted (e.g. densities are too low for fertilisation).
- In the case of populations with biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals, which take this into account.
- Where the population size fluctuates, use a lower estimate. In most cases this will be much less than the mean.
- Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g. corals).

- In the case of taxa that naturally lose all or a subset of mature individuals at some point in their life cycle, the estimate should be made at the appropriate time, when mature individuals are available for breeding.
- Re-introduced individuals must have produced viable offspring before they are counted as mature individuals.

4. Generation (Criteria A, C and E)

Generation length is the average age of parents of the current cohort (i.e. newborn individuals in the population). Generation length therefore reflects the turnover rate of breeding individuals in a population. Generation length is greater than the age at first breeding and less than the age of the oldest breeding individual, except in taxa that breed only once. Where generation length varies under threat, the more natural, i.e. pre-disturbance, generation length should be used.

5. Reduction (Criterion A)

A reduction is a decline in the number of mature individuals of at least the amount (%) stated under the criterion over the time period (years) specified, although the decline need not be continuing. A reduction should not be interpreted as part of a fluctuation unless there is good evidence for this. The downward phase of a fluctuation will not normally count as a reduction.

6. Continuing decline (Criteria B and C)

A continuing decline is a recent, current or projected future decline (which may be smooth, irregular or sporadic) which is liable to continue unless remedial measures are taken. Fluctuations will not normally count as continuing declines, but an observed decline should not be considered as a fluctuation unless there is evidence for this.

7. Extreme fluctuations (Criteria B and C)

Extreme fluctuations can be said to occur in a number of taxa when population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude (i.e. a tenfold increase or decrease).

8. Severely fragmented (Criterion B)

The phrase 'severely fragmented' refers to the situation in which increased extinction risk to the taxon results from the fact that most of its individuals are found in small and relatively isolated subpopulations (in certain circumstances this may be inferred from habitat information). These small subpopulations may go extinct, with a reduced probability of recolonisation.

9. Extent of occurrence (Criteria A and B)

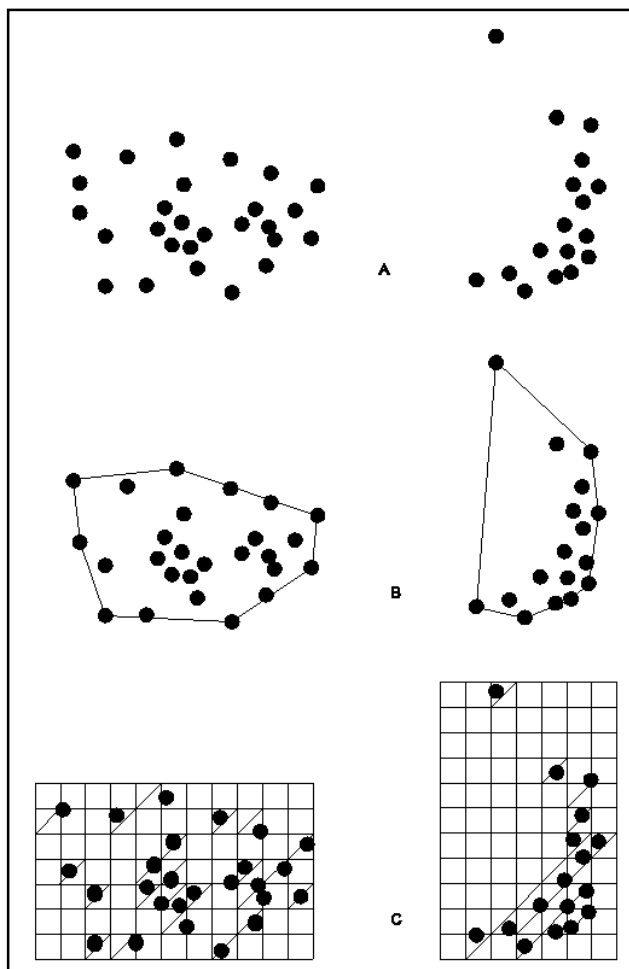
Extent of occurrence is defined as the area contained

within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy (see Figure 2). This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g. large areas of obviously unsuitable habitat) (but see ‘area of occupancy’, point 10 below). Extent of occurrence can often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence).

10. Area of occupancy (Criteria A, B and D)

Area of occupancy is defined as the area within its ‘extent of occurrence’ (see point 9 above) which is occupied by a

Figure 2. Two examples of the distinction between extent of occurrence and area of occupancy. (A) is the spatial distribution of known, inferred or projected sites of present occurrence. (B) shows one possible boundary to the extent of occurrence, which is the measured area within this boundary. (C) shows one measure of area of occupancy which can be achieved by the sum of the occupied grid squares.



taxon, excluding cases of vagrancy. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats. In some cases (e.g. irreplaceable colonial nesting sites, crucial feeding sites for migratory taxa) the area of occupancy is the smallest area essential at any stage to the survival of existing populations of a taxon. The size of the area of occupancy will be a function of the scale at which it is measured, and should be at a scale appropriate to relevant biological aspects of the taxon, the nature of threats and the available data (see point 7 in the Preamble). To avoid inconsistencies and bias in assessments caused by estimating area of occupancy at different scales, it may be necessary to standardise estimates by applying a scale-correction factor. It is difficult to give strict guidance on how standardisation should be done because different types of taxa have different scale-area relationships.

