Restoration of the endangered Arabian Oryx *Oryx leucoryx*, Pallas 1766 in Saudi Arabia: lessons learnt from the twenty years of re-introduction in arid fenced and unfenced protected areas

(Mammalia: Artiodactyla)

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Abstract. In Saudi Arabia, a conservation and restoration programme for Oryx *Oryx leucoryx*, Pallas, 1766 was started in 1989 by the Saudi Wildlife Commission (formerly the National Commission for Wildlife Conmservation and Development). Concurrent conservation programmes were launched for the protection of large areas within the former range of the Arabian Oryx, and captive breeding at the National Wildlife Research Center (NWRC). Together, these have enabled the restoration of wild self-sustaining populations of Arabian Oryx in Saudi Arabia using animals from the 'World Herd' to improve their genetic variability. The success of the oryx conservation programme is described here together with the constraints faced in the arid environments and the consequent lessons learnt. As rainfall has a strong influence on the presence of annual plants, it is the single most important factor in the production of grazing. Poor rainfall had a major detrimental impact on forage in the re-introduction sites from 1999 to 2008 and mortality of oryx was higher during this period. As oryx historically moved over great distances in response to rain, the fence around one site, the Mahazat as-Sayd Protected Area, prevents natural movements of animals and artificially concentrates ungulate populations into seasonally unfavourable habitat. We propose some management strategies to minimize mortalities in the wild, and assesses post-release monitoring and adoption of various estimation techniques to assess oryx populations in both the fenced and free-ranging areas. As poaching is still a problem, strict law enforcement and a public-awareness programme to inform citizens of the biological and historical significance of the Arabian Oryx is recommended.

Key words. Arabian Oryx, reintroduction success, drought related mortalities of ungulates, species management strategy, Saudi Arabia.

Introduction

The Arabian Oryx (*Oryx leucoryx*, Pallas 1766) or White Oryx in English and *Al Maha / Al Wudehi* in Arabic, is the smallest member of the genus Oryx, and is native to desert and steppe areas of the Arabian Peninsula. In the early 1800s Arabian Oryx were found in the Sinai, lower Palestine, Transjordan, much of Iraq, and most of the Arabian Peninsula. During the 19th and early 20th centuries, the range of the Arabian Oryx was pushed back towards Saudi Arabia, and by 1914 there were only a few survivors outside that country (STANLEY-PRICE 1989). There were a few reports of Arabian Oryx in Jordan into the 1930s, but by the mid-1930s the only remaining populations were in the Nafud Desert in the northwest of Saudi Arabia and the Rub' al Khali in the south (TALBOT 1960), and in southern Oman. In

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the 1930s, Arabian Oryx began to be huntedwith high-powered rifles and automobiles. Hunts grew in size, and some were reported to involve as many as 300 vehicles, and by 1950, the northern population was effectively exterminated (TALBOT 1960). The last Arabian Oryx in the wild were reported in 1972 in Oman (HENDERSON 1974).

The species is classified as Endangered (IUCN 2010) and since 1975 it has been listed on Appendix 1 of CITES. As of 2008, populations were estimated at about 1100 individuals in the wild and 6000-7000 individuals in captivity worldwide in zoos, preserves, and private collections (IUCN 2010).

In Saudi Arabia, an oryx conservation and restoration programme was started in 1989 by the National Wildlife Research Center (NWRC) under the Saudi Wildlife Commission (SWC). Concurrent conservation programmes for the protection of large areas within the former range of the Arabian Oryx, and the captive breeding of oryx at the NWRC in Taif have together enabled the restoration of the species in the Kingdom, with the following goals:

- to re-establish wild and self-sustaining populations of Arabian Oryx in Saudi Arabia;
- develop breeding techniques in semi-captivity to allow the production of healthy herds of Oryx;
- study the most suitable habitats and establish protected areas in which vegetation can recover;
- manage the reintroduction of the herds in the protected areas;
- reintroduce oryx from the "World Herd" into suitable habitats in order to improve their genetic variability;
- study the ecology and biology of the Arabian Oryx in the wild.

The objective of this paper is to assess the effectiveness of the oryx reintroduction program in Saudi Arabia

Captive Breeding

In 1962-63, due to concern for the survival of the species, the *Fauna and Flora Preservation Society* captured three Arabian Oryx (2 ♂, 1 ♀) in Yemen. These three animals were sent to the Phoenix Zoo in the USA and later moved to the San Diego Zoo. To these were added one female from Kuwait and four animals given by His Majesty King Saud. These eight animals initiated what was called "The World Herd". The World Herd grew and by December 1981 numbered approximately 130 captive individuals (STANLEY-PRICE 1989).

