ARABIAN ORYX CONSERVATION BREEDING IN SAUDI ARABIA

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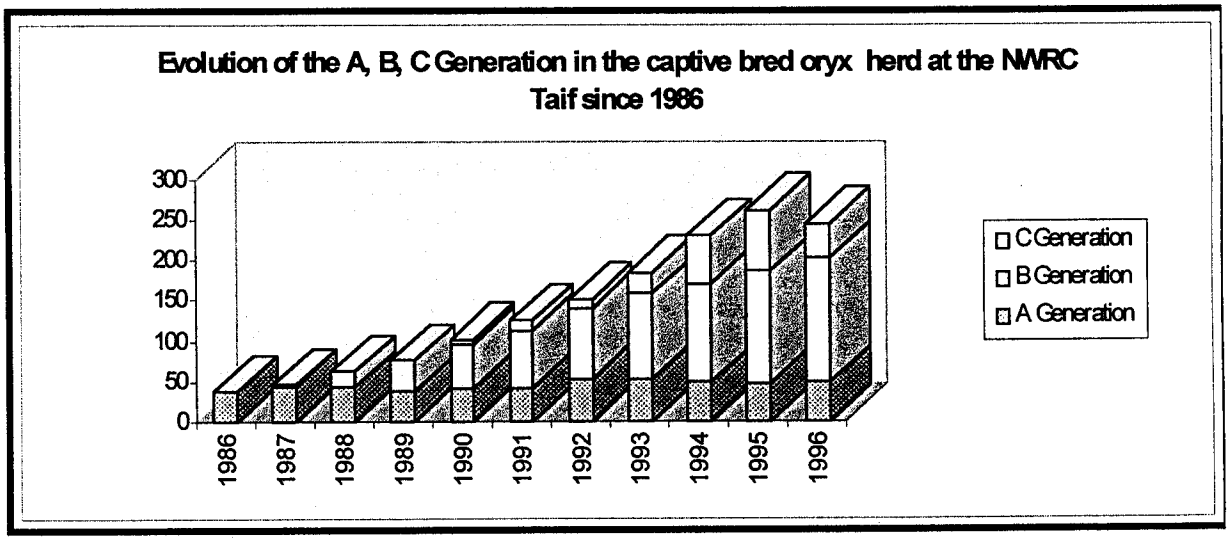
INTRODUCTION

The Arabian oryx was pursued and hunted over hundreds of years in even its most remote desert strongholds. Through captive breeding, the return of descendants from the founder herd to Arabian lands was possible. With the release of oryx into the Mahazat as-Sayd and 'Uruq Bani Ma'arid protected areas, the restoration of the Arabian oryx to the deserts of Saudi Arabia became a reality.
The restoration of the Arabian oryx in Saudi Arabia is a core programme of the National Commission for Wildlife Conservation and Development (NCWCD), and thus proceeds with support from the highest governmental levels. Concurrent projects for the protection of large areas within the former range of the species, and the captive breeding of oryx at the National Wildlife Research Center (NWRC) have together enabled the restoration of the oryx in Saudi Arabia. Nowadays with releases into the wild, attention has shifted from the captive breeding stock to the free-ranging Mahazat as-Sayd and 'Uruq Bani Ma'arid oryx populations. The present work summarizes ten years of captive breeding at the NWRC and describes the efforts to reintroduce Arabian oryx in Saudi Arabia.

