Shifting spatial distributions of Arabian oryx in relation to sporadic water provision and artificial shade

Yolanda van Heezik, Khairy Ismail and Philip J. Seddon

Abstract The spatial distributions of 20 female and 15 male Arabian oryx *Oryx leucoryx*, reintroduced into the fenced Mahazat as-Sayd protected area (2,244 km^2) in western Saudi Arabia between 1990 and 1994, were examined from their release until the end of 1999. Over this period we observed a westward shift in home range location of most male and female founder oryx to include the Rangers' Camp within core areas of activity, despite rain falling in patches throughout most of the reserve. Sporadic and unplanned availability of water had occurred at the Camp during several years. The pre-release enclosure was also located at the Camp, and high quality shading areas could be found underneath portacabins. Oryx that maintained independence of the Camp tended to be older individuals and those released in the first years (1990–1992). Concentration of oryx in the western part of the protected area and around the Camp could potentially reduce the effective carrying capacity of the reserve, change the social structure of the population, facilitate the transmission of disease, modify habitat in the form of a piosphere (a zone of attenuating animal impact away from a watering point) around the Camp, and reduce potential genetic flow within the reintroduced population. Whereas wild-born oryx were observed at the Camp, founders were disproportionately represented, suggesting that potential problems associated with dependence on the Camp may diminish as the total population increases and ages.

Keywords Arabian oryx, home range, *Oryx leucoryx*, reintroduction, Saudi Arabia, spatial distribution, water availability.

Introduction

Since their extirpation in the wild in the 1970s, three populations of Arabian oryx *Oryx leucoryx* have been established from captive individuals: one in Oman (Stanley Price, 1989) and two in Saudi Arabia (Ostrowski *et al*., 1998). The first reintroduction in Saudi Arabia occurred within the fenced Mahazat as-Sayd protected area in the west-central part of the Kingdom (Fig. 1) between 1988 and 1994. By May 2000 the Mahazat as-Sayd protected area had a population of *c*. 350 oryx (Seddon *et al*., 2003), some captive-bred (approximately 20–30) and the remaining the wild offspring of captive-bred and wild-born animals.

Precipitation in all areas where oryx have been reintroduced is highly stochastic with long periods of drought punctuated by pulses of rain, after which there are temporary pools of water. Arabian oryx have evolved physiological and behavioural mechanisms that reduce water expenditure in the desert so that they can survive independent of drinking water (Tear *et al*., 1997; Williams *et al*., 2001, Seddon & Ismail, 2002). Through its effect on vegetation growth, rainfall appeared to be the single most important factor in determining range use among reintroduced Arabian oryx in Oman (Stanley Price, 1989), although there were large variations in individual responses to rainfall, and patterns of changes in home range after different rainfall events (Corp *et al*., 1998).

The Mahazat as-Sayd protected area (2,244 km^2) was deemed large enough to support a population of oryx without the need for supplementary food and water. However, oryx have occasionally had access to water at the Rangers' Camp at the western end of the reserve, where the pre-release enclosure is also sited (Fig. 1). The Camp consists of accommodation and facilities for rangers and research staff in the form of prefabricated buildings (portacabins) and tents, which provide several good shading areas. In the summer of 1996 the Camp was a focus of activity for up to 40 oryx, with some individuals digging up and chewing pipes and entering tents (Ostrowski & Bedin, 1997). Some animals were reported to have regularly used waste water at the Camp for several years. By the beginning of summer 1997 waste water had been diverted into a septic tank, and a fence was built around the Camp to exclude animals, although some rangers often gave oryx water in the following summer, despite being instructed to the contrary, and animals continued to remain within

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Received 10 September 2002. Revision requested 14 January 2003. Accepted 19 May 2003.