In the meantime His Majesty King Khalid established a herd on his farm at Thumamah near Riyadh with animals from Saudi Arabia, Qatar and from the World Herd. The captive-breeding of Arabian Oryx for re-introduction in Saudi Arabia was initiated in 1989, when 57 animals were transferred from the King Khalid farm to NWRC (ASMODÉ & KHOJA 1988, 1989, OSTROWSKI et al. 1998a, b). Additional founders from the United States (4.0), and from the Middle East (Bahrain = 1.0; Qatar = 4.1, Abu Dhabi = 0.1) were added to the herd which made the NWRC herd the most genetically diverse in the world (OSTROWSKI & MÉSOCHINA 2005). This herd suffered an outbreak of tuberculosis in October 1986 that reduced its number to 37 individuals (FLAMAND 1990). After antibiotic treatments and

Fig. 1. Weak Arabian Oryx about to die in the dried vegetative area in Mahazat as-Sayd (photograph: M. Z. ISLAM).

Fig. 2. Arabian Oryx found dead under the dry Aacia tree 100 meter from the fence in Mahazat as-Sayd Protected Area (Photograph: M. Z. ISLAM).

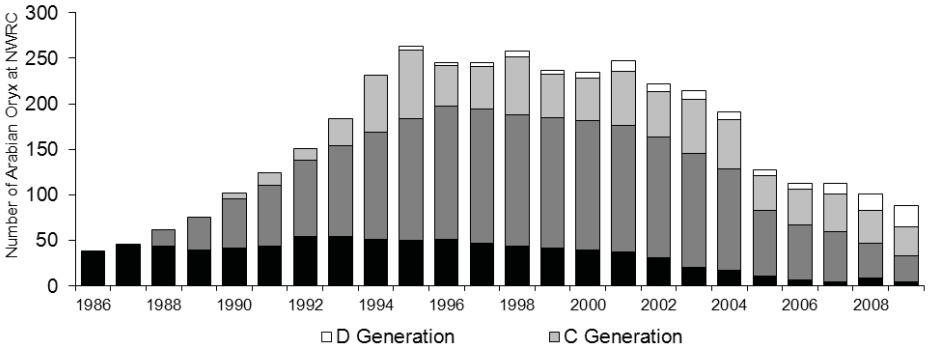

Fig. 3. Development of captive-bred Arabian Oryx population at the NWRC. Herd growth reduction is mainly due to reintroduction effort increase since 1996.

implementation of intensive sanitary measures, tuberculosis was finally eradicated and within six months seven calves were born (FLAMAND et al. 1994). The founder population, called the 'A' generation, was kept isolated and bred in individual pens to avoid risk of transmission of the disease, the 'B' generation consisted of hand-reared tuberculosis-free oryx, which became the main herd for the production of animals suitable for reintroduction (GRETH et al. 1994, OSTROWSKI et al. 1998b). There was a 'C' generation that was mother-reared in large enclosures and transferred to the reintroduction site when nine to 15 months old (OSTROWSKI et al. 1998a, b). Currently there is also a 'D' generation (mix of 'B' and 'C' generations). The present total number of oryx in captivity at NWRC as of December 2008 is 101 of (A=9), (B=38), (C=36), and (D=18) generations, respectively (Fig. 3).

Since the NWRC herd has the greatest genetic diversity of all captive and wild herds of Arabian Oryx in the world with identified blood lineages, these animals are carefully screened regularly for contagious disease and are maintained with strict health management and annual prophylaxis policies (OSTROWSKI & MÉSOCHINA 2005, ANAJARIYYA & MOHAMMED 2009). MARSHALL et al. (1999) suggested that perhaps they contained as much as 50% of the neutral genetic variation present in the pre-extinction populations. The key goal of genetic management at NWRC has been to maintain the initial genetic diversity through careful breeding and to limit the inbreeding level of the animals to be re-introduced (MÉSOCHINA et al. 2003). The degree of relatedness within the original Oryx herd of the NWRC was unknown, and the Arabian Oryx microsatellite loci discovered up to now are not sufficiently polymorphic to carry out a large-scale parentage inference analysis (MARSHALL et al. 1999). The NWRC herd was composed of 88 individuals by the end of 2009; the maximum number was 258 in 1999 (ANAJARIYA & MOHAMMED 2009, see Fig. 3).

Reintroduction Areas

Source populations for the re-introduction programs were obtained from areas where the environment is comparable to that at the release sites, following the IUCN re-introduction guidelines (IUCN1998). Two sites were selected for re-introduction of Arabian Oryx in

Saudi Arabia based on the known historical distribution; these were Mahazat as-Sayd and Uruq bani Ma'arid Protected Areas (BÜTTIKER & GRAINGER 1989, CHILD & GRAINGER1990, OSTROWSKI et al. 1998a, b, ISLAM et al. 2010a).