THE PAST – SUMMARY

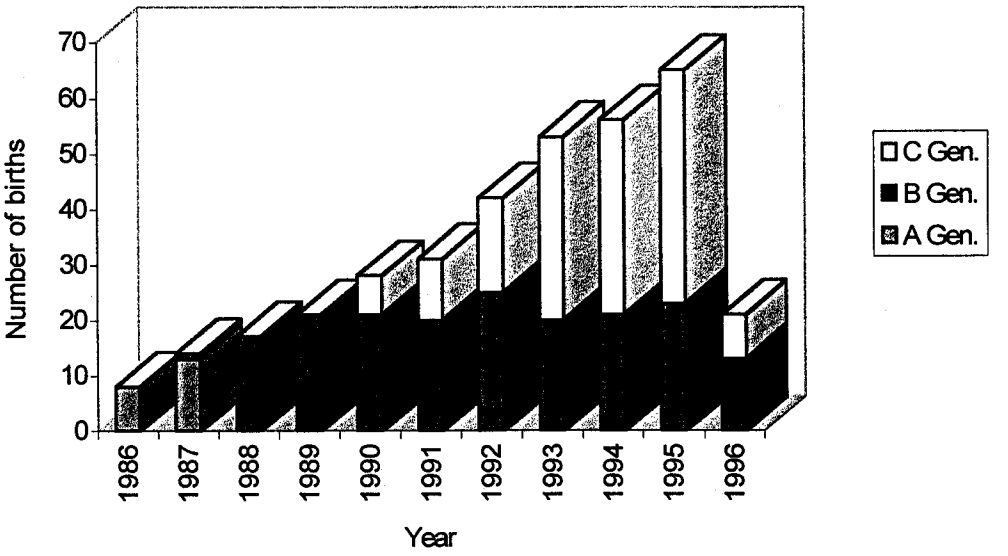
1. RESULTS OF CAPTIVE BREEDING

Over the ten years of captive breeding, the population of oryx has never decreased (Fig. 1) **until the year 1996.** The mean rate of population growth was 24 % between 1986 and 1995.



However in 1996, the population recorded a fall of 6.1% compared to 1995. This large reduction in calf production (Fig. 2) was brought about because of uncertainty concerning new areas of release and the lack of facilities to hold numerous C-generation herds at NWRC.

Fig. 2: Annual distribution of births by generation at the NWRC (1986-96)



a). Calf production

1. Over ten years

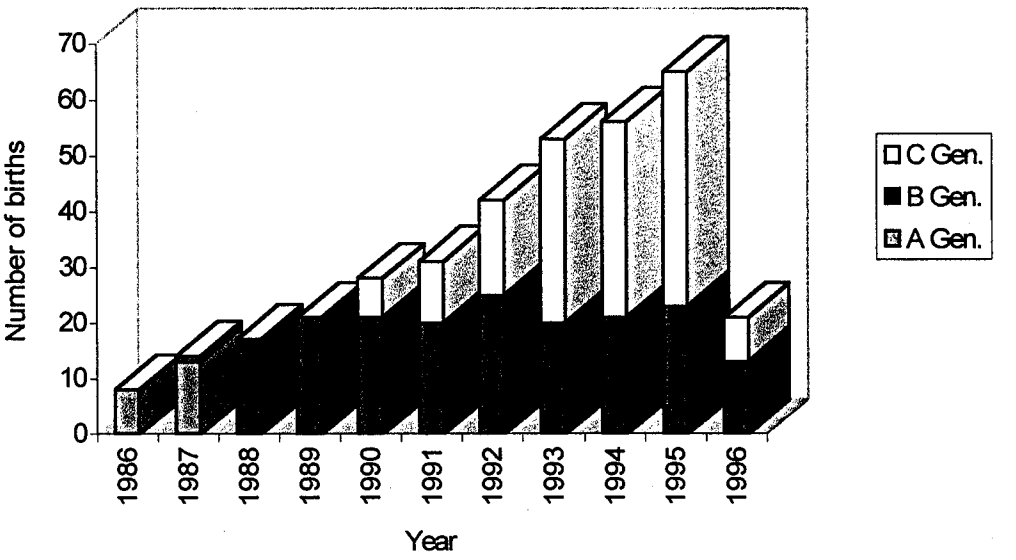
Since 1986, 356 calves have been produced. The breakdown by generation is as follows: 21 A-generation, 182 B-generation, 153 C-generation animals (Fig. 2).
The first goal of the captive breeding programme at the NWRC has been to produce a high number of B-generation animals in order to reach the largest genetic pool possible and the planned minimal viable population (MVP) size. This policy was followed until 1995. In addition, work in 1993, 1994 and 1995 was dedicated to the production of potentially suitable animals for releases (C-generation). As a result there has been constant annual growth of the Taif herd from 1986 to 1995, even though 24 animals have been translocated from the NWRC to 'Uruq Bani Ma'arid in 1995.
A second stage was reached in 1996 when oryx production became more selective and the MVP nearly reached. In 1996 and 1997 the NWRC focused on the production of calves with blood lineages that were under-represented in the captive and wild populations. Births in 1996 in B- and C-generations represent respectively 7.2 % and 5.2 % of the B- and C-generation total births since the creation of the NWRC. In contrast, 71.9 % of the C-generation animals have been produced in 1993, 1994 and 1995, while only 36.3 % of the B-generation oryx have been produced during the same period.