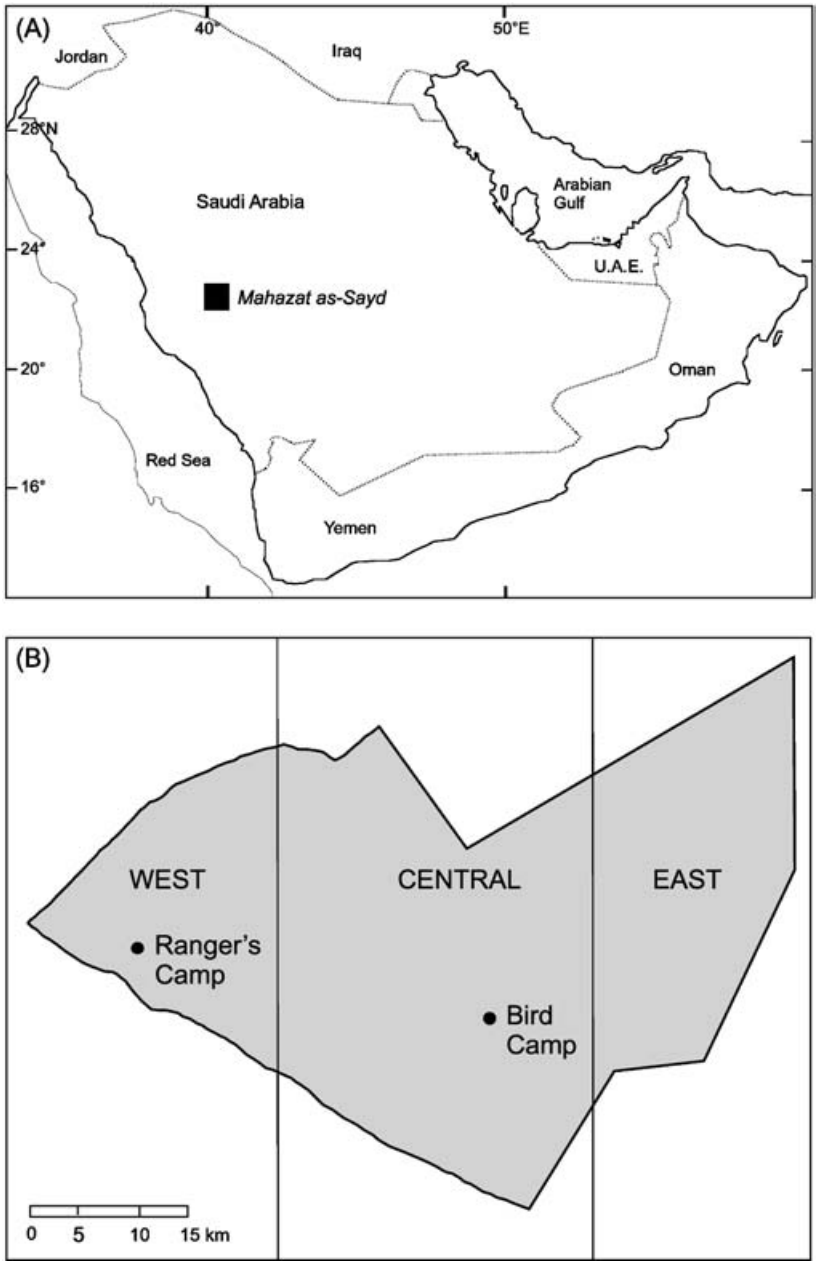

Fig. 1 (A) The location of the Mahazat as-Sayd protected area (2,244 km^2) in west-central Saudi Arabia, and (B) Mahazat as-Sayd, with the location of the Rangers' Camp and Bird Camp, and showing the areas designated as West (Universal Transverse Mercator coordinates 13800–16500), Central (16500–19000) and East (>19000).

0.2–3 km of the Camp, shading under trees, an old portacabin and a tent (Ismail, 1997). No records were kept of the amount of water provided nor the frequency with which it was made available. A second, smaller camp (Bird Camp) is located in the south-eastern part of the protected area (Fig. 1). Oryx were not released from this site, but water was also occasionally available due to burst pipes, and the Camp provided a good shading site.

In this study we examined changes in the spatial distribution of home ranges of a sample of 35 founder oryx released between 1990 and 1994, during the period 1991–1999, to determine the impact of the location of the camps and the sporadic availability of water on spatio-temporal use of the protected area.

Methods

Mahazat as-Sayd protected area

This completely fenced reserve of 2,244 km^2 was created in 1988 as a reintroduction site for oryx, gazelle (*Gazella* spp.) and houbara bustard *Chlamydotis* [*undulata*] *macqueenii*, and lies on a gently undulating open plain of sand and gravel on the eastern edge of the Nadj pediplain (Child & Grainger, 1990). There are no permanent

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water sources, although after heavy rains pools of water collect in depressions and may persist for up to several weeks. Vegetation consists of patchy cover of mostly dwarf shrubland with emergent small trees of *Acacia tortillis* and other *Acacia* species, as well as *Maerua crassifolia*. Perennial grasses include *Panicum turgidum*, *Lasiurus scindicus* and *Octhochloa compressa*, which are more abundant on deeper sand and low-lying ground, and *Stipagrostis* spp., which are more abundant in rocky areas. Many perennial shrubs such as *Haloxylon salicornicum* and forbs grow among the perennial grasses.

Weather data have been recorded systematically at two localities in the reserve since 1992. Mean monthly minimum and maximum temperatures were 6–25°C and 19–42°C, respectively, for 1992–1999. There was considerable inter-annual variation in the amount of rainfall during this period (Fig. 2). Because rainfall was recorded at only two locations up until 1996, it was not possible to determine reserve-wide patterns in the spatial distribution of rainfall. However, systematic transect surveys across the reserve during 1995–1999 and prior haphazard surveys indicated considerable annual variation in the spatial distribution of patches of rainfall and vegetation greenness, rather than any consistent year-to-year geographic patterns (Ismail, 1996, 1997; Seddon & Ismail, 1999).