The first releases took place in the Mahazat as-Sayd Protected Area, which was completely fenced in 1989 to prevent access by poachers and livestock. The founder herd was as diverse as possible and comprised animals from national and overseas collections as well as the NWRC herd. The second release site was the 'Uruq Bani Ma'arid Protected Area, situated on the western edge of the Rub al-Khali or Empty Quarter in the south-west part of Saudi Arabia. This reintroduction site is unfenced and oryx releases commenced in 1995.

Mahazat as-Sayd Protected Area

Mahazat as-Sayd Protected Area (22°15'N, 41°40'E and altitude 900-1,100 m asl) was declared in 1988 and ratified in 1989 by the Council of Ministers. The site, which is in Makkah Province comprises a fairly level, sandy plain of about 2,244 km^2 (Fig. 4a). The substrate at Mahazat is sand, gravel, or alluvial clays, and is usually loose, but not shifting, forming an even surface. The entire perimeter is fenced with 2 m high chain-link fencing, topped with 3 strands of barbed wire, with 0.9 m of mesh buried in the ground, and lying behind a large earth embankment. Protection from livestock grazing has allowed a spectacular recovery of native vegetation – the grasslands of the reserve are a reminder of what much of central Saudi Arabia must have once looked like. The vegetation recovery allowed the reintroduction of Arabian oryx, Arabian Sand Gazelle or Reem (*Gazella subgutturosa marica*) [Vulnerable], Houbara Bustard (*Chlamydotis macqueenii*) [Vulnerable] and Red-necked Ostrich (*Struthio camelus camelus*).

Climate of the Mahazat reserve is subtropical arid. Between 1991 and 2009, mean minimum and maximum temperatures measured were 9°C and 42°C, respectively. During the same period, mean monthly humidity ranged from approximately 18 to 72%. The weather data from the last 18 years show considerable inter-annual variation in the average amount (range 0-22 mm) and timing of rainfall. Relatively substantial rainfall typically occurs between March and May each year (Fig. 5). Rainfall has a strong influence on the presence of annual plants, and is thus the most important factor in the production of grazing. Poor rainfall had a major detrimental impact on forage in the reserve in 2006-2008. Average monthly rainfall recorded from 1991 to 2009 at Mahazat was approximately 7 mm (Fig. 5). Notably low rainfall years included 2003 and 2007 with less that 5 mm of annual rainfall, and 1.3 mm in 2009.

Uruq Bani Ma'arid Protected Area

Uruq Bani Ma'arid (19°10'N, 45°30'E in the Najran and the Riyadh Emirates) is situated along the western edge of Ar-Rub' al-Khali, the Empty Quarter, which is widely considered the largest and driest sand desert on Earth (MEIGS 1952, PHILBY 1933 and Fig. 4b). With the world's largest longitudinal sand dunes, overlying a dissected limestone plateau, and the southern end of the Tuwayq Escarpment, this protected area contains greater biological diversity than any other part of the Empty Quarter, with vegetated wadis, gravel plains, and inter-dune corridors. The oryx was reported in the Empty Quarter before the last animal was shot in Oman, and this region is now the focus of an intensive and successful reintroduction

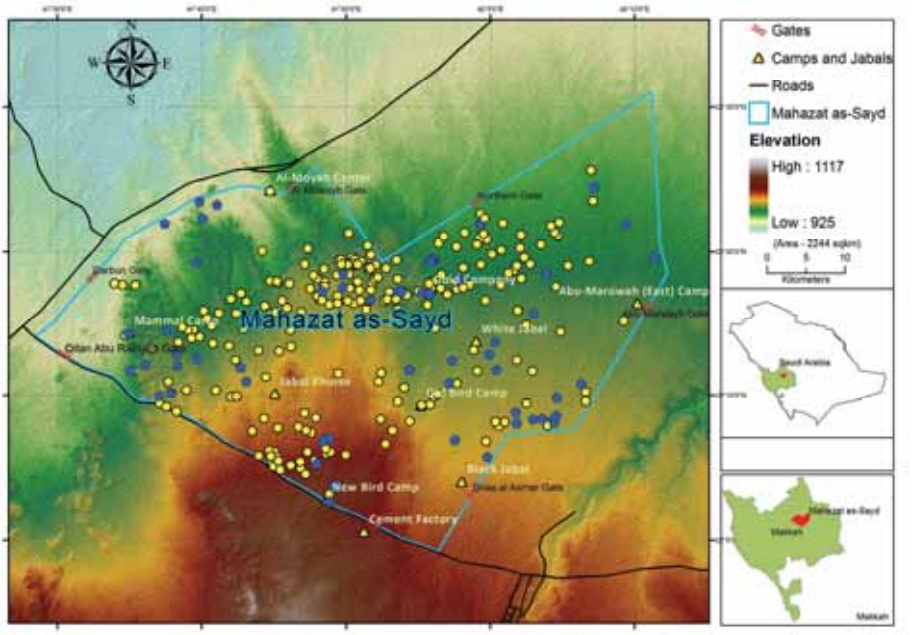

Fig. 4a: Oryx distribution (●) and dead oryx (⬟) in Mahazat as-Sayd Protected Area in Saudi Arabia.