2. Monthly calf production

Although the Arabian oryx is a polyoestrus non-seasonal species in captivity as well as in the wild, fewer calvings are observed from June to November (Fig. 3). This is the result of herd management in order to:

- avoid births during the warmest months
- concentrate births in a short period to have homogeneously aged populations
- concentrate births in a short period to allow sanitary rotation between enclosures

Fig. 2: Annual distribution of births by generation at the NWRC (1986-96)

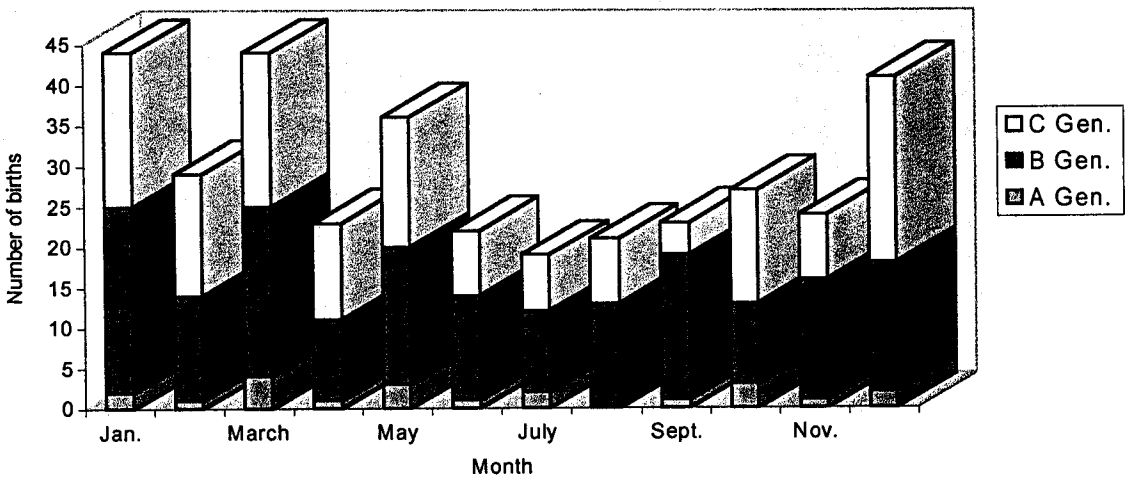


b). General Mortality

Over ten years

The NWRC recorded a total of 90 oryx deaths over 10 years of breeding (Fig 4). The breakdown of deaths by generation is as follows: 58 A-generation, 23 B-generation, 12 C-generation animals.

Fig. 3: Monthly distribution of births at the NWRC (1986-96)



Over 10 years of breeding, the average mortality rate was 8.3% per annum. The mortality rate reached 41.5% in 1986 due to an outbreak of tuberculosis. Excluding 1986 and 1987, when death rates were elevated by the tuberculosis event, a mean annual mortality rate of 4.2% was achieved for the next years, a figure far below those usually encountered in captive wild ungulate herds (e.g. Kirkwood et al., 1987; Fowler, 1986).
Over this period, the mean mortality rate during the first month of life was 3.9%, with a total of 14 neonate deaths. This represents 15.5% of the total deaths occuring in the herd. However, during the three last years, calf loss during the first month of life was recorded only twice.