Home range calculation

Annual home ranges were calculated for 20 females and 15 males, all captive-bred. Origin, sex, age and release details of these oryx are listed in Table 1. These individuals were selected because they provided long-term records of regular sightings, and there was no evidence to suggest they were behaving atypically with respect to the general population. Individuals belonged to herds made up of founder and wild-born individuals, the composition of which constantly changed throughout the study period. All oryx were kept for varying periods in a pre-release enclosure situated at the Rangers' Camp in the western part of the reserve, before being released. Rangers tracked released individuals to monitor survival and births, locating them at irregular intervals. Research staff collected further locations opportunistically. The mean number of locations used to calculate an annual home range was 36 (SD = 15.6, $n = 187$), and the protected area was divided into West, Central and East zones.

We estimated home ranges using the software *Ranges V* (Kenward & Hodder, 1996), in order to determine range use in relation to the location of the Rangers' Camp. The kernel home range estimator, which attempts to assess an animal's probability of occurrence at each point in space (Harris *et al*., 1990) was used to examine the location of cores of activity within home ranges. Five percent probability contours revealed in most cases either a single core of home range use, or two cores: a primary (larger) core and a secondary (smaller) core. In seven cases three cores were identified, but the third core never included the Rangers' Camp. Each individual's annual home range was thus categorized as (1) not including the Rangers' Camp; (2) the sole or primary core including the Rangers' Camp, and (3) the secondary core including the Rangers' Camp, with the primary core elsewhere (Fig. 3).

The influence of season on spatial distribution was examined by calculating home ranges for individuals during the coolest, wettest months (December–March, when mean maximum and minimum temperatures were 22–28°C and 12–14°C, respectively) and during the hottest, driest months (June–August, with mean maxima

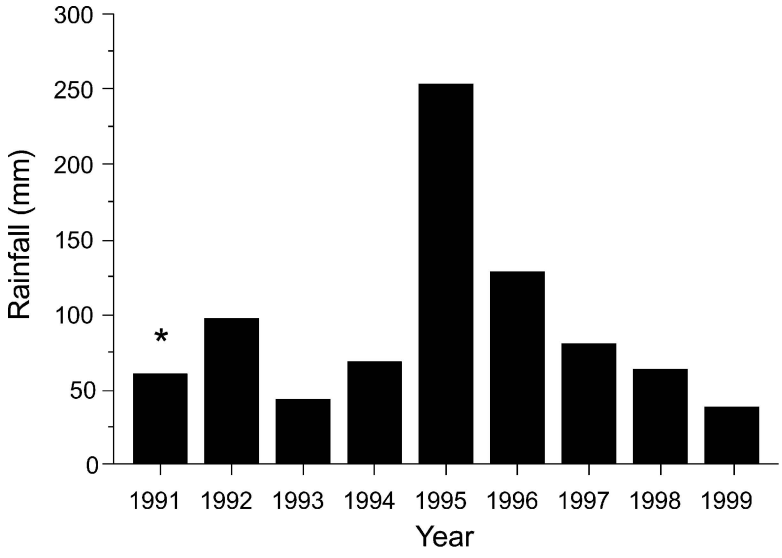

Fig. 2 Annual rainfall in Mahazat as-Sayd protected area, measured at a single locality. In 1991 no measurements were taken between 1 January and 8 April; to obtain an estimate of total rainfall for this year the mean value for these months over the years 1992–1999 was added to the total.

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Table 1 Origin, arrival date in the protected area, age at and date of release, and the percentage of years with home ranges centred around the Rangers' Camp, of 20 female and 15 male Arabian oryx in Mahazat as-Sayd protected area. All individuals were captive-bred. For dominance, ** indicates the dominant male of the group on most or all sightings, * the dominant male on some occasions, and – not recorded as dominant.

