A comparison of derived population estimate, mark-resighting and distance sampling methods to determine the population size of a desert ungulate, the Arabian oryx

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Abstract Post-release monitoring, including abundance estimation, is an important part of reintroductions, providing a basis for management intervention designed to achieve long-term persistence. The Arabian oryx *Oryx leucoryx* became extinct in the wild in 1972, surviving as captive populations. Since 1982 reintroductions of Arabian oryx have taken place in Oman and Saudi Arabia. Modelling of oryx population dynamics has highlighted the importance of precise estimation of population size (*N*). Between 1990 and 2000 three methods of estimating *N* have been applied in Mahazat as-Sayd protected area in Saudi Arabia: derived population estimates (DPE) based on known births and deaths, distance sampling, and mark-resighting (MR). This study assesses the feasibility and precision of these methods. Inability to assess precision, interdependence of consecutive estimates, and the assumption that all gains and losses are recorded, make DPE of limited value. At current densities, distance sampling along 455 km of driven transects yields too few detections to derive precise estimates of *N*. To achieve a coefficient of variation of 20% it would be necessary to drive up to *c.* 2,900 km of transect; this amount of survey effort could be achieved through pooling of data across repeat surveys of established transects. MR estimates, based on re-sighting of collared oryx, have the potential to yield the most precise estimates of *N* when the proportion of marked animals reaches 30% of the total population. The most reliable MR estimates available indicate the Mahazat as-Sayd Arabian oryx population had grown to >400 animals by 2000.

Introduction

The IUCN guidelines for reintroductions (IUCN, 1998) emphasize the importance of post-release monitoring. Such monitoring is essential in order to assess both the current status and the degree of management intervention necessary to achieve long-term persistence of a re-established population (Seddon, 1999). A key objective for post-release monitoring is to determine the abundance of the target species, either as an index of relative abundance, or an estimate of absolute density (Krebs, 1999).

The Arabian oryx *Oryx leucoryx* was extirpated from central Saudi Arabia in the early 1900s (Carruthers, 1935) and was hunted to extinction in the wild by 1972 (Henderson, 1974). This left only captive populations as founders for reintroduction programmes in Oman (Stanley Price, 1989) and Saudi Arabia (Ostrowski *et al.*, 1998). Although it is a white, relatively large ungulate, occupying open landscapes, the Arabian oryx roams at low densities over vast areas and thus accurate estimation of population size is difficult. In the Jiddat al-Harasis region of Oman, site of the first reintroduction of Arabian oryx in 1982, the free-ranging population was assessed until 1993 through regular monitoring of all individuals (A. Spalton, pers. comm.). Regular and frequent monitoring of oryx movements and demography provide a basis for assessing population size when the population is relatively small and all animals can be accounted for. However, as a population increases in size, precise assessment becomes more difficult. Derived estimates, based on known births and deaths, may lack the precision and thus the power to detect population trends. From 1990, when the Omani population numbered *c.* 100 animals, attempts were made to estimate total population size using the mark-resighting technique, and this method was used exclusively from 1993 when absolute counts were no longer possible (A. Spalton, unpub. data). At its peak in 1996 the Omani Arabian oryx population was estimated to number *c.* 400 free-ranging animals, using over 16,000 km^2 of the Arabian Oryx Sanctuary (Spalton *et al.*, 1999).

Between 1990 and 1994 a total of 72 Arabian oryx were released into the Mahazat as-Sayd protected area in western central Saudi Arabia (Fig. 1). Individuals came