Disregarding the deaths of A-generation that resulted mainly from the outbreak of tuberculosis in 1986 and 1987 during the months of August and September, deaths in B and C-generation oryx occurred throughout the year without any significant mortality peak.

c). Tuberculosis outbreak in NWRC captive breeding

1. History

The Arabian oryx herd of the NWRC originated from late King Khaled's collection. The herd was composed of animals from Saudi genetic lineages, as well as animals originating from the World Herd. The herd in Thumamah contained about 70 individuals (Seitres, 1989), and was kept in a 600 ha enclosure sharing the area with at least 15 other ungulate species (Flamand et al, 1994).
On April 29th 1986, 57 oryx were transported by air from Thumamah to the NWRC at Taif. During the first two months, there was a significant mortality rate in the Taif herd (Haagsma and Poilane, 1989).
By September 1987, 16 animals had died of tuberculosis, a mortality rate of 25%. Due to the inestimable genetic value of the herd in relation to the rest of the world herd, it was decided to attempt to eradicate the infection by the use of sanitary, therapeutic and management measures (Greth and al., 1994).

2. Eradication of the disease

The following has been detailed in Dr J. Flamand' *et al*'s paper: *An oubreak of tuberculosis in a captive herd of Arabian oryx (Oryx leucoryx): diagnosis and monitoring. Veterinary Record 134, 115.* All the following data were taken from this article.

3. Treatment

After the deaths of the most infected individuals and euthanasia of suspected ones, treatment was implemented on the rest of the herd. The animals received an antibiotic combination of isoniazid (10 mg/kg BW), ethambutol hydrochloride (15 mg/kg BW) and rifampicin (10 mg/kg BW) administred daily in the drinking water for nine month (beginning in June 1988). Animals were confined to treatment pens, where they remained confined for the rest of their life, in an isolated corner of the NWRC.

Diagnosis

Four diagnostic tests were used for each individuals to define its tuberculosis status, thus minimising the risk of misjudment.

Comparative skin tests
Difficulties in the use of the comparative skin tests for diagnosing tuberculosis in individual animals arose from their lack of precision and inability to be used on wild animals. More refined tests were tried.

Indirect ELISA test
This is a serological test, detecting the immunological markers of *Mycobacterium bovis* in the sera. Initially, because the herd was known to be infected with *M. bovis*, a conservative interpretation was used and titers of 1:5 and higher were considered as positive. After two years, a less severe interpretation was used because the *M. bovis* infection was under control and because a problem of non-specific reactions became apparent. New tresholds were used during the next years.

Comparative ELISA tests
There are based on the comparison of the test serum activity to different purified protein derivative antigens of *M. avium*, *M. bovis* and MPB70 of *M. bovis*. In 1994 and 1996 reactivity of antigens of *M. paratuberculosis* was also compared. The ELISA tests are useful for detecting seriously infected animals, but may miss animals with a low grade of infection.

Lymphocyte Transformation test

This measures *in vitro* lymphocytic immune T cell reactivity and was developed as a sensitive marker for tuberculosis in deer (Griffin and Cross, 1986). This test can detect disease early in its course and with a high level of sensitivity.

Difficulties in the interpretation of these tests stemmed principally from the fact that false negatives and false positives were encountered and that the threshold of positivity was difficult to establish with the ELISA tests.

4. Results

In 1996 and 1997 all A-generation animals were considered "low risk". No animal belonged to "high risk" class. Since 1991, the number of doubtful cases is decreasing among B-generation animals.
Paradoxically, the number of doubtful cases among C-generation animals is increasing, 6% in 1995 and 14.3% in 1996. This alarming increase was analysed, and was found to occur in old C-generation animals which hadn't been released due to lack of a suitable re-introduction site for them. Some of them are more than three years old now, and could be considered as B-generation animals in term of their microbial flora. It is clear that many unexplained doubtful and positive ELISA test reactions could be due to sentisation with environmental mycobacteria, as is duggested by their presence in some necropsied oryx. The significant reduction in immunological markers of *M. bovis* in the B-generation oryx provided evidence against the transmission of the disease to the offspring.