ID	Sex	Origin	Arrival date	Age at release (years)	Release date	% years with core around Camp	Dominance
101	F	Bahrain	June 1990	3.5	May 1992	100	
106	F	USA	Feb. 1992	3.0	Mar. 1993	0	
107	F	USA	Feb. 1992	4.0	Mar. 1993	75	
109	F	USA	Feb. 1992	8.5	Mar. 1993	100	
110	F	USA	Feb. 1992	3.5	Mar. 1993	43	
112	F	Taif	Nov. 1992		Mar. 1993	86	
114	F	Taif	Nov. 1992	1.0	Mar. 1993	57	
115	F	Taif	Feb. 1992	1.0	Mar. 1993	71	
118	F	Taif	Nov. 1992	1.0	Mar. 1993	71	
119	F	Taif	Nov. 1992	1.3	Mar. 1993	50	
120	F	Taif	Nov. 1992	1.0	Mar. 1993	86	
121	F	USA	Feb. 1992	3.5	Mar. 1993	100	
124	F	USA	Feb. 1992	7.0	Mar. 1993	50	
Ashire	F	USA	Nov. 1988	4.0	Mar. 1990	0	
Bushrah	F	USA	May 1990	3.0	Jan. 1991	22	
Mala	F	USA	Nov. 1988	3.5	Mar. 1990	0	
Mayu	F	USA	Nov. 1988	9.0	Mar. 1990	0	
Ramly	F	USA	May 1990	2.5	Jan. 1991	29	
Safa	F	Jordan	Mar. 1989	3.5	Mar. 1990	0	
Zahrah	F	USA	May 1990	3.0	Jan. 1991	33	
103	M	Taif	May 1991	2.0	Apr. 1992	72	*
104	M	USA	Feb. 1992	6.0	Mar. 1993	100	–
116	M	Taif	Nov. 1992	1.0	Mar. 1993	86	*
122	M	Taif	Apr. 1992	1.0	Mar. 1993	33	–
126	M	Taif	Oct. 1992	0.4	Mar. 1993	83	–
128	M	Taif	Oct. 1992	0.4	Mar. 1993	100	–
130	M	Taif	Dec. 1992	0.25	Mar. 1993	0	–
131	M	Taif	Nov. 1992	1.0	Mar. 1993	67	–
136	M	Taif	Sept. 1993	1.5	May 1994	100	**
145	M	Taif	Oct. 1993	1.3	May 1994	83	–
Achue	M	USA	May 1990	5.0	Jan. 1991	25	–
Badr	M	Taif	Feb. 1989	1.0	Mar. 1990	0	*
Jafr	M	Jordan	Nov. 1988	4.0	Mar. 1990	20	**
Sakr	M	Taif	Mar. 1989	1.0	Mar. 1990	0	*
Zain	M	Jordan	Mar. 1989	3.5	Mar. 1990	0	**

and minima of 40–41°C and 24–25°C, respectively). No rain fell between June and August in all years except 1992 (55 mm) and 1996 (3.1 mm). Generally, between 38 and 95% of the annual rainfall fell between December and March, except in 1992, when only 1% fell during this period. The locations of all years were combined for seasonal comparisons because sample size was often too small to calculate annual home ranges for each season.

Results

The 35 Arabian oryx were located over virtually the entire protected area during 1991–1999. However, the distribution of locations underwent a shift over time (Fig. 4). In 1990 and 1991 the largest proportion of locations were in the east of the reserve. Between 1992 and 1994 a greater proportion of locations were found in the west and central regions, and on from 1995 onwards there was an increasingly larger proportion in the west, with a concurrent decrease in the east.

Annual home ranges of both male and female oryx were more likely to include the Rangers' or Bird Camp within a core of activity with increasing time after release and during the years 1990–1999 (Fig. 5). Most animals visited the Rangers' Camp. Only one male visited Bird Camp regularly during 4 years, and another male during 1 year. Individuals of both sexes started visiting the Rangers' Camp in 1992; between 1994 and 1996 50–57% of the animals monitored were visiting the

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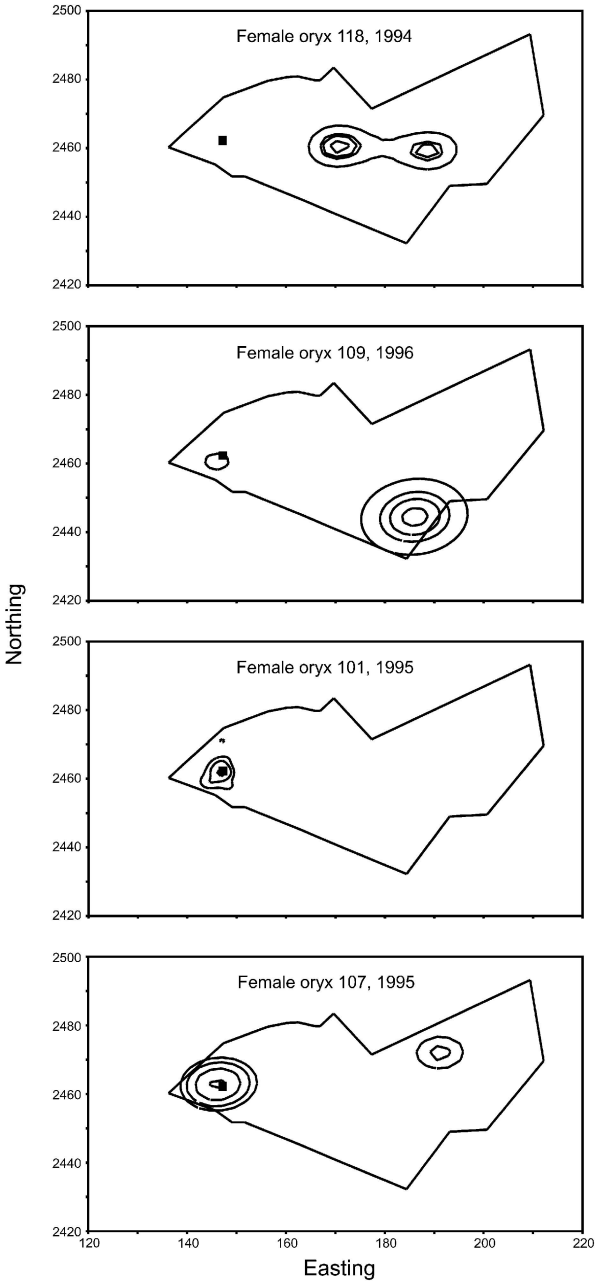