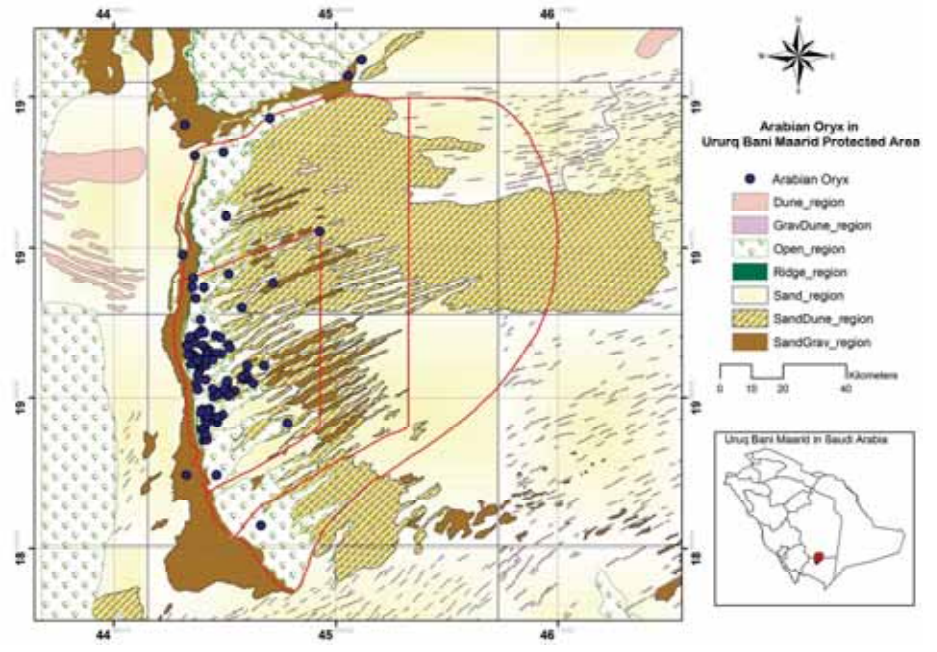

Fig. 4b. Oryx distribution (●) from June 2010 within the core area of Uruq Bani Ma'arid Protected Area.

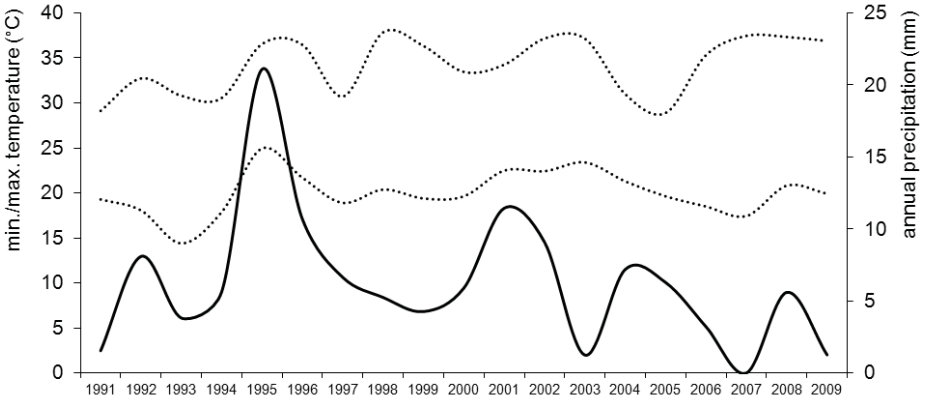

Fig. 5. Mean maximum and minimum temperature (°C, dotted lines) and average monthly rainfall (mm, solid line) from 1991 to 2009 in Mahazat as-Sayd Protected Area in Saudi Arabia.

program for Arabian Oryx, Reem Gazelle, and Idmi Gazelle (*Gazella gazella*). The area is arid and hot, the nearest weather station at Sharurah (725 m asl) recorded annual ambient temperatures and average monthly rainfall of 28.4°C and (3.2) mm from 1985–2009. There are no permanent water sources but the ability of the sandy substrate to retain moisture means that significant rain can have an effect on vegetation for up to five years post the event (ISLAM et al. 2009, 2010b).