5. Conclusions and perspectives

Tuberculosis no longer poses a threat to the NWRC herd. All the high risk oryx of 1989 and 1990 have yielded low ELISA titres. Post-mortem examination of 58 oryx done between 1987 and 1997, revealed no gross lesions indicative of tuberculosis infection. Additionally, none of the systematic bacteriological research carried out on dead oryx has succeeded to isolate *Mycobacterium bovis*.
However, a strict sanitary policy should be followed, and even constitute a mandatory specification to any request of reintroduction of captive-born oryx from anywhere in the world. Although some concerns have been expressed about the necessity of continuing our very strict sanitary management in view of the serological results, risks of false negative animals are still possible. There is actually a recrudescence of tuberculosis in captive populations of wild animals around the world. It would be a mistake to relax the serological follow up of our captive herd and unpardonable to build the future wild population frame on doubtful sanitary basis.

6. Recommendations for the following years

- Carry out comparative ELISA tests on:
  - all C-generation oryx;
  - parents of C-generation oryx;
  - breeding A-generation oryx;
  - any ungulate imported to the Center.
- Limit the veterinary visits to other wildlife collections in order to avoid possible reinfection of TB or spreading of other pathological agents.
- Avoid any contact with fallow deers, addax, oryx, idmi and dorcas gazelles which are known to be highly susceptible to the disease.
- Segregate and retest twice within a one year period all positive or doubtful animals.
- All animals tested negative three consecutive times will be regarded as TB free, and used in reintroductions.

7. Benefits

The historical presence of clinical TB disease demands that all stock held at the NWRC must be certified clean as a result of the most comprehensive testing methods known to exclude the disease. Utilisation of these animals for reintroduction demanded that there was a minimal risk of TB being present. The certified disease-free status of

these animals has ensured that NWRC Arabian oryx stock has achieved a status superior to any other collection of animals without testing history designed to exclude TB. Indirect benefits have resulted through the definition of new capture, holding and restraint techniques necessary for the completion of the test schedule.

By implementing these sanitary projects both in KKWRC gazelle collection and in NWRC, Taif, Saudi Arabia has laid new standards of TB control in wildlife which will become the benchmark for the control of this disease. Tuberculosis is no doubt present in many other collections of wildlife internationally, and Saudi Arabia has established a precedent in disease control which will have wide applications in disease management in wild animals.

2. *SUMMARY*

a). Results

A wide genetic base of oryx exists at the NWRC. After 10 years of captive breeding Taif's oryx herd is one of the largest in the world.
Genetic diversity within the Taif herd is unique and NWRC is now focusing on production of under-represented blood lineages.
The reproductive programme has been successful. Three hundred and fifty six calves have been produced since 1986.
The health policy at the Center has resulted in a mortality rate of less than 5 % (except in 1986-87). Further deaths due to old age are expected in the A-generation herd on coming years.

b). Perspectives

Population growth should be positive (approximatively + 5 %) in 1997, with some thirty births expected, and despite sixteen animals transported to 'Uruq Bani Ma'arid.
Ten new enclosures will prevent accidents, fights and diseases within the herd by decreasing the density of animals.
Creation of new release areas will boost the breeding unit and will assert the leading position of Saudi Arabia in ungulate reintroductions.

THE FUTURE – PERSPECTIVES

The future of the Arabian oryx captive breeding at the NWRC of Taif can be assessed according to four major issues:
A genetic point of view: the minimal viable captive population.
The status of released herds in Mahazat as-Sayd and 'Uruq Bani Ma'arid.
Perspectives for the re-introduced population
The oryx reintroduction site scheduling.
We will assess consecutively these four points.

1. *THE MINIMAL VIABLE CAPTIVE POPULATION*

Because all genetic threats (such as increased genetic loss and inbreeding coefficients) are a function of the population's size, it was important to establish an adequate effective population size for our captive bred population. The ideal would have been as many animal as possible. However logistical and economical constraints limited the number, and a lower limit for effective population size needed to be defined; the MVP size. The MVP size is a recent and powerful concept for conservation biologists.
From a demographic point of view, a population of vertebrates numbering less than 50 to 100 individuals may be

particularly vulnerable to extinction due to random demographic causes such as epidemic diseases, natural disasters or sex ratio distortions.

a). Parameters

A minimum viable population depends primarily on the genetic goals of the management programme.