Fig. 3 The fenced protected area Mahazat as-Sayd and the Rangers' Camp (small square), showing examples of: a home range with two cores of activity away from the Camp (oryx 118), a primary core away from the Camp and a secondary core at the Camp (oryx 109), a single core at the Camp (oryx 101), and a primary core at the Camp with a secondary core away from the Camp (oryx 107). The contours are for 5, 25, 45 and 75% of locations; northing and easting are Universal Tranverse Mercator coordinates.

camps, increasing to 70–88% in 1997–1999. Proportions of male and female founders visiting the camps appeared to increase up until the 5th year after release (71% and 63%, respectively), and subsequently declined to 50–60% of the sample.

The proportion of males and females with a single or primary core of activity located around the camps tended to increase steadily from 1992 to 1999 (Fig. 6). Secondary cores of activity including the camps were first observed in 1994 among females and 1993 among males; their proportion remained small, and were no longer found among females after 1997.

Most females ($n = 13$) visited the Rangers' Camp during both the hot and cool months. Some ($n = 4$) visited only during the hot months, and remained away during the cool months; none were found at the Camp only in the cool months, and three didn't visit the Camp at all. Among those males that visited the Camp ($n = 11$), eight visited in both seasons, one only during the hot months, and two only during the cool months.

When males and females were combined, individuals released in the years 1990–1992 remained relatively more independent of the Rangers' Camp (>50% of years spent away from the Camp; Fisher's exact test, $P = 0.0016$; Table 1). A greater proportion of older oryx (>5 years in 1995) spent fewer years around the Camp (<50% of years) than did younger oryx (<5 years by 1995; Fisher's exact test, $P = 0.006$). There was no relationship between time spent in the pre-release enclosure and the proportion of years with a home range including the Camp ($R^2 = 0.062$, $P > 0.05$, $n = 35$). Males that never or infrequently visited the Camp were mostly more dominant individuals, found east or centrally in the reserve, although one dominant individual released in 1993 based its home range around the Camp (Table 1).

Discussion

Various arid-zone ungulates show migratory movements in the dry season, often towards areas with permanent water sources (Western, 1975; Rautenstrauch & Krausman, 1989). Arabian oryx are one of the few arid-zone ungulates apparently able to maintain independence of water sources during summer. They fulfil their water needs from their forage, spend the hot part of the day lying completely inactive under shade trees, conducting body heat into the ground to reduce water loss from evaporation, and they forage at night, selecting water-rich food species (Stanley Price, 1989; Asmodé, 1990; Spalton, 1999; Williams *et al.*, 2001; Seddon & Ismail, 2002). Food quality (crude protein and water content) peaks just after rainfall (Spalton, 1999), and oryx move quickly to areas of recent rain to take advantage of new grazing (Corp *et al.*, 1998). Rainfall was identified as the single most important factor determining range use among the reintroduced female oryx in Oman (Stanley Price, 1989; Corp *et al.*, 1998).

The predominant and consistent large-scale trend among the founder population in Mahazat as-Sayd