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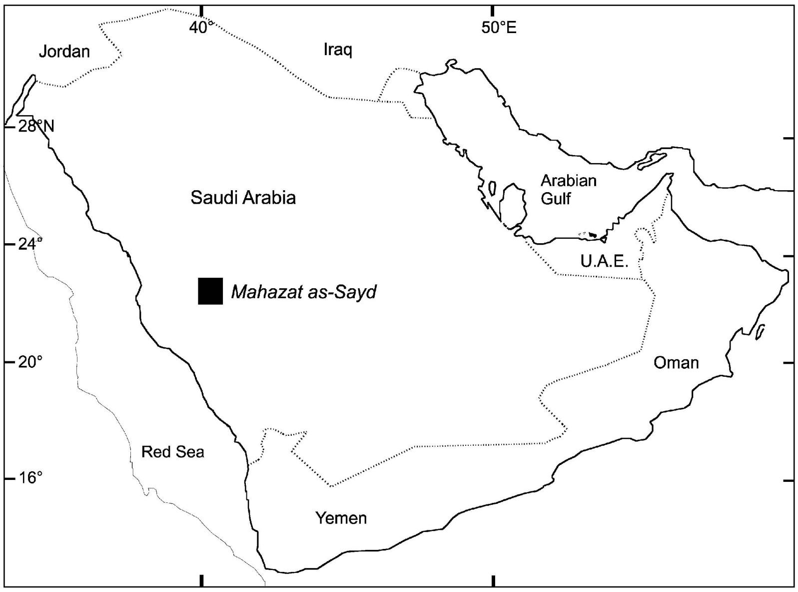

Fig. 1 The location of the Mahazat as-Sayd protected area (2,244 km^2) in west-central Saudi Arabia.

from foreign private or national collections in Jordan, Bahrain, Qatar, Switzerland, Germany and the USA, and from the captive-breeding programme at the National Wildlife Research Center in Saudi Arabia (Ostrowski *et al*., 1998). Mahazat as-Sayd was the first reintroduction site for Arabian oryx in Saudi Arabia, and now holds the largest semi-natural population in the world. With the aim of ensuring the long-term persistence of this key population Treydte *et al*. (2001) developed a model to evaluate the probability of extinction of the Mahazat as-Sayd Arabian oryx population under various management strategies. They concluded that the most successful management plan, i.e. that resulting in low probabilities of extinction and small fluctuations in total population size, consisted of removing all oryx above 70% of annual carrying capacity (Treydte *et al*., 2001). This strategy would require annual assessment of population size with reasonable precision.

This study compares three approaches to the estimation of population size of Arabian oryx within Mahazat as-Sayd. The three methods were population size derived from known births and deaths, distance sampling using driven transects, and mark-resighting methods to calculate a Lincoln index. In addition, a one-day 'total' count was attempted in order to yield a mark-resighting population estimate with relatively high precision.

Study Area

In 1988 the Mahazat as-Sayd protected area was designated a Special Natural Reserve, Saudi Arabia's highest level of protection for protected areas (Child & Grainger, 1990). In 1989 the entire 2,244 km^2 was fenced to exclude livestock. The enclosed area lies within the western central Saudi Arabian plateau (Fig. 1), and consists of an undulating plain of sand and gravel, with scattered rocky outcrops of basalt. Previously overgrazed vegetation recovered rapidly after enclosure, and now comprises extensive, patchy dwarf shrubland with emergent small trees of *Acacia* spp. and *Maerua crassifolia* (Fisher *et al*., 1998). The climate of the region is characterized by hot summers (maximum ambient temperatures frequently $>45°C$) and sparse, highly variable rainfall (mean annual rainfall measured within the reserve is <100 mm) (Treydte *et al*., 2001).

Methods

Derived population estimate

Since 1990, rangers stationed permanently in Mahazat as-Sayd have monitored births and deaths of individually identifiable oryx. Based on the size of the founder population and by adding births and subtracting deaths, the rangers are able to derive monthly estimates of total population size. The underlying assumption is that the rangers are able to account for every birth and every death through their daily programme of haphazard survey drives within the protected area.

Distance sampling surveys

The increasing size of the Mahazat as-Sayd oryx population, and the increasing proportion of unmarked, wild-born animals, raised concerns by 1995 that a derived population estimate was no longer either an adequate or accurate means of assessing population size or trends. Systematic surveys, mostly monthly, were therefore started in 1995. Because commitment of vehicles and personnel necessary for monthly counts could not be sustained beyond 1997, no surveys were made in 1998, but surveys were recommenced from 1999, and conducted twice a year to provide pre- and post-summer population estimates.