Uruq Bani Ma'arid was declared a protected area in 1994, with an area of 12,658 km² divided into three zones: the core Natural Reserve of 2,400 km², a managed grazing zone, and a wider controlled hunting zone (Fig. 4b). The site was selected due to suitability of habitats for re-introduced species and is representative of the exposed limestone escarpment, parallel dunes and inter-dune corridors of the western Rub' al-Khali.

Pre-release enclosures

Pre-release enclosures were constructed at the re-introduction sites to allow them to acclimatize to their new environment.

Mahazat: A total of 2.5 km^2 with two 25 ha enclosures one kilometre apart are connected to a 200 ha enclosure. The enclosure site was selected because of the landscape variety present in that area, which in case of fighting will allow the subordinate animals to hide from the dominant ones. The oryx were kept for a longer period in these enclosures with provisions that include water and alfalfa until they formed an aggregation/herd. When the aggregation was cohesive and the conditions in the reserve became adequate, the animals were released gradually.

Uruq: Oryx were sent to Uruq either from NWRC or from Mahazat and were kept in an enclosure 4 ha in size, divided into two areas of 2 ha each. Alfalfa and hay as well as water, were supplied on a daily basis until the animals became accustomed to the enclosure and to eating the natural vegetation present.

Population estimation techniques

Ungulate surveys have been carried out on a regular basis in the Mahazat as-Sayd Protected Area since 1988. In 1995 14 permanent transect lines were established (MAGIN 1995; SEDDON et al. 2003). We used distance sampling (BUCKLAND et al. 1993) techniques to generate estimates of the oryx and gazelle population sizes. In addition, a much cruder technique based on known births and deaths has also been used since the first animals were released (ISLAM et al. 2008a).

Since 1989 whenever a carcass was located (Fig. 4a), skulls were collected. All the skulls were kept systematically at the Mammal Camp in the Reserve (Fig. 4a). This method was useful in avoiding re-counts and also provided a minimum number of dead animals each year, particularly 1999 and 2006 to 2009 when high mortality of sand gazelle and oryx occurred (OSTROWSKI & ISMAIL 2000, ISLAM et al. 2010a).

Two key methods were adopted for monitoring the ungulates. A sector-wise count to know the animal distribution in the reserve, that was covered using the system of six sectors identified to both verify the status of the oryx and gazelle in the area and to collect data on the relative abundance of ungulates across the reserve (ISMAIL 2006, ISLAM et al. 2008b). SEDDON et al. (2003) have indicated that the results obtained from this technique was unsatisfactory as no marked Gazelle were present within the area. The distance sampling technique was used to assess gazelle and oryx numbers (SEDDON 1999; SEDDON et al. 2003).

As most of the dead animals have been found near the fence mainly under the *Acacia* and *Maerua crassifolia* trees, the distance from the fence to the location of dead animals was also measured. Regular monitoring of animals was carried out by vehicle and dead animals were located, GPS coordinates and vegetation around the carcass were recorded and each location was plotted on the map (Fig. 4a).

Besides monitoring of oryx, NWRC scientists study the behavioral ecology and reproductive physiology of the animals. As the population grew and animals dispersed into many small groups it become increasingly difficult to account for all the oryx each day.

Post release monitoring: Due to the aridity of their environments, oryx in the wild usually survive at low densities and therefore estimates of population size have a low accuracy, owing to the small number of individuals encountered during surveys. For example, even in the closed and intensively surveyed oryx population in Mahazat, the coefficient of variation of individual survey estimates often exceeded 50% (SEDDON et al. 2003). We have used two approaches to avoid this imprecision; (1) we use two methods in Mahazat accumulated births and deaths recorded by field workers supplemented by transect counts on 14 lines by cars and aircraft. These monitoring efforts allow us to cross-check convergent indications, and to carry out surveys four times a year. In Uruq, we do intensive post-release population monitoring and also transects by vehicle and aircraft on four pre-defined transect lines twice a year to improve the monitoring efficacy (ISLAM et al. 2010b).

Reintroduction Efforts and Results

Released animals were marked with identification tags and fitted with radio collars to enable them to be relocated after release. The post-release progress of Oryx has been carefully monitored and the information gained from early releases utilized in planning subsequent

attempts where appropriate. Animals intended for release were selected on the basis of sex, age and social structure as well as the genetic composition of individuals (STRAUSS 2003).