11. Location (Criteria B and D)

The term ‘location’ defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat.

12. Quantitative analysis (Criterion E)

A quantitative analysis is defined here as any form of analysis which estimates the extinction probability of a taxon based on known life history, habitat requirements, threats and any specified management options. Population viability analysis (PVA) is one such technique. Quantitative analyses should make full use of all relevant available data. In a situation in which there is limited information, such data as are available can be used to provide an estimate of extinction risk (for instance, estimating the impact of stochastic events on habitat). In presenting the results of quantitative analyses, the assumptions (which must be appropriate and defensible), the data used and the uncertainty in the data or quantitative model must be documented.

IV. The Categories¹

A representation of the relationships between the categories is shown in Figure 1.

EXTINCT (EX)

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat,

at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

EXTINCT IN THE WILD (EW)

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.

ENDANGERED (EN)

A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see Section V), and it is therefore considered to be facing a very high risk of extinction in the wild.

VULNERABLE (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild.

NEAR THREATENED (NT)

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

LEAST CONCERN (LC)

A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

DATA DEFICIENT (DD)

A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data

on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

NOT EVALUATED (NE)

A taxon is Not Evaluated when it has not yet been evaluated against the criteria.

1 Note: As in previous IUCN categories, the abbreviation of each category (in parentheses) follows the English denominations when translated into other languages (see Annex 2).

V. The Criteria for Critically Endangered, Endangered and Vulnerable

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of $\geq 90\%$ over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
 - a) direct observation
 - b) an index of abundance appropriate to the taxon
 - c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
 - d) actual or potential levels of exploitation
 - e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of $\geq 80\%$ over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of $\geq 80\%$, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
 4. An observed, estimated, inferred, projected or suspected population size reduction of $\geq 80\%$ over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
- B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:**
1. Extent of occurrence estimated to be less than 100km^2 and estimates indicating at least two of a–c:
 - a. Severely fragmented or known to exist at only a single location.
 - b. Continuing decline, observed, inferred or projected, in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) area, extent and/or quality of habitat
 - iv) number of locations or subpopulations
 - v) number of mature individuals.
 - c. Extreme fluctuations in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) number of locations or subpopulations
 - iv) number of mature individuals.
 2. Area of occupancy estimated to be less than 10 km^2 , and estimates indicating at least two of a–c:
 - a. Severely fragmented or known to exist at only a single location.
 - b. Continuing decline, observed, inferred or projected, in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) area, extent and/or quality of habitat
 - iv) number of locations or subpopulations
 - v) number of mature individuals.
 - c. Extreme fluctuations in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) number of locations or subpopulations
 - iv) number of mature individuals.
- C. Population size estimated to number fewer than 250 mature individuals and either:**
1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer (up to a maximum of 100 years in the future) OR
 2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b):
 - a) Population structure in the form of one of the following:
 - i) no subpopulation estimated to contain more than 50 mature individuals, OR
 - ii) at least 90% of mature individuals in one subpopulation.
 - b) Extreme fluctuations in number of mature individuals.
- D. Population size estimated to number fewer than 50 mature individuals.**
- E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years).**
- ENDANGERED (EN)**
A taxon is Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a very high risk of extinction in the wild:
- A. Reduction in population size based on any of the following:**
1. An observed, estimated, inferred or suspected population size reduction of $\geq 70\%$ over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
 - a) direct observation
 - b) an index of abundance appropriate to the taxon
 - c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
 - d) actual or potential levels of exploitation
 - e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
 2. An observed, estimated, inferred or suspected population size reduction of $\geq 50\%$ over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have

ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of $\geq 50\%$, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of $\geq 50\%$ over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 5,000 km², and estimates indicating at least two of a–c:
 - a. Severely fragmented or known to exist at no more than five locations.
 - b. Continuing decline, observed, inferred or projected, in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) area, extent and/or quality of habitat
 - iv) number of locations or subpopulations
 - v) number of mature individuals.
 - c. Extreme fluctuations in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) number of locations or subpopulations
 - iv) number of mature individuals.
2. Area of occupancy estimated to be less than 500 km², and estimates indicating at least two of a–c:
 - a. Severely fragmented or known to exist at no more than five locations.
 - b. Continuing decline, observed, inferred or projected, in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) area, extent and/or quality of habitat
 - iv) number of locations or subpopulations
 - v) number of mature individuals.
 - c. Extreme fluctuations in any of the following:
 - i) extent of occurrence

- ii) area of occupancy
- iii) number of locations or subpopulations
- iv) number of mature individuals.

C. Population size estimated to number fewer than 2,500 mature individuals and either:

1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, (up to a maximum of 100 years in the future) OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b):
 - a) Population structure in the form of one of the following:
 - i) no subpopulation estimated to contain more than 250 mature individuals, OR
 - ii) at least 95% of mature individuals in one subpopulation.
 - b) Extreme fluctuations in number of mature individuals.