Unlike strip transects, which require the assumption that all objects of interest are detected within a predefined strip each side of the transect line, distance sampling assumes only that objects directly on the centre of the transect line are never missed. Thus the major advantage of distance sampling is that it takes into account the decreasing ability of the observer to detect objects with increasing distance from the survey line. As objects are detected, their perpendicular distance from the transect is recorded, and through the fitting of a detection function to the distance data, an estimate of density can be made (Buckland *et al*., 1993). If the size of the sample area is known, density estimates can be converted into estimates of sample population size. Distance sampling techniques have been applied to estimate the density of a wide variety of taxa, including benthic fishes (Ensign *et al*., 1995), ant mounds (Forbes *et al*., 2000), reptiles (Dickinson & Fa, 2000), birds (Buford *et al*., 1996; Gillings *et al*., 1998; Guix *et al*., 1999; Marsden, 1999), and mammals (Hein, 1997; Corn & Conroy, 1998; Heydon *et al*., 2000).

A total of 14 north-south transects were established, systematically traversing the protected area between its northern and southern boundary fences. Transects were placed at regular intervals every three minutes of longitude, equivalent to *c.* 5 km apart. The same 14 transects were used in all surveys. Teams consisting of a driver/observer and at least one additional observer were assigned one or more transects to be driven between approximately 06.00 and 13.00 on the specified survey day. In general, oryx are less easily observed in the afternoons, when they seek shade (Seddon & Ismail, 2002).

Transects were kept as straight as possible within the limits imposed by the rugged terrain, by reference to a dash-mounted compass, Geographical Positioning System and natural landmarks. At each sighting of oryx the time, group size and composition, presence and identity of any marked animals, and the perpendicular distance from the transect line to the location at first sighting of the individual oryx or the centre of each group of oryx were recorded. As range-finding equipment was not available, perpendicular distances (the distance between the transect line and the exact point at which oryx were first seen, located for long distances using oryx tracks or adjacent landmarks) were estimated or paced when within 50 m of the transect line. From 50 m to 3.3 km (the maximum recorded) perpendicular distances were measured by vehicle odometer to the nearest 50 m. On average, each survey entailed driving a total of 455 km of transects.

For each survey the raw data, consisting of sightings and perpendicular distances were plotted as number of observations in 20 equal-sized perpendicular distance intervals, facilitating the identification of any outlying observations at extreme distances, or the presence of clumping, and thus indicating appropriate levels of truncation and grouping for detection function fitting. Examination of scatter plots of cluster size and perpendicular distance indicated no evidence of cluster size detection bias, whereby small groups of oryx might have been less easily detected at longer distances from the transect line.

After truncation and grouping, as recommended in Buckland *et al*. (1993), data were analysed using the software *Distance* (Distance, 2003), in two stages. The first involved fitting of alternative models (key function + adjustment terms) for the detection function curve, using the Akaike Information Criteria (AIC) to choose between competing models (Burnham & Anderson, 1998). The second stage used the most parsimonious model to derive an estimate of oryx population size, based on a total study area size of 2,244 km^2. The precision of the resulting estimate was estimated by the 95% confidence interval.

Low numbers of detections within given surveys, particularly when oryx densities were relatively low, made fitting of detection functions difficult, and resulted in low precision of estimates. One solution is to pool distance data across surveys to derive a single estimate of abundance for a given year. Pooling across surveys assumes that $f(0)$, the value of the probability density function at zero distance, is constant over time. Potentially there could be differences in the ability of observers to detect oryx, arising from seasonal changes in behaviour such as increased shading in hotter conditions. To explore the validity of pooling data across surveys, evidence of seasonal variation in detection function was examined by creating two strata: cool conditions (December 1995–March 1996; $n = 34$ observations) and hot conditions (June–August 1996; $n = 30$ observations). The detection function was fitted to the data pooled across seasons, and in separate analyses by season. The sum of the AIC values across seasonal strata was found to be greater than the AIC value from the pooled strata, indicating that the detection function did not differ between season, and that pooling of data was justified (Buckland *et al*., 2001).

Mark-resighting estimates

An application of the mark-resighting method known as the Peterson method or Lincoln index (Greenwood, 1996) assumes that a known-sized sample of the free-ranging population is marked and therefore identifiable. It is appropriate for the estimation of the size of closed populations, i.e. populations for which there has been neither gain (immigration and births) nor loss (emigration and deaths) between marking and re-sighting. Mahazat as-Sayd is fenced and so no immigration or emigration is possible. A summary of known collared oryx was compiled in the week before each survey, and only those tagged oryx seen within the last 4 weeks were included in the analysis. We assume therefore that the Mahazat as-Sayd oryx population was effectively closed between marking and re-sighting.