Mahazat as-Sayd Protected Area

A total of 82 Oryx (with almost equal sex ratio) have been released since 1990 to 2009. Forty-four came from the NWRC captive breeding unit and 38 from other private collections, mainly from Zoological Society of San Diego in the USA and from Shaumari in Jordan (ANONYMOUS 1972). From NWWRC to Mahazat 2 (1:1) origin BHRN Zoo in 1990, 2 (1 ♂, 1 ♀) origin NWRC released in 1991, 20 (9 ♂, 11 ♀) origin NWRC released in 1992, 12 (4 ♂, 8 ♀) origin NWRC released in 1993, and 8 (6 ♂, 2 ♀) released in 2005.

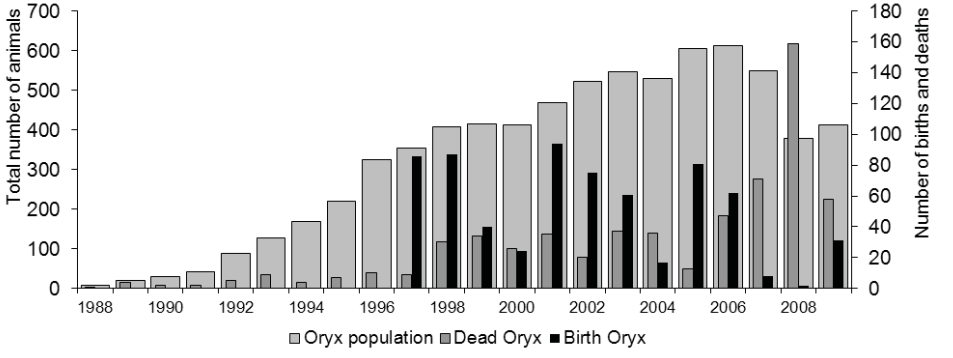

Fig. 6. Status of Arabian Oryx in Mahazat as-Sayd Protected Area: total population and number of deaths and births from 1988 to 2009.

The animals have been monitored annually since their reintroduction in 1988 (ASMODE 1990, 1991, ISLAM et al. 2008a, 2008b, Fig. 6). There has been a sharp decline in the oryx population of Mahazat in recent years. The monthly average rainfall in 1999, 2001, 2007, 2008 and 2009 was 4.3 mm, 11.5, 0.1, 5.6 and 12.7, respectively, which was not sufficient for the vegetation to regenerate. From 1998 to 2005 the number of dead oryx vaied between 12-35, while from 2006 -2008 there was a dramatic increase to a high of 159 animals, probably in response to a declining average rainfall. Most of the dead animals were adults and also a few calves. Arabian Oryx move long distances in search of food and the Mahazat fence prevents its movement especially when food availability is extremely low. It is noticeable that many animals died near the fence (ISLAM et al. 2010a).

Uruq Bani Ma'arid Protected Area

Since 1995, a total of 174 oryx (79 ♂, 95 ♀) were translocated without any transport related deaths. A total of 146 oryx originated from the NWRC captive breeding facility while 28 came from the Mahazat as-Sayd Protected Area. The age of the translocated animals ranged between three and 10 years.

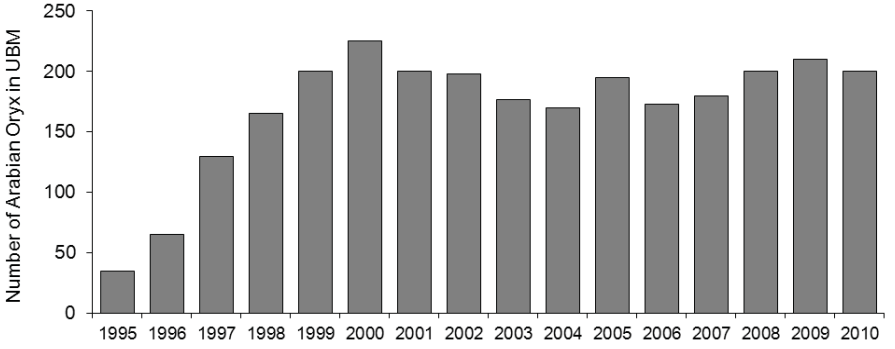

Fig. 7. Population of Arabian Oryx from 1995 to 2010 in Uruq Bani Ma'arid Protected Area.

The oryx population in Uruq in June 2010 was estimated at around 200 animals by a survey using four fixed transect lines by vehicles and also by aircraft (Fig. 7). The population fluctuates, when poaching increases. At the beginning of 2010 more than five oryx were killed by poachers. These are the known cases and there might be others. Another factor influencing oryx population decline the effect of rainfall on herbivore population dynamics, has been well documented (TREYDTE et al. 2001, SPALTON 1995, ILLIUS & CONNOR 1999, SAETHER 1997, MÉSOCHINA et al. 2003, ISLAM et al. 2008a).