D. Population size estimated to number fewer than 250 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years)

VULNERABLE (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of $\geq 50\%$ over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
 - a) direct observation
 - b) an index of abundance appropriate to the taxon
 - c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
 - d) actual or potential levels of exploitation
 - e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of $\geq 30\%$ over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
 3. A population size reduction of $\geq 30\%$, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
 4. An observed, estimated, inferred, projected or suspected population size reduction of $\geq 30\%$ over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
- B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:**
1. Extent of occurrence estimated to be less than 20,000 km², and estimates indicating at least two of a–c:
 - a. Severely fragmented or known to exist at no more than 10 locations.
 - b. Continuing decline, observed, inferred or projected, in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) area, extent and/or quality of habitat
 - iv) number of locations or subpopulations
 - v) number of mature individuals.
 - c. Extreme fluctuations in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) number of locations or subpopulations
 - iv) number of mature individuals.
 2. Area of occupancy estimated to be less than 2,000 km², and estimates indicating at least two of a–c:
 - a. Severely fragmented or known to exist at no more than 10 locations.
 - b. Continuing decline, observed, inferred or projected, in any of the following:
 - i) extent of occurrence
 - ii) area of occupancy
 - iii) area, extent and/or quality of habitat
 - iv) number of locations or subpopulations
 - v) number of mature individuals.
- C. Population size estimated to number fewer than 10,000 mature individuals and either:**
1. An estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer, (up to a maximum of 100 years in the future) OR
 2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a–b):
 - a) Population structure in the form of one of the following:
 - i) no subpopulation estimated to contain more than 1,000 mature individuals, OR
 - ii) all mature individuals are in one subpopulation.
 - b) Extreme fluctuations in number of mature individuals.
- D. Population very small or restricted in the form of either of the following:**
1. Population size estimated to number fewer than 1,000 mature individuals.
 2. Population with a very restricted area of occupancy (typically less than 20 km²) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.
- E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.**

Annex 1: Uncertainty

The Red List Criteria should be applied to a taxon based on the available evidence concerning its numbers, trend and distribution. In cases where there are evident threats to a taxon through, for example, deterioration of its only known habitat, a threatened listing may be justified, even though there may be little direct information on the biological status of the taxon itself. In all these instances

there are uncertainties associated with the available information and how it was obtained. These uncertainties may be categorised as natural variability, semantic uncertainty and measurement error (Akçakaya *et al.* 2000). This section provides guidance on how to recognise and deal with these uncertainties when using the criteria.

Natural variability results from the fact that species' life histories and the environments in which they live change over time and space. The effect of this variation on the criteria is limited, because each parameter refers to a specific time or spatial scale. Semantic uncertainty arises from vagueness in the definition of terms or lack of consistency in different assessors' usage of them. Despite attempts to make the definitions of the terms used in the criteria exact, in some cases this is not possible without the loss of generality. Measurement error is often the largest source of uncertainty; it arises from the lack of precise information about the parameters used in the criteria. This may be due to inaccuracies in estimating the values or a lack of knowledge. Measurement error may be reduced or eliminated by acquiring additional data. For further details, see Akçakaya *et al.* (2000) and Burgman *et al.* (1999).

One of the simplest ways to represent uncertainty is to specify a best estimate and a range of plausible values. The best estimate itself might be a range, but in any case the best estimate should always be included in the range of plausible values. When data are very uncertain, the range for the best estimate might be the range of plausible values. There are various methods that can be used to establish the plausible range. It may be based on confidence intervals, the opinion of a single expert, or the consensus opinion of a group of experts. Whichever method is used should be stated and justified in the documentation.

When interpreting and using uncertain data, attitudes toward risk and uncertainty may play an important role. Attitudes have two components. First, assessors need to consider whether they will include the full range of plausible values in assessments, or whether they will exclude extreme values from consideration (known as dispute tolerance). An assessor with a low dispute tolerance would include all values, thereby increasing the uncertainty, whereas an assessor with a high dispute tolerance would exclude extremes, reducing the uncertainty. Second, assessors need to consider whether they have a precautionary or evidentiary attitude to risk (known as risk tolerance). A precautionary attitude will classify a taxon as threatened unless it is certain that it is not threatened, whereas an evidentiary attitude will classify a taxon as threatened only when there is strong evidence to support a threatened classification. Assessors should resist an evidentiary attitude and adopt a precautionary but realistic attitude to uncertainty when applying the criteria, for example, by using plausible lower bounds, rather than best estimates, in determining population size, especially if it is fluctuating. All attitudes should be explicitly documented.

An assessment using a point estimate (i.e. single numerical value) will lead to a single Red List Category. However, when a plausible range for each parameter is used to evaluate the criteria, a range of categories may be obtained, reflecting the uncertainties in the data. A single category, based on a specific attitude to uncertainty, should always be listed along with the criteria met, while the range of plausible categories should be indicated in the documentation (see Annex 3).