A programme of darting and tagging free-ranging oryx has ensured that at any time *c.* 10–20% of the population is marked with individually numbered collars. Collars were chosen as the method of marking as they have lower rates of loss compared with ear tags, and are easier to read in the field. Re-sighting took place in conjunction with distance sampling during driven survey transects. Observers recorded the total number of oryx seen closely enough to discern the presence of collars, and the total number with and without collars.

An estimate of population size (N) was calculated (Seber, 1982) as $N = [(n_1 + 1)(n_2 + 1)/(m_2 + 1)] - 1$, where: n_1 = the number of marked animals, n_2 = the number of animals seen closely enough to discern tags, and m_2 = the number of marked animals seen during the survey. The variance for each estimate was calculated as $[(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)]/[(m_2 + 1)^2(m_2 + 2)]$ and 95% confidence intervals as $\pm 1.96\sqrt{\text{variance}}$.

'Total' count

In December 2000 an attempt was made to conduct a total count of Arabian oryx in Mahazat as-Sayd. In effect however, because it is not feasible over a relatively short period of time to locate every oryx within the 2,244 km^2 area, the total count served as a high intensity re-sighting session to derive a mark-resighting estimate of population size with relatively high precision. The protected area was divided into nine sectors of unequal size and shape, based on topography and delimited by major tracks, fence gates, and other readily observable features. One vehicle, each with a driver, or a driver/observer team, was assigned to each sector. In principle, more than one vehicle could be used to census a sector. No set routes were defined, and there were no time limits for the census in any given sector. Teams were directed to attempt to locate as many oryx as they could within their sector, using a combination of haphazard transects, scanning from vantage points, checking of known shade trees and other favoured sites. At each sighting of oryx the time, location, group size and composition, and the number of tagged and untagged animals were recorded.

Results

Estimates of the size of the Mahazat as-Sayd Arabian oryx population are presented in Table 1. For 1990–1994 only derived population estimates are available. From May 1995 estimates are available from distance sampling, and from September 1995 using the mark-resighting method. The most recent date for which estimates are available based on all three methods is November 2000, with estimates of a population size of 405, 484 and 398 using the derived population estimate, distance sampling and mark-resighting methods, respectively. Note that a confidence interval cannot be calculated for derived population estimates, and that in general the 95% confidence interval is narrower for estimates based on mark-resighting than for those based on distance sampling.

Fig. 2 illustrates the annual estimates of the size of the oryx population between 1990 to 2000, based on the most precise estimate available for each year. From 1997 onwards the population size appears to have levelled off at a little over 400.

Discussion

Although population estimates for Arabian oryx in the Mahazat as-Sayd protected area derived from known births and deaths were not inconsistent with more statistically rigorous methods of estimation (Table 1), the approach suffers from four shortcomings. Firstly, a given estimate is dependent on the previous estimate, from which deaths have been subtracted and births added; thus errors may be perpetuated and biases expanded over successive estimations. Secondly, determination of the precision of derived population estimates is not possible. Thirdly, the assumption that all births and deaths are accounted for has not been tested, and may be expected to vary with population size. Fourthly, the presumed accuracy of derived population estimates will depend on sustained search effort relative to population size. Decreases in funding, personnel numbers or experience, or logistic support will reduce search effort and may lead to violation of the assumption of complete coverage, reducing the accuracy of the estimate to an unknown degree. The regular and frequent monitoring of the oryx in Mahazat as-Sayd will, however, yield information on distribution, body condition, age and sex

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Table 1 Estimates of the size of the Arabian oryx population in the Mahazat as-Sayd protected area over 1990–2000, using three methods: derived population estimate (DPE), distance sampling (Distance), and mark-resighting (MR).