Population Management and Conclusions

Carrying capacity

OSTROWSKI & ISMAIL (2000) mention that the difficulties in estimating the carrying capacity of arid habitats, such as are found in Mahazat as-Sayd, are compounded by seasonal,annual and spatial variations in plant production and carrying capacity in desert landscapes. Other factors may significantly affect Oryx population productivity, e.g., availability of trees for shade, male fights at good forage sites, and competition for food with reem gazelles and rodents (ISLAM et al. 2010a). The abundance of rodents has been shown to considerably influence the potential grazing capacity of an area for larger herbivores (STRAUSS et al. 2008, WELLS 1999). Furthermore, it is thought that the competition for shade and resources probably occurred in Mahazat as-Sayd during the summer of 2006. Studies to determine the ecological capacity of the protected area need to be done on an annual basis. Coarse indications of overgrazing, such as the formation of bare areas, soil erosion, and the increasing incidence of opportunistic plant species such as *Argemona ochroleuca* have begun to be observed in the reserve, albeit infrequently.

The mean growth rate in the Mahazat as Sayd protected area oryx population by 2008 was r = 0.258 (95% CI: 0.035 – 0.444; SE_{mean} = 0.132) (ISLAM et al. 2008a, Fig. 8). Here is the logistic equation for population growth: DN/dt = rN[(K-N)/K]. Where r is the intrinsic rate of population increase, N is population size, and K is carrying capacity. Mathematically, K is the limit at which the rate of growth dN/dt=0. If the population exceeds its carrying capacity, the number of individuals will be reduced until N<=K. The carrying capacity for the protected area was estimated in 2008 to be about 525 animals.

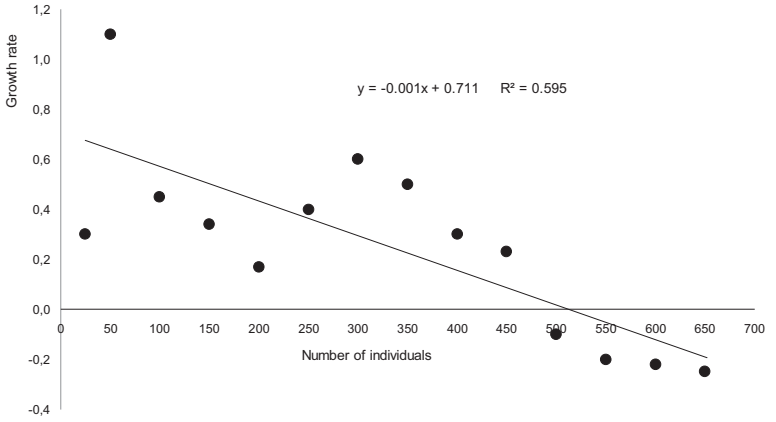

Fig. 8. The growth rate of the oryx population in Mahazat as-Sayd Protected Area.

Probability of extinction

A computer model was developed to evaluate the probability of extinction (frequency with which 100 initial population fall to zero within 100 years) of the predator-free Mahazat Oryx population under various management options (TREYDTE et al. 2001, MÉSOCHINA et al. 2003). It was suggested that if no conservation management was applied to the population, the probability of extinction was high, between 0.3 and 0.92 according to combination of assumptions (MÉSOCHINA et al. 2003) whereas it has been suggested that removing all Oryx above 70% of carrying capacity will provide the lowest probability of extinction (TREYDTE et al. 2001), and the lowest population size variation whatever was the combination of assumptions (MÉSOCHINA et al. 2003, ISLAM et al. 2008a, b, ISLAM & KNUTSON 2008).

Impact of fencing

Large die-offs of Arabian Oryx and Arabian Sand Gazelle were recorded from 1999 to 2009 in the fenced Mahazat protected area, with highest mortality recorded during summer months when the rainfall was negligible or insignificant. Deaths were due to starvation because of reduced availability, accessibility and quality of food plants in the area. In total, 560 oryx and 2815 Sand Gazelle deaths were recorded since the reintroduction projects until 2009. Mortality was higher in 1999-2001, 2006, 2007 and 2009 (Fig. 6). Oryx habitat depends on rainfall and the animals move over great distances in response to rainfall events. The fence around the Mahazat as-Sayd Protected Area prevents wide ranging natural movements of animals, artificially concentrating the animals in unfavorable habitat at times of the year. The Sand Gazelle is a highly gregarious and migratory species, is also known to move long distances in search of good quality pastures, similar to goitered gazelle in Central Asia (HEPTNER et al. 1996, GRIMWOOD 1962, STEWART 1963). It is therefore obvious that by preventing natural movements of Arabian Oryx, fencing may have reinforced the effects of stressful conditions such as drought (OSTROWSKI & ISMAIL 2000, ISLAM et al. 2010a).