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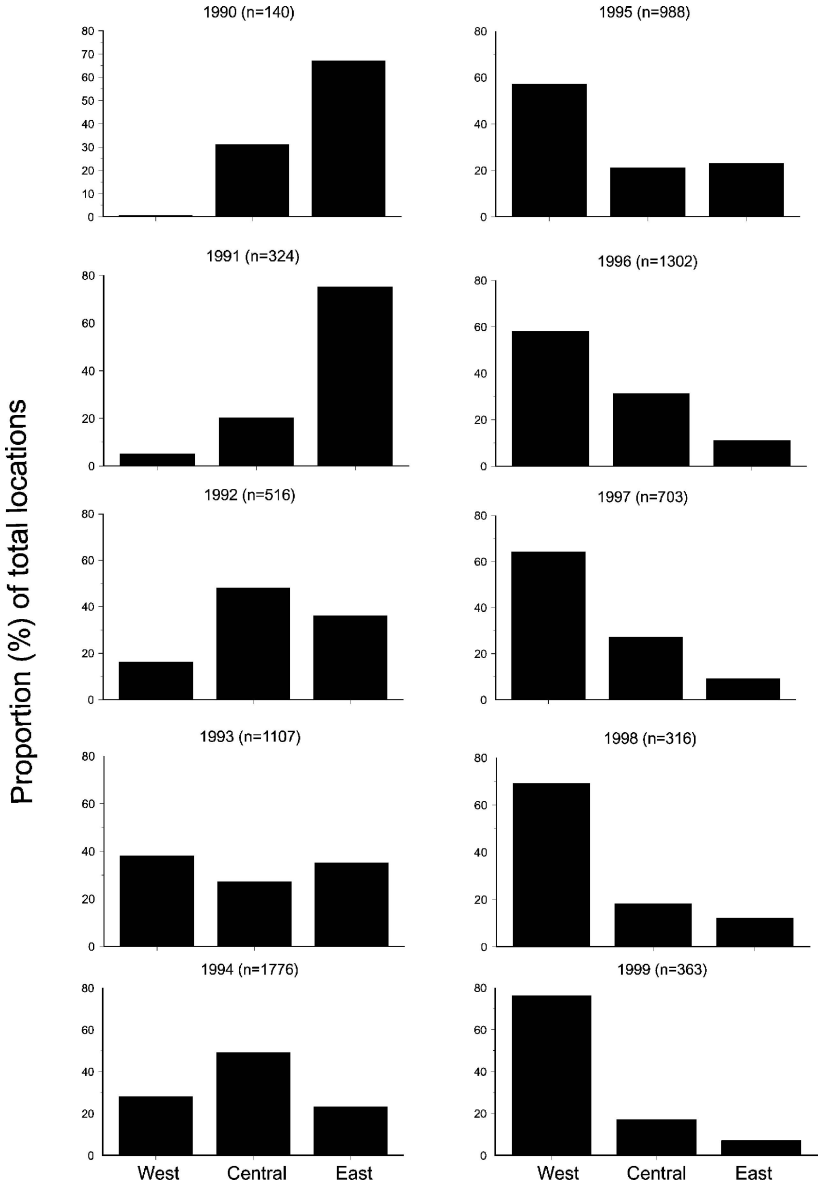

Fig. 4 Proportions of locations of Arabian oryx in the West, Central and Eastern parts of the protected area (see Fig. 1) from 1990 to 1999.

between 1992 and 1999 was a shift in distribution to the west of the reserve, unrelated to rainfall that fell patchily throughout the reserve during this period. Localized rainfall might have been responsible for inter- and intra-annual patterns in range use, but this westward shift involved an increasing proportion of animals including the Rangers' Camp in their home ranges, usually within a single or primary core of activity. Among females, secondary cores including the Camp occurred only between 1994 and 1997, suggesting the Camp initially played a minor role in influencing home range location, but progressively took on a more important role. The westward shift is unlikely to be attributable to a concurrent shift in effort by rangers and research staff, because the number of locations obtained annually for oryx that remained away from the Camp was not consistently lower than the average number of locations collected from all oryx each year. We suggest that intermittent and unpredictable access to water at the Rangers' Camp, as well as the availability of good quality shade provided by buildings, had a significant impact on the spatial distribution of oryx within the protected area. Sporadic and unpredictable water availability comprises a form of intermittent behavioural reinforcement that results in a response that is much harder to extinguish than if it was acquired during continuous reinforcement (Gleitman, 1986).

Bird Camp in the south-east lay within a core of activity for only one male during 4 years and another in 1 year, despite the availability of shade areas and

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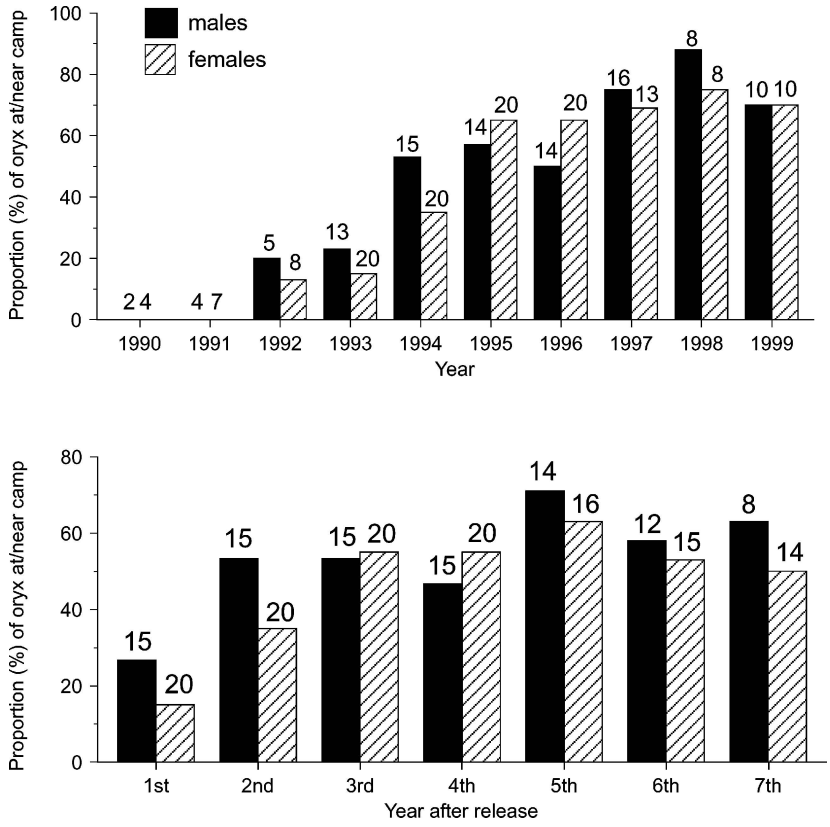