Year	Month	DPE[1]	Distance	95% CI[2]	MR[3]	95% CI[2]
1990	Dec	31	no count		no count	
1991	Dec	42	no count		no count	
1992	Dec	89	no count		no count	
1993	Dec	125	no count		no count	
1994	Dec	166	no count		no count	
1995	May	171	140	30–610	no count	
	June	198	194	48–790	no count	
	Aug	196	95	25–380	no count	
	Sep	222	no count		230	192–268
	Dec	219	64	22–188	no count	
1996	Jan	232	no count		167	89–245
	Feb	236	835	205–3,415	306	214–398
	Mar	237	220	55–850	173	118–228
	Apr	239	230	60–880	229	159–299
	May	248	240	85–690	220	155–285
	June	251	200	85–460	330	170–490
	Jul	253	no count		225	100–355
	Aug	257	106	38–302	282	153–411
	Sep	262	510	120–2,162	373	214–532
	Oct	265	418	128–1,363	294	179–409
	Nov	274	131	52–331	299	168–430
	Dec	286	152	58–391	326	174–478
1997	Jan	291	142	31–647	377	199–555
	Feb	296	542	153–1,921	378	208–548
	Apr	302	286	105–780	379	242–516
	May	304	240	69–834	524	261–787
	Jun	307	77	31–192	539	111–967
	Jul	313	236	96–577	587	196–978
	Aug	325	152	52–448	383	183–583
	Dec	351	350	146–835	471	314–590
1998	Jan	356	no count		no count[4]	
	Dec	407	no count		no count	
1999	Jun	429	146	50–431	303	158–448
	Nov	416	306	133–702	427	249–605
	Dec	416	no count		no count	
2000	May	412	458	171–1,227	346	273–419
	Nov	405	484	215–1,091	398	177–619
	Dec	405	no count		444[5]	333–555
2001	May	430	no count		623	344–902
	Nov	no data	335	182–617	737	329–1,143

[1]DPE = population estimate derived from known births and deaths.
[2]95% Confidence Interval.
[3]Mark-resighting estimate.
[4]Logistical problems prevented the completion of surveys in 1998.
[5]Derived from 'total' count survey (see text for details).

specific birth and death rates, and individual fecundity, and thus remains an important source of information for management of the herd.

The application of distance sampling methods to population estimation of Arabian oryx is intuitively attractive. Arabian oryx are relatively large and white and, except when in deep shade, visible over large areas of open desert. However, oryx live at relatively low densities, and consequently detection rates per survey were low, and the resulting estimates have disappointingly wide 95% confidence intervals. Thus the power of the current system of limited transect sampling to detect even modest changes in population size is low. Two possibilities are available to increase the precision of distance sampling: increase the distance driven during each survey and thus increase the rates of detection, or pool distance data across surveys to derive a single estimate.

The coefficient of variation of the density estimate $cv(D) = SE(D)/D$), where D is density, is another measure

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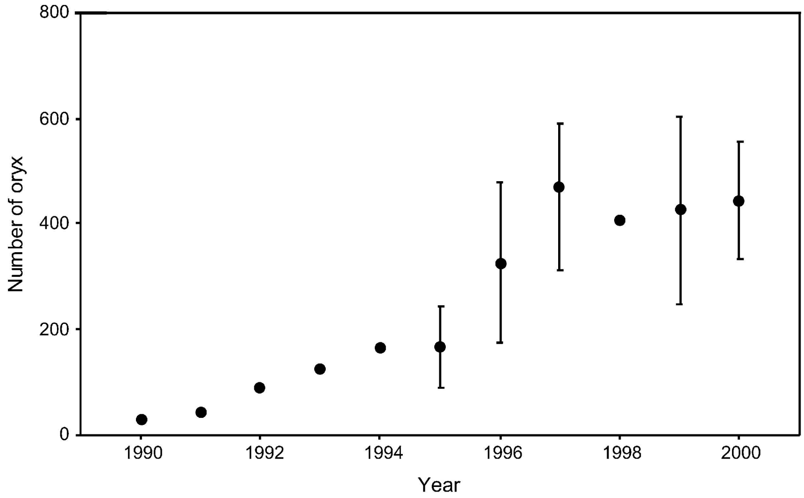