- The desired percentage heterozygosity to maintain: **We chose as an objective 90 %**
- The time period over which this heterozigosity is to be maintained: **We chose 100 years**

A second group of factors covers the nature of the captive bred population, including biological characteristics of the species.

- The number of effective founders is a basic parameter, as it provides all the genetic variability that can be transmitted in the future. In the case of Taif's herd, the exact number of represented founders is difficult to assess as in the early times Thumamah's herd was not managed from a "pedigree" point of view, nor were the herds in Qatar and Abu Dhabi from whom we received animals. **We thus considered our founder herd to number 10 animals.**
- The number of years per generation: **We use 9 years** for the generation lenght.
- The growth rate: **The yearly growth rate (lambda = 1+r) is 1.25.**
- Effective population size (N_e). It is a measure of the way the population transmits its genes to the next generation. It is a function of the number of animals that reproduce, the sex ratio of the breeding animals, the variance in family size. There are many ways to estimate N_e. The case of the Center oryx is still quiet simple, as there are no overlapping generations, no fluctuations in population size (it increases regularly) and only 3 successive generations in the herd. **We used N_e/N= 0.6 or 0.8.**

b). Calculation of the MVP size

- desired percentage of retained heterozigosity = 90%
- lenght of periods (years) = 100
- effective number of founders = 10
- number of years per generation = 9.0
- annual growth rate = 1.25
- estimated N_e/N ratio = **0.6 or 0.8**

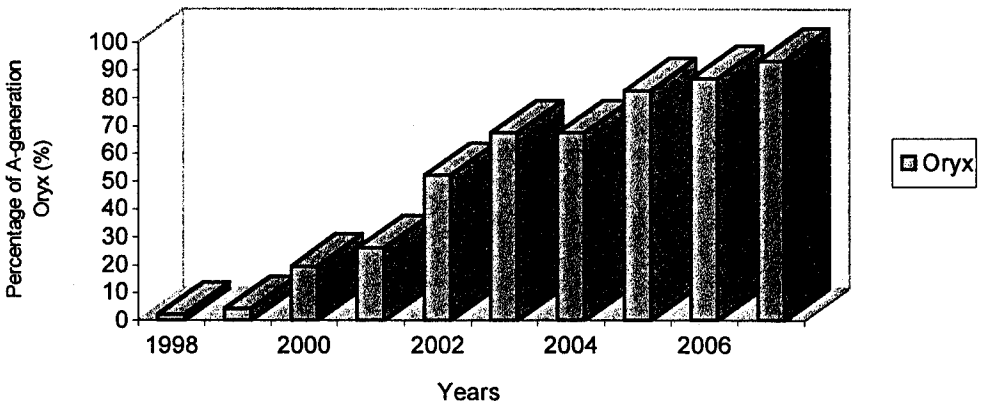
Table 1. Actual effective population size required to maintain 90 % of the original heterozygosity under two N_e/N ratios

Nb of effective founders = 10		
N_e/N ratio	0.6	158
	0.8	119

As the yearly growth rate attained at the NWRC is satisfactory, it can be assumed that the maintenance of a population of 200 individuals, actively managed for genetic purposes will give us all the guarantees to reach this recommended goal.

In August 1997, the total oryx captive population was 245 individuals (47 A-generation, 152 B-generation and 46 C-generation animals). The population of A-generation oryx is decreasing due to old age and we can expect an increased mortality rate among this subpopulation within the next five years (Fig. 5). C-generation animals will be released in protected areas. The subpopulation of B-generation oryx is expected to be stable with less than 3.5% annual mortality. Therefore, a sustained breeding performance is still required in order to reach the required MVP and balance annual mortality (between 0.5 and 0.9 birth/month every year) (Table 2).