Where data are so uncertain that any category is plausible, the category of 'Data Deficient' should be assigned. However, it is important to recognise that this category indicates that the data are inadequate to determine the degree of threat faced by a taxon, not necessarily that the taxon is poorly known or indeed not threatened. Although Data Deficient is not a threatened category, it indicates a need to obtain more information on a taxon to determine the appropriate listing; moreover, it requires documentation with whatever available information there is.

Annex 2: Citation of the IUCN Red List Categories and Criteria

In order to promote the use of a standard format for citing the Red List Categories and Criteria the following forms of citation are recommended:

1. The Red List Category may be written out in full or abbreviated as follows (when translated into other languages, the abbreviations should follow the English denominations):

Extinct, EX
Extinct in the Wild, EW
Critically Endangered, CR
Endangered, EN
Vulnerable, VU
Near Threatened, NT
Least Concern, LC
Data Deficient, DD
Not Evaluated, NE

2. Under Section V (the criteria for Critically Endangered, Endangered and Vulnerable) there is a hierarchical alphanumeric numbering system of criteria and subcriteria. These criteria and subcriteria (all three levels) form an integral part of the Red List assessment and all those that result in the assignment of a threatened category must be specified after the Category. Under the criteria A to C and D under Vulnerable, the first level of the hierarchy is indicated by the use of numbers (1–4) and if more than one is met, they are separated by means of the '+' symbol. The second level is indicated by the use of the lower-case

alphabet characters (a–e). These are listed without any punctuation. A third level of the hierarchy under Criteria B and C involves the use of lower case roman numerals (i–v). These are placed in parentheses (with no space between the preceding alphabet character and start of the parenthesis) and separated by the use of commas if more than one is listed. Where more than one criterion is met, they should be separated by semicolons. The following are examples of such usage:

EX
CR A1cd
VU A2c+3c
EN B1ac(i,ii,iii)
EN A2c; D
VU D1+2
CR A2c+3c; B1ab(iii)
CR D
VU D2
EN B2ab(i,ii,iii)
VU C2a(ii)
EN A1c; B1ab(iii); C2a(i)
EN B2b(iii)c(ii)
EN B1ab(i,ii,v)c(iii,iv)+2b(i)c(ii,v)
VU B1ab(iii)+2ab(iii)
EN
A2abc+3bc+4abc; B1b(iii,iv,v)c(ii,iii,iv)+2b(iii,iv,v)c(ii,iii,iv)

Annex 3: Documentation Requirements for Taxa Included on the IUCN Red List

The following is the **minimum** set of information, which should accompany every assessment submitted for incorporation into the *IUCN Red List of Threatened Species*TM:

- Scientific name including authority details
- English common name/s and any other widely used common names (specify the language of each name supplied)
- Red List Category and Criteria
- Countries of occurrence (including country subdivisions for large nations, e.g. states within the USA, and overseas territories, e.g. islands far from the mainland country)
- For marine species, the Fisheries Areas in which they occur should be recorded (see <http://www.iucn.org/themes/ssc/sis/faomap.htm> for the Fisheries Areas as delimited by FAO, the Food and Agriculture Organisation of the United Nations)
- For inland water species, the names of the river systems, lakes, etc. to which they are confined
- A map showing the geographic distribution (extent of occurrence)

- A rationale for the listing (including any numerical data, inferences or uncertainty that relate to the criteria and their thresholds)
- Current population trends (increasing, decreasing, stable or unknown)
- Habitat preferences (using a modified version of the Global Land Cover Characterisation (GLCC) classification which is available electronically from <http://www.iucn.org/themes/ssc/sis/authority.htm> or on request from redlist@ssc-uk.org)
- Major threats (indicating past, current and future threats using a standard classification which is available from the SSC web site or e-mail address as shown above)
- Conservation measures, (indicating both current and proposed measures using a standard classification which is available from the SSC web site or e-mail address as shown above)
- Information on any changes in the Red List status of the taxon, and why the status has changed
- Data sources (cited in full; including unpublished sources and personal communications)
- Name/s and contact details of the assessor/s
- Before inclusion on the IUCN Red List, all assessments will be evaluated by at least two members of a Red List Authority. The Red List Authority is appointed by the Chair of the IUCN Species Survival Commission and is usually a sub-group of a Specialist Group. The names of the evaluators will appear with each assessment.

In addition to the minimum documentation, the following information should also be supplied where appropriate:

- If a quantitative analysis is used for the assessment (i.e. Criterion E), the data, assumptions and structural equations (e.g. in the case of a Population Viability Analysis) should be included as part of the documentation.
- For Extinct or Extinct in the Wild taxa, extra documentation is required indicating the effective date of extinction, possible causes of the extinction and the details of surveys which have been conducted to search for the taxon.
- For taxa listed as Near Threatened, the rationale for listing should include a discussion of the criteria that are nearly met or the reasons for highlighting the taxon (e.g. they are dependent on ongoing conservation measures).
- For taxa listed as Data Deficient, the documentation should include what little information is available.