Fig. 5 Proportions of male and female Arabian oryx whose home ranges comprised a core of activity including either of the two camps, according to year, and number of years after release. Numbers indicate the total number of oryx in each case.

infrequent water. It is not completely clear why the Rangers' Camp was favoured so strongly over the smaller Bird Camp, but animals were actively discouraged from using Bird Camp for shade or water in at least some years (R. Maloney, pers. comm.). Release site fidelity may also play an important role in influencing distributions. Although we did not find any relationship between the time spent in the pre-release enclosure and the proportion of years that individuals included the Rangers' Camp in their home range, a disproportionate number of the oryx recorded at the Camp between 1996 and 1999 were founder individuals, suggesting animals may return to the site from which they were once provisioned, especially if range conditions deteriorate. Captive-bred individuals may lose out in competition with better-adapted wild individuals. This behaviour is then reinforced when food or water is occasionally made available. If this is the case, then detrimental impacts on reserve use caused by the concentration of animals at the Camp should be lessened as founder animals drop out of the population. Few reintroduced oryx in Oman returned to the release site, but these animals had a much larger unfenced area over which to forage, and most animals in the Omani population did not drink from the permanent water source at the release site even during drought conditions (Spalton, 1999). There were no consistent spatial trends in vegetation quality in Mahazat as-Sayd that would explain the westward drift. Records from driven transects quantifying vegetation greenness, carried out during 1995–1999, showed a pattern of spatially stochastic patchy greenness in response to local rainfall. The provision of water might not be the sole cause of the westward shift. Thirty-seven shade trees or rocks have been identified throughout the protected area, but unlike the shade provided by trees, which is related to foliage and canopy structure, the portacabins provide an area in which solar radiation is virtually absent between 08.00 and sunset. Animals are, figuratively, ''buried in a den'' (S. Ostrowski, pers. comm.).

Similar proportions of males and females (26 and 25%, respectively) remained independent of the Ranger's Camp. These were mainly individuals that were released in 1990 and 1991, and were mostly older individuals. Three of the four males that remained completely independent of the Camp were characterized as socially dominant individuals and remained in home ranges in the north-east and centre of the reserve. Four of the 15

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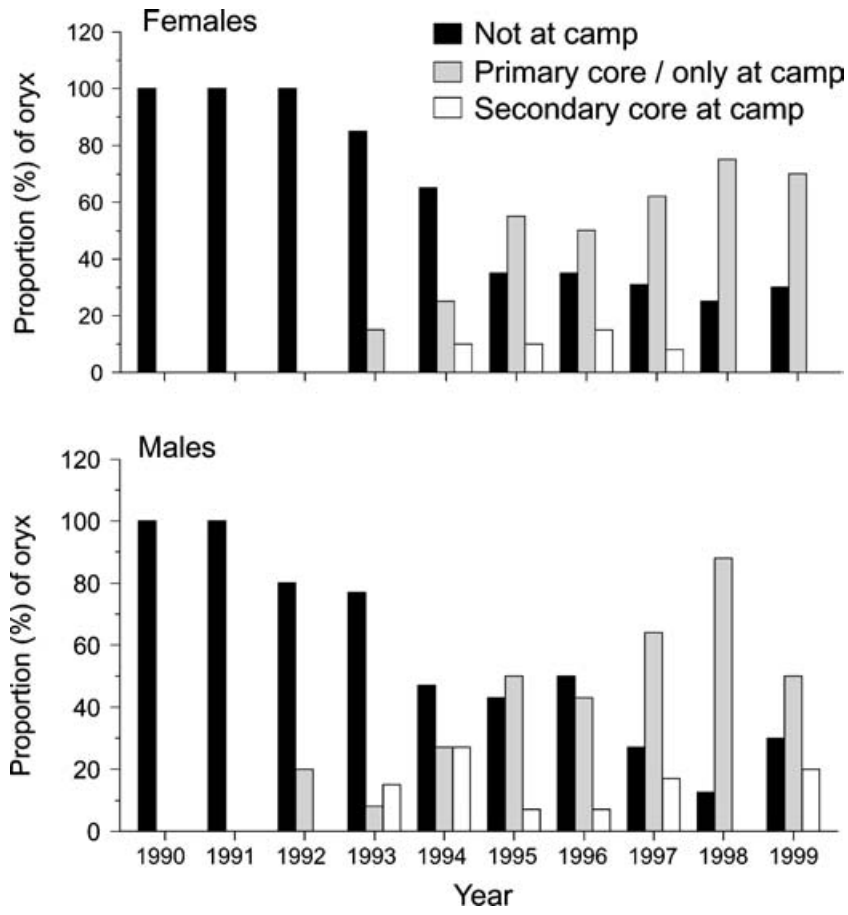