Fig. 2 Estimates of the population size of Arabian oryx in the Mahazat as-Sayd protected area between 1990 and 2000. Estimates are presented for December each year, except for 1995 when the nearest estimate was January 1996. Closed circles without error bars represent derived population estimates based on known births and deaths; errors bars are 95% confidence intervals around mark-resighting estimates derived from driven transects (1995, 1996, 1997, 1999) and an intensive reserve-wide 'total count' in 2000 (see text for explanation).

of precision, and was 30–51% for the surveys, this imprecision being a result of low numbers of detections per survey. Over 24 surveys the mean number of detections of groups or single oryx was 14 (SD = 6.4, range 7–29). It is possible to calculate the transect length (L), and thus sample size, necessary to achieve a given level of precision ($cv(D)$), based on recorded detection of n_0 objects over a total line length of L_0, and using the actual $cv(D)$ derived from the survey data (Buckland *et al.*, 2001), as $L = L_0\{cv(D)\}^2/\{cv_t(D)\}^2$, where cv_t is the target value for the coefficient of variation. Calculating L for the lower and upper $cv(D)$ derived from survey data, with $cv_t = 20$, gives 1,024 and 2,959, respectively, and thus to achieve a coefficient of variation of 20% it would be necessary to drive between 1,024 and 2,959 km of transect, depending on detection rates.

Results indicated that pooling of data is justified as there is no evidence that the detection function differed between seasons. Pooled population estimates (Table 2) indicate that greater precision is obtainable when surveys are combined. However, estimates derived from pooled surveys over an entire year may violate the assumption that the population is stable within the time period encompassed by the surveys. Pooled estimates could therefore be insensitive to rapid population expansion or contraction.

Given the sparse distribution of oryx, an alternative approach would be to apply distance sampling methods to count oryx dung and thus estimate oryx density indirectly. Surveys of dung have been used to derive estimates of population size for a number of species, including elephant *Loxodonta africana* (Barnes *et al.*, 1995;

Table 2 Annual estimates of the size of the Arabian oryx population (N) in the Mahazat as-Sayd protected area, over 1995–1999 using distance sampling (see text for details). Estimates are derived for a given year by pooling data from repeat surveys (see Table 1 for number of surveys conducted annually).

Year	N	n[1]	%CV[2]	95% CI[3]	Effective Strip Width (m)	Effort (km)[4]
1995	66	43	27.16	38–114	866	2,270
1996	275	140	17.73	193–392	474	5,422
1997	218	73	24.62	134–355	660	2,751
1998		no count				
1999	200	36	45.00	78–515	601	910
2000	465	55	31.31	248–874	533	916

[1] n = number of observations (sightings of clusters of oryx) pooled over all surveys within each year.
[2] %CV = percentage coefficient of variation.
[3] 95% CI = 95% Confidence Interval.
[4] Effort = total length of transects driven.

Barnes, 2001), feral pigs *Sus scrofa* (Hone & Martin, 1998), white-tailed deer *Odocoileus virginianus* (Fuller, 1991), red *Cervus elaphus* and roe deer *Capreolus capreolus* (Latham *et al.*, 1997), fallow deer *Dama dama* (Bailey & Putman, 1981), and sika deer *Cervus nippon* (Marques *et al.*, 2001). In principle the method is straightforward; dung density is estimated using perpendicular distances (often small) from a transect line to the centre of every pellet group located (Buckland *et al.*, 2001). However, conversion of estimates of dung density to estimates of animal density requires estimates of defecation rates and dung decay rates (Buckland *et al.*, 2001). Decay rate may vary spatially (Marques *et al.*, 2001), as well as seasonally (Plumptre & Harris, 1995; Nchabji & Plumptre, 2001), and possibly also annually in a desert environment with variable rainfall. It would therefore be necessary to determine decay rates (Buckland *et al.*, 2001) for dung piles on the ground at the time of the survey. Defecation rates can be estimated through the observation of wild or, more easily, captive individuals (Buckland *et al.*, 2001), although defecation rates of some species may reflect seasonal variation in diet (Rogers, 1987; Mattson *et al.*, 1991), and significant changes in diet and defecation rates may exist between captive and wild individuals (Rogers, 1987). At the present time these various difficulties almost certainly preclude the use of this method to estimate the size of the oryx population in Mahazat as-Sayd.