Assessments may be made using version 2.0 of the software package RAMAS[®] Red List (Akçakaya and Ferson 2001). This program assigns taxa to Red List Categories according

to the rules of the IUCN Red List Criteria and has the advantage of being able to explicitly handle uncertainty in the data. The software captures most of the information required for the documentation above, but in some cases the information will be reported differently. The following points should be noted:

- If RAMASO Red List is used to obtain a listing, this should be stated.
- Uncertain values should be entered into the program as a best estimate and a plausible range, or as an interval (see the RAMASO Red List manual or help files for further details).
- The settings for attitude towards risk and uncertainty (i.e. dispute tolerance, risk tolerance and burden of proof) are all pre-set at a mid-point. If any of these settings are changed this should be documented and fully justified, especially if a less precautionary position is adopted.
- Depending on the uncertainties, the resulting classification can be a single category and/or a range of plausible categories. In such instances, the following approach should be adopted (the program will usually indicate this automatically in the Results window):
 - If the range of plausible categories extends across two or more of the threatened categories (e.g. Critically Endangered to Vulnerable) and no preferred category is indicated, the precautionary approach is to take the highest category shown, i.e. CR in the above example. In such cases, the range of plausible categories should be documented under the rationale including a note that a precautionary approach was followed in order to distinguish it from the situation in the next point. The following notation has been suggested e.g. CR* (CR–VU).
 - If a range of plausible categories is given and a preferred category is indicated, the rationale should indicate the range of plausible categories met e.g. EN (CR–VU).
- The program specifies the criteria that contributed to the listing (see Status window). However, when data are uncertain, the listing criteria are approximate, and in some cases may not be determined at all. In such cases, the assessors should use the Text results to determine or verify the criteria and sub-criteria met. Listing criteria derived in this way must be clearly indicated in the rationale (refer to the RAMASO Red List Help menu for further guidance on this issue).
- If the preferred category is indicated as Least Concern, but the plausible range extends into the threatened categories, a listing of ‘Near Threatened’ (NT) should be used. The criteria, which triggered the extension into the threatened range, should be recorded under the rationale.

- Any assessments made using this software must be submitted with the RAMASO Red List input files (i.e. the *.RED files).

New global assessments or reassessments of taxa currently on the IUCN Red List, may be submitted to the IUCN/SSC Red List Programme Officer for incorporation (subject to peer review) in a future edition of the *IUCN Red List of Threatened Species*TM. Submissions from within the SSC network should preferably be made using the Species Information Service (SIS) database. Other submissions may be submitted electronically; these should preferably be as files produced using RAMASO Red List or any of the programs in Microsoft Office 97 (or earlier versions) e.g. Word, Excel or Access. Submissions should be sent to: IUCN/SSC Red List Programme, IUCN/SSC UK Office, 219c Huntingdon Road, Cambridge, CB3 0DL, United Kingdom. Fax: +44-(0)1223-277845; Email: redlist@ssc-uk.org

For further clarification or information about the IUCN Red List Criteria, documentation requirements (including the standards used) or submission of assessments, please contact the IUCN/SSC Red List Programme Officer at the address shown above.

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Appendix 3

Plains Zebra (*Equus burchellii*) Populations by Subspecies and Country

	Size (km ²)	Year	Number		Trend	Census method	Source of data
GRANT'S			493,665				
(<i>Equus boehmi boehmi</i>)							
Sudan			33,050				
Jonglei Canal area	68,000	1983	3,890	(dry)	Decreasing	Aerial sample	Mefit-Babtie SRL 1983
Boma NP	22,800	1983	29,160	(dry)	Decreasing	Aerial sample	J. Fryxell, in litt. 9/95
Ethiopia			7,470				
Omo NP-Mago NP-Tama WR	8,909	1997	1,630		Decreasing	Aerial sample	Graham <i>et al.</i> 1997
Nechisar NP	700	1995	3,000		Increasing	Informed guess	C. Zewdie and G. Wondimu, EWCO
Yabello WS	2,496	1995	2,840		Stable/ increasing	Aerial sample	Thouless 1995
Somalia			1,000?			Decreasing?	Duncan 1992
Kenya			152,490				
Marsabit District		1995	260		Decreasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Samburu District		1995	6,140		Stable	Aerial sample	Grunblatt <i>et al.</i> 1996
Isiolo District		1995	364		Stable/ decreasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Baringo District		1995	373		Stable/ increasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Laikipia District		1996	33,388	(wet)	increasing	Aerial total	Georgiadis 1996
Garissa District		1995	1,238		Decreasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Narok District (incl. Masai Mara NaR)		1995	42,699		Stable	Aerial sample	Grunblatt <i>et al.</i> 1996
Kajiado District (incl. Amboseli NP)		1995	47,890		Increasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Kitui District (incl. Tsavo NP)		1995	1,174		Stable/ decreasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Tana River District (incl. Tsavo NP)		1995	2,653		Decreasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Taita District (incl. Tsavo NP)		1995	9,736		Stable/ decreasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Lamu District		1995	935		Stable	Aerial sample	Grunblatt <i>et al.</i> 1996
Kilifi District		1995	2,395		Increasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Kwale District		1995	3,245		Increasing	Aerial sample	Grunblatt <i>et al.</i> 1996
Uganda			3,137				
Kidepo Valley NP	1,575	1997	500		Stable	Aerial sample	E. Buhanga, in litt. 6/97
Bokora GR	2,056	1997	3			Aerial total	R. Lamprey, in litt. 7/97
Pian Upe WR	3,250	1997	10			Aerial total	E. Buhanga, in litt. 6/97
South Karamoja CHA	8,972	1996	189		Decreasing?	Aerial total	E. Buhanga, in litt. 6/97
Lake Mburo NP and Ankole ranches	1,563	1996	2,430		Decreasing	Aerial sample	E. Buhanga, in litt. 6/97
Katonga GR	208	1997	5			Aerial total	R. Lamprey, in litt. 7/97
Rwanda			3,048				
Akagera NP and Mutara HR	1,500	1997	3,048		Decreasing	Ground total	Williams and Ntayombya 1999
Burundi			EXTINCT				
Tanzania			296,508				
Serengeti NP ecosystem	26,741	1996	150,834	(dry)	Stable/ decreasing	Aerial sample	P. Viljoen, TWCM
Ngorongoro Crater	300	1997	2,770	(wet)	Stable	Ground total	V. Runyoro, NCAA
Lake Eyasi area	2,500	1992	381	(dry)	Decreasing	Aerial sample	P. Viljoen, TWCM
Tarangire NP-Lake Manyara NP and area	12,389	1994	41,398	(dry)	Stable/ increasing	Aerial sample	P. Viljoen, TWCM
Kilimanjaro West area	2,537	1997	2,687	(wet)	Stable/ decreasing	Aerial sample	P. Viljoen, TWCM