Fig. 5: Expected cumulative percentages of death among the A-generation oryx herd during the next ten years (1998-208)



	1998	1999	2000	2001	2002	2003	2004
A-generation	2 (1M:1F) from Abu Dhabi*	none	none	none	none	none	none
B-generation	0.5-0.9** birth/month	0.5-0.9 birth/month	0.5-0.9 birth/month	0.5-0.9 birth/month	0.5-0.9 birth/month	0.5-0.9 bith/month	0.5-0.9 birth/month
C-generation	25 for 'Uruq Bani Magarid 4 (2M:2F) for Mahazat as-Sayd	25 for 'Uruq Bani Magarid	According to new releases planned	According to new releases planned	According to new releases planned	According to new releases planned	According to new releases planned

* Importation if possible

** Turn-over rate to balance annual mortality

2. *THE STATUS OF RELEASED HERDS IN MAHAZAT AS-SAYD AND 'URUQ BANI MA'ARID*

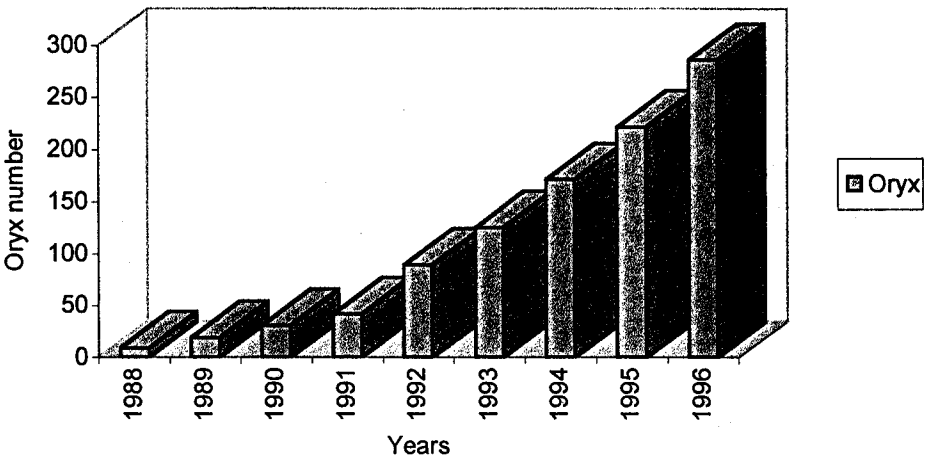
Captive breeding requirements depend also on the success of first released populations.

a). Mahazat as-Sayd

The initial re-introduction site for Arabian oryx in Saudi Arabia was Mahazat as-Sayd, a 2,200km^2 area of desert steppe habitat near Taif, east of the Asir mountains. Oral tradition and early written records indicate that this area was within the former range of the Arabian oryx. The area has been fenced to protect oryx from hunting and to allow the vegetation to recover. Since 1st March 1990, 72 (32 males and 40 females) oryx have been released: thirty-four came from the NWRC captive breeding unit and 38 from other private collections (mainly from the Zoological Society of San Diego in the USA and from Shaumari in Jordan) (Fig.). The animals are followed daily by the NCWCD ranger staff and monitoring of population dynamics as well as studies on the behavioural ecology and reproductive physiology of the animals are carried out by NWRC scientists. As population grew and animals dispersed into many small groups it became increasingly difficult to account for all of the oryx each day. Since May 1995, a monthly transect census is carried out in the reserve. The Mahazat as-Sayd population has increased rapidly and was estimated on 1st January 1998 to number 400 individuals. No supplementary food or water has been made available to the wild animals, as recovery of vegetation within the reserve has been remarkable, providing considerable optimism for the successful re-establishment of this wild population. The wild herd has demonstrated its potential for future reproduction with a high percentage of young-age classes. A simulation model

based on observed rates of productivity and survival indicates that the population will continue to grow for the next few years, reaching probably 500 to 600 individuals by the year 2000. The future wildlife management prospects should focuse on the prediction of the carrying capacity of the reserve.
Mahazat as-Sayd is also a re-introduction site for the Houbara bustard *Chlamydotis undulata macqueenii* (Seddon et al., 1995), Sand gazelle *Gazella subgutturosa* (Nayerul Haque and Smith, 1995) and an introduction site for the Red-necked ostrich *Struthio camelus camelus* (Smith and Nayerul Haque, 1994).