Management Plan

TREYDTE et al. (2001) and ISLAM & KNOTSON (2008) suggested reducing the number of Arabian Oryx to have a self-sustainable population in Mahazat. We captured more than 50 Oryx between 2005 and 2010 and transferred them to Uruq Bani Maarid Protected Area and to private animal collections. For January 2011, we are planning to capture 150 Oryx and to transfer them to Uruq and some to private collection. We also investigated the possible number of Oryx that could be accommodated in Uruq and the possibility to transfer some animals to Jordan for re-introduction purposes.

The main challenges of the oryx conservation program have been identified as:

- The identification and avialability of suitable habitat during the initial stages of re-introduction and their protection via fencing in some cases;
- High mortality rate of adult as well as young animals during summer in the fenced area of Mahazat as-Sayd is a serious issue and evidence that wild born Oryx are also in poor condition during the drought like situation or stressfull period;
- The difficulty in implementing the species management plan for the fenced reintroduction site (Mahazat);
- No study on genetic diversity of oryx in reintroduction sites in recent years.

As a consequence, a management plan for the ungulate populations in the Mahazat as-Sayd Protected Area was developed in 2008 by a group of experts from various fields e.g., ecologists, biologists, botanists, vets, sociologists and policy and decision makers to minimize periodic large-scale mortalities in the Reserve (ISLAM & KNUTSON 2008, ISLAM et al. 2010c). The plan suggested artificial provision of water and alfalfa at five different locations to minimize mortality. It was observed that during the second week of September 2008 oryx had started breeding though the condition in the reserve was not suitable as it is completely dry all over. There is a possible danger that pregnant females might not come with the group to provision sites and if they do not get sufficient food and water they might die and there will be a great loss to the reserve. Therefore, it was recommended that as many oryx may be removed from the protected Area as possible. There is currently not enough vegetation to support the population and additional deaths appear imminent unless preventative action is taken, which in turn will be exacerbated by the provision of artificial water.

The removal of oryx from Mahazat as-Sayd Protected Area has to begin immediately, which will be facilitated by the provision of supplementary food and water in the west enclosure sites. Since many of the animals are currently on the east side of the protected area, it is expected that an enclosure may need to be constructed on that side to assist in the possible passive capture of animals. If necessary, additional portable enclosures will be utilized throughout the reserve to ensure that a large percentage of the animals are removed from the protected area.

Beside these, several research project proposals will be developed to investigate aspects such as vegetation and habitat, carrying capacity, identification of potential protected areas for translocation of animals from Mahazat, and feeding ecology of gazelles and oryx.

For monitoring the achievements of the re-introduction measures, the following success indicators have been developed:

- The captive-breeding program at NWRC has achieved its goals.
- The captive herd at NWRC is maintained for re-introduction programs in other protected areas.

Fig. 9. Arabian oryx waiting to get water near the Camp in Mahazat and fence could be seen in the background and most right oryx has radio collar (Photograph: M. Z. ISLAM).

- The establishment of a partly self sustaining population of Arabian Oryx in Mahazat as-Sayd over the last 20 years is considered to a success. This populations represents 98% of the gene pool, ideal for further introductions.
- The establishment of a a free-ranging population in Uruq Bani Ma'arid after 14 years is also considered as success.

Overall conclusion

As the IUCN guidelines for reintroduction (IUCN 1998) state: "if captive bred stock is to be used (for re-introductions), it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology". It also states that reintroduction is defined as an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or became extinct. These basic principles lead to the following conclusions and recommendations:

- Arabian Oryx should be selected from populations similarly exposed to the same environmental conditions as the planned re-introduction sites.
- When wide-ranging species are confined to restricted areas, even if such areas are large, it is essential that an effective population management plan is in place before any re-introduction is carried out and that the plan is properly implemented. If this is not done, large-scale mortalities will occur.

- Prior to any re-introduction, the range conditions in the release area need to be improved and area protected from the impact of uncontrolled livestock grazing. Once pasture conditions show adequate signs of improvement and the site is adequately protected, re-introduction of the animals can be contemplated.
- The time of release should be when the vegetation conditions are better to have least environmental stress to animals.
- Keeping the animals in pre-release enclosures within the reintroduction site to get them acclimatized to the natural environment and provide minimal amount of food and water as per the natural conditions.
- Strict law enforcement to minimize poaching of Arabian oryx.
- A public-awareness program had been started to inform citizen of the biological and historic significance of the Arabian Oryx in the society in order to encourage their participation in the conservation program.

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