Appendix 3 ... continued. Plains zebra (*Equus burchellii*) populations by subspecies and country.

	Size (km ²)	Year	Number		Trend	Census method	Source of data
Tanzania ... continued							
Mkomazi GR	3,600	1996	2,731	(wet)	Stable	Aerial sample	P. Viljoen, TWCM
Sadani GR and area	1,179	1997	272	(wet)	Stable/	Aerial sample decreasing	P. Viljoen, TWCM
Burigi-Biharamulo GRs and area	6,957	1990	6,552	(wet)	Stable	Aerial sample	P. Viljoen, TWCM
Moyowosi-Kigosi GRs	21,870	1994	3,971	(wet)	Stable	Aerial sample	P. Viljoen, TWCM
Ugalla River GR	6,524	1996	0	(wet)		Aerial total	P. Viljoen, TWCM
Katavi NP and Rukwa area	12,641	1991	20,865	(dry)	Increasing	Aerial sample	P. Viljoen, TWCM
Ruaha NP ecosystem	41,831	1996	26,325	(wet)	Stable	Aerial sample	P. Viljoen, TWCM
Selous GR-Mikumi NP ecosystem	91,981	1994	37,722	(dry)	Increasing	Aerial sample	P. Viljoen, TWCM
UPPER ZAMBEZI			19,219				
(<i>E. b. zambesiensis</i>)							
Dem. Rep. Congo (Zaire)			<1,000				
Upemba NP	11,730		<1,000		Decreasing	Informed guess	Verschuren 1975
Kundelungu NP	7,600		Extinct				Duncan 1992
Angola			EXTINCT?				
Iona NP	15,150		?				IUCN/ROSA 1992
Moçamedes NP	7,500		?				IUCN/ROSA 1992
Bikuar NP	8,000		?				IUCN/ROSA 1992
Mupa NP	4,000		?				IUCN/ROSA 1992
Mavinga CP	15,000		?				IUCN/ROSA 1992
Luiana CP	8,400		?				IUCN/ROSA 1992
Mucusso CP	13,000		?				IUCN/ROSA 1992
Luenge CP	8,000		?				IUCN/ROSA 1992
Zambia			18,219				
Mweru Wantipa NP	3,134	1994	Present		Decreasing		B. Dooley, in litt. 7/95
Lusenga Plain NP	880	1994	Present		Decreasing		B. Dooley, in litt. 7/95
Kafue NP	22,357	1994	2,830		Stable	Aerial sample	Yoneda and Mwima, 1995
Kafue flats region	6,000	1994	9,000		Stable	Informed guess	B. Dooley, in litt. 3/95
Liuwa Plain NP	3,660	1994	6,000		Decreasing	Informed guess	B. Dooley, in litt. 3/95
Sioma Ngwezi NP	5,240	1991	389		Decreasing?	Aerial sample	Tembo 1995
CRAWSHAY'S			23,020				
(<i>E. b. crawshayi</i>)							
Mozambique			1,100				
Rovuma-Niassa GR and area	8,000	1997	1,100		Increasing?	Ground sample	Leo-Smith <i>et al.</i> 1997
Malawi			670				
Nyika NP	3,132	1997	320		Stable	Aerial and ground sample	F.X. Mkanda, in litt. 3/97, 10/97
Vwaza Marsh GR	986	1997	15		Decreasing	Aerial and ground sample	F.X. Mkanda, in litt. 3/97, 10/97
Kasungu NP	2,316	1997	85		Decreasing	Aerial and ground sample	F.X. Mkanda, in litt. 3/97, 10/97
Nkhotakota GR	1,802	1997	250		Increasing	Aerial and ground sample	F.X. Mkanda, in litt. 3/97, 10/97
Zambia			21,250				
Musalangu GMA	5,183	1994	230		Decreasing	Aerial sample	Kapungwe 1994
North Luangwa NP	4,636	1995	9,050		Stable	Aerial sample	D. and M. Owens, in litt. 6/95
Lumimba GMA	2,700	1994	2,710		Stable	Aerial sample	Jachmann and Kalyocha 1994
Munyamadzi GMA	2,500	1994	340		Decreasing	Aerial sample	Jachmann and Kalyocha 1994
Luambe NP	320	1994	320		Stable	Aerial sample	Jachmann and Kalyocha 1994
Lukusuzi NP	1,920	1994	450		Decreasing	Aerial sample	Jachmann and Kalyocha 1994
South Luangwa NP	9,050	1994	5,100		Stable	Aerial sample	Jachmann and Kalyocha 1994