Fig. 6: Arabian oryx population in Mahazat as-Sayd (1988-1996)

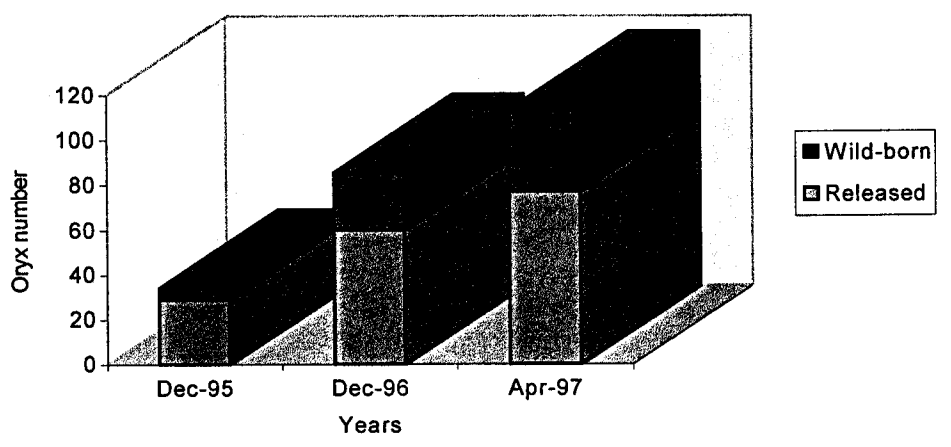


There is little need for further re-introductions into the reserve as the herd displays a 40% annual growth rate. This growth rate is the highest among all Arabian oryx herds re-introduced in the Arabian peninsula. It is probable that lack of predators, domestic grazing competitors (the area is fenced), disturbance and good natural forage every winter allowed this remarkable productivity. However blood lineage from Qatar and Abu Dhabi are missing in the herd and are worth adding to Mahazat as-Sayd. A limited importation from Taif of two couples presenting Qatari and Abu Dhabi's blood lineages would be appropriate and has been planned for 1998 (Table 2).

b). 'Uruq Bani Ma'arid

A total of 100(47.53) oryx have been re-introduced in the protected area. Ninety two are captive-born animals from the NWRC and eight are wild-born animals from Mahazat as-Sayd protected area. It is too early to know if the population is self sustaining despite a very quick and efficient adaptation by the released animals to their new environment.

Fig. 7: Arabian oryx population in 'Uruq Bani Ma'arid



However, blood lineages from Qatar and Abu Dhabi are still needed to complete the genetic polymorphism of the re-introduced herd. Two re-introductions are expected; one has been planned for March 1998, and the other one in Spring 1999 (Table 2). After this last release the population will be considered self sustainable from a genetic point of view. Further addition of oryx will depend on population dynamics, disease outbreaks, other catastrophic events or significant poaching.

The number of oryx to be released is also of major concern. However if we compare the MVP calculated for Taif's herd, with the one for `Uruq Bani Ma'arid's herd, in unmanaged populations such as that in `Uruq Bani Ma'arid, common ratios of N_e, compared to the total size of the population, are 0.2 to 0.5. If the ratio N_e/N is low, the MVP size will increase by the same proportion (if 250 individuals are to be maintained for the aims of the programme, but the N_e ratio is only 0.25, then the MVP will be 1000 individuals). In captivity, managing the sex ratio and family size can significantly reduce the MVP size required. This management is of course no longer possible in `Uruq Bani Ma'arid.

The growth rate of the population is also a basic parameter allowing the calculation of the MVP. Until small population attains its MVP, the rate of loss of genetic diversity is rapid. Thus, decreasing the genetic loss by maximizing the growth rate will also reduce the population size required to reach recommended goals. It is therefore recommended to translocate a large number of animals to `Uruq