Fig. 6 Proportions of female and male Arabian oryx with a primary or single core of activity including either camp, a secondary core of activity, or none at all.

females that included the Camp within a core of activity did so only during the hot months of the year, possibly in response to reproductive status and the different energetic demands of lactation and gestation. Many animals did not limit their visits to the vicinity of the Camp to the hot months, because patches of rain fell in the region of the Camp during the wet cooler months in some years.

Occasional access to water at the camp has the potential to have far-reaching consequences with respect to range use, social structure, disease transmission and carrying capacity. Treydte *et al*. (2001) suggested, on the basis of a data-driven model, that should supplemental food and water be provided to the Mahazat as-Sayd population, birth and survival rates would remain high, allowing the population to grow when density-dependent factors would normally control population size, eventually having an adverse effect on the reserve through overgrazing. There is no evidence that overgrazing has occurred to date. For example, there is no discernible difference in vegetation between the interior and exterior of a large (4 km^2) enclosure that excludes oryx and gazelles, located at Bird Camp. Moreover, the population increased rapidly to *c*. 500 animals in 2002 after drought conditions eased (S. Ostrowski, pers. comm.), indicating an absence of density-dependent factors regulating population growth. However, an effective management scheme for the reserve should rely on a measure of the annual carrying capacity of the reserve (Treydte *et al*. 2001). Carrying capacity can be determined by monitoring forage quality and predicting annual intake (Williams *et al*., 2001), but should not assume that all forage is equally available to all individuals. Home range distribution needs to be taken into consideration when determining how many animals the protected area can support.

The shift in home ranges of founder oryx towards the western end of the reserve has resulted in a reduction in the effective carrying capacity of the reserve, even though habitat quality appears to be fairly homogeneous throughout. Some females remaining close to the Rangers' Camp throughout the year may never

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encounter some of the more dominant males, reducing potential genotypic variability in the population. The higher density of animals at the Camp, particularly in the shade sites, may facilitate the transmission of diseases.

Creating artificial watering holes can also have a significant impact on the surrounding habitat. In Wankie National Park, Zimbabwe, effects were diverse, affecting soil, vegetation, invertebrates and distribution of nutrients, all of which eventually alter the environment (Weir, 1971). The zone of attenuating animal impact away from a watering point is called a piosphere (Andrew, 1988). Piosphere patterns occur with respect to the accumulation of faeces, resultant increase in soil nutrients near the water and depletion further away, density of animal tracks, soil compaction, the amount of bare soil and the biomass and degree of defoliation of herbage (Andrew, 1988; Thrash *et al*., 1991a & b). The main cause of inefficient livestock distribution in rangelands is often an inadequate number of watering points, which should be used to redistribute animals for game viewing or habitat management (Andrew, 1988).

This study does not address whether wild-born individuals have shown the same westward shift, although wild-born oryx were recorded as regular visitors to the Rangers' Camp. Because wild-born oryx comprise an increasing proportion of the total population, if proportionately fewer individuals do not exhibit the same distributional shift, the impact of the concentration of animals at the Camp would decline as the total population increases and ages. However, as long as founder animals influence the movements of wild-born oryx, the effective carrying capacity of the protected area may remain depressed. This study illustrates the impact that lapses in management practices may have, potentially undermining the outcome of a conservation project. Managers need to decide on a strategy concerning water provision, and if supplementation is the policy, design watering points to optimize the efficient use of the reserve. An increase in aridity associated with climate warming, resulting in a decrease in available habitat for native ungulates, means that issues concerning water supply to populations within fenced or otherwise confined protected areas are likely to become increasingly pertinent.

Acknowledgements

We thank HRH Prince Saud al Faisal, General Manager, and Dr Abdulaziz H. Abuzinada, Secretary General of the National Commission for Wildlife Conservation and Development, for supporting this work, and the rangers of Mahazat as-Sayd and other National Wildlife Research Center staff for collecting oryx locations. The comments of Stephane Ostrowski and two anonymous referees greatly improved the manuscript.

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https://doi.org/10.1017/S0030605303000553 Published online by Cambridge University Press