Appendix 3 ... continued. Plains zebra (<i>Equus burchellii</i>) populations by subspecies and country.							
	Size (km²)	Year	Number	Trend	Cencus method	Source of data	
Zambia ... continued							
Lupande GMA	4,500	1994	1,490	Stable/ decreasing	Aerial sample	Jachmann and Kalyocha 1994	
Sandwe GMA	1,500	1994	140	Stable?	Aerial sample	Jachmann and Kalyocha 1994	
Chisomo GMA	3,450	1994	?			Jachmann and Kalyocha 1994	
West Petauke GMA	3,842	1994	660	Stable?	Aerial sample	Jachmann and Kalyocha 1994	
Lower Zambesi NP	4,132	1995	410	Decreasing	Aerial sample	Mwima and Yoneda 1995	
Private farms and game ranches		1994	350	Stable/ increasing	Informed guess	Zambia NPWS, in litt. 6/95	
CHAPMAN'S			20,294				
(<i>E. b. chapmanni</i>)							
Mozambique			65				
Gorongosa NP-Marromeu GR	19,970	1994	65	Increasing?	Aerial sample	Dutton 1994	
Botswana			94				
Sibuyu and Kazuma FRs		1994	94	Decreasing	Aerial sample	DWNP 1995	
Zimbabwe			20,135				
Hwange NP and Deka SA	15,219	1995	3,040	Stable	Aerial sample	Davies <i>et al.</i> 1996	
Matetsi SA, and area	3,856	1995	2,290	Stable	Aerial sample	Davies <i>et al.</i> 1996	
Kazuma Pan NP, Zambezi NP	543	1995	240	Stable	Aerial sample	Davies <i>et al.</i> 1996	
Ngamo and Sikumi FRs	2,344	1995	140	Stable	Aerial sample	Davies <i>et al.</i> 1996	
Chizarira and Matusadona NPs, Chete and Chirisa SAs, Sengwa WRA,	16,082	1995	1,250	Stable	Aerial sample	Davies <i>et al.</i> 1996	
Mana Pools NP, Charara, Hirungwe Sapi and Chewore SAs	11,020	1995	1,650	Stable	Aerial sample	Davies <i>et al.</i> 1996	
Dande SA and area	3,822	1995	260	?	Aerial sample	Davies <i>et al.</i> 1996	
Zambezi Valley Escarpment CL	1,283	1995	5	?	Aerial sample	Davies <i>et al.</i> 1996	
Gonarezhou NP and Malipati SA	5,377	1995	780	Stable	Aerial sample	Davies <i>et al.</i> 1996	
Matobo NP		1997	Present			J. Anderson, in litt. 10/96	
Tuli SA		1997	Present			J. Anderson, in litt.10/96	
Mcllwaine and Kyle RPs		1997	Present			J. Anderson, in litt.10/96	
Private farms and game ranches		1996	10,480	Stable/ increasing	Informed guess	J. Anderson, in litt.10/96	
DAMARA			103,976				
(<i>E. b. antiquorum</i>)							
Botswana			34,200				
Makgadikgadi Pans GR and Nxai Pan NP	9,000	1994	12,190	Decreasing	Aerial sample	DWNP 1995	
Chobe NP-Moremi WR area	15,000	1994	17,260	Stable/ decreasing	Aerial sample	DWNP 1995	
Private farms and game ranches		1994	4,750	Decreasing?	Aerial sample	DWNP 1995	
Namibia			13,090				
Etosha NP	22,270	1995	8,920	Stable?	Aerial sample	W. and K. Gasaway, in litt. 8/97	
Kaudon GR			?			W. and K. Gasaway, in litt. 8/97	
Eastern Caprivi GR			?			W. and K. Gasaway, in litt. 8/97	
Private farms and game ranches		1992	4,170	Increasing	Mail survey	Barnes and de Jager 1996	
Swaziland			1,000				
Hlane GR		1994	250	Stable	Aerial and ground total	J. Culverwell, in litt. 7/94	
Mlawula NR		1994	50	Stable	Aerial and ground total	J. Culverwell, in litt. 7/94	

Appendix 3 ... continued. Plains zebra (*Equus burchellii*) populations by subspecies and country.