The Lincoln index assumes that the population is effectively closed during the survey period, no marks are lost, and all animals are equally catchable. Because many mark-resighting programmes rely on passive capture techniques, the assumption of equal catchability may easily be violated. However, the programme of darting and tagging oryx in Mahazat as-Sayd allows specific individuals and age or sex classes to be targeted, and re-sighting of marked animals does not require recapture or handling. Mark-resighting techniques also assume that there is no heterogeneity in re-sighting probability for different age or sex classes; for oryx, marked and unmarked individuals are readily identified within mixed age and sex groups. Darting, regular review of the status of tagged animals and the perimeter fence provide confidence that the assumptions required for successful mark-resighting sampling are upheld.

Ongoing tagging has meant that *c.* 20% of the population has been marked in recent years. On average 71 oryx were located during each survey (SD = 32.8, range 25–156, $n = 24$ surveys), the majority of which are observed closely enough to discern tags. The calculation of percent relative precision (*PRP*), the difference between the estimated population size (*N*) and its 95% confidence intervals (CI), enables comparison between different situations (Greenwood, 1996), where $PRP = 50(CI_1 - CI_2)/N$, and 1 and 2 are the upper and lower values of the confidence interval, respectively. It is possible therefore, for example, to compare the estimate derived from the November 2000 survey along the distance sampling transects ($PRP = 56\%$), with the more complete coverage attempted in the December 2000 'total' count ($PRP = 25\%$). As with distance sampling, it is possible to calculate the required sample sizes of marked and re-sighted oryx to achieve a given *PRP* (*Q*) (Greenwood, 1996), where $Q = 200\sqrt{(N/n_1 n_2)}$, and n_1 is the number of marked animals and n_2 the number of animals seen closely enough to discern tags. Assuming a population size of 400 oryx, a *PRP* of *c.* 25% could be achieved by tagging 120 oryx (30% of the population) and detecting 200 oryx (50%) during a given survey. As *c.* 20% of the population is currently tagged, and the December 2000 count detected 191 oryx, it would be feasible to aim for estimates with this level of precision.

Regular monitoring of the oryx by rangers should be maintained to obtain information on population parameters, but the derived population estimate is of limited utility and probably able to detect only very large population fluctuations. At present densities, detection rates of oryx during transect surveys are too low to yield estimates of acceptable precision using distance sampling analysis of single surveys. Increased precision of estimates may be obtained by pooling of distance data across repeat surveys, but care is needed to ensure that only surveys during periods of relatively stable population size are pooled. The use of a light aircraft to conduct large-scale transect counts of Arabian oryx should be investigated, as this would provide a means to cover more ground in a given time and thus increase sample size.

Reasonably precise population estimates may be achieved using mark-resighting methods, with increased precision possible through tagging of a greater proportion of the population, and/or attempts to detect a greater proportion of the population during surveys. For species in which heterogeneity of re-sighting probabilities is perceived to be a problem, the use of log-based confidence intervals (Buckland *et al.*, 2001) may provide better estimates of precision. The use of strict transect surveys will limit the numbers of animals detected, although subsidiary information on vegetation status, for example, may be collected during such surveys. A 1-day, haphazard ground search within defined sectors, as undertaken in December 2000, may yield a population estimate with good precision, and with acceptable and sustainable application of resources. For current management purposes it would be appropriate to mount a major survey effort once, at the same time each year, to obtain a precise estimate of the Mahazat as-Sayd Arabian oryx population. A count in November or December each year would avoid the hot period of the year during which shading by oryx early in the day can potentially make animals less visible, although reduced visibility due to animals sheltering in cold weather can also be a problem (A. Spalton, pers. comm.). Additionally, a winter count would take into account the mid-summer period of potentially increased calf mortality during dry years (Treydte *et al*., 2001), and would enable assessment of inter-annual trends. These results are applicable for the monitoring of Arabian oryx reintroduced into other areas within their former range, and for other desert ungulates that are the focus of reintroduction or other intensive management programmes.

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Khairy Ismail has worked within the Mahazat as-Sayd protected area since its creation in 1989, and has been involved in all phases of the reintroduction of the Arabian oryx. He also directs the monitoring of reintroduced sand gazelle within the reserve.

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