	Size (km ²)	Year	Number	Trend	Census method	Source of data
Swaziland ... continued						
Malolotja NR		1994	200	Increasing	Aerial and ground total	J. Culverwell, in litt. 7/94
Private farms and game ranches		1994	500	Increasing	Aerial and ground total	J. Culverwell, in litt. 7/94
Lesotho						
			EXTINCT			G. Castley, in litt. 7/97
South Africa						
			55,686			
<i>Northern, Gauteng, Mpumalanga</i>						
Kruger NP	21,682	1995	31,000	Stable/ increasing	Aerial total	Castley and Knight 1997
Marakele NP	399	1995	69	Stable/ increasing	Aerial and ground total	Castley and Knight 1997
Other provincial reserves		1995	5,000	Stable	Informed guess	B.K. Reilly, in litt. 5/95
Private farms and game ranches		1995	>5,000	Stable/ increasing	Informed guess	B.K. Reilly, in litt. 5/95
<i>Natal (excluding KwaZulu)</i>						
Hluhluwe-Umfolozi PP	965	1996	3,000	Increasing	Ground sample	A.J. Armstrong, in litt. 8/97
Vernon Crookes NR		1997	100	Increasing	Ground total	A.J. Armstrong, in litt. 8/97
Greater St Lucia WP	2,587	1996	300	Increasing	Aerial sample	A.J. Armstrong, in litt. 8/97
Mkuze GR		1996	1,150	Increasing	Ground sample	A.J. Armstrong, in litt. 8/97
Chelmsford Dam NR		1996	211	Increasing	Ground total	A.J. Armstrong, in litt. 8/97
Itala GR		1996	729	Increasing	Ground total	A.J. Armstrong, in litt. 8/97
Spioenkop Dam NR		1996	234	Increasing	Ground total	A.J. Armstrong, in litt. 8/97
Weenen NR		1996	160	Increasing	Ground total	A.J. Armstrong, in litt. 8/97
16 other provincial reserves (n<100/)		1997	495	Increasing	Ground total	A.J. Armstrong, in litt. 8/97
Private farms and game ranches		1997	4,580	Stable/ increasing	Ground total	A.J. Armstrong, in litt. 8/97
<i>Free State</i>						
Golden Gate Highlands NP	116	1997	107	Increasing	Aerial and ground total	Castley and Knight 1997
Qwa-Qwa NP	200	1994	182	Stable?	Aerial and ground total	Castley and Knight 1997
Sandveld NR		1997	100	Stable	Aerial total	P. Nel, in litt. 8/97
Tussen die Riviere NR		1997	150	Stable	Aerial total	P. Nel, in litt. 8/97
Six other provincial reserves (n<100/)		1997	224	Stable	Aerial total	P. Nel, in litt. 8/97
30 private farms and game ranches		1997	1,067	Stable/ increasing	Mail Survey	P. Nel, in litt. 8/97
<i>Northern Cape</i>						
Vaalbos NP	227	1997	144	Stable/ increasing	Aerial and ground total	Castley and Knight 1997
Rooipoort NR (private)	425	1997	540	Increasing	Aerial total	M. Berry, in litt. 7/97
One other provincial reserve		1997	20	Stable	Ground total	J. Koen, in litt. 8/97
<i>Eastern Cape, North-west</i>						
Addo Elephant NP	515	1997	24	Increasing	Ground total	Castley and Knight 1997
Other provincial reserves		1995	>100	Increasing	Informed guess	P.H. Lloyd, in litt. 10/95
Private farms and game ranches		1995	>1,000	Stable/ increasing	Informed guess	P.H. Lloyd, in litt. 10/95
Abbreviations:						
CL	Communal Lands	SA	Safari Area			
CHA	Controlled Hunting Area	WP	Wetland Park			
CP	Coutada Pública (Game Reserve)	WRA	Wildlife Research Area			
FR	Forest Reserve	WR	Wildlife Reserve			
GMA	Game Management Area	WS	Wildlife Sanctuary			
GR	Game Reserve					
HR	Hunting Reserve	EWCO	Ethiopian Wildlife Conserv. Org.			
NP	National Park	TWCM	Tanzanian Wildlife Cons. Monitor.			
NaR	National Reserve	NCAA	Ngorongoro Cons. Area Author			
NR	Nature Reserve	ROSA	Regional Off. Southern Africa			
PP	Provincial Park	NPWS	National Parks and Wildlife Service			
RP	Recreational Park	DWNP	Dept. of Wildlife and National Parks			

Disease: Selected Additional References

Parasites of wild equids

Zebras (Plains, Mountain, Grévy's zebras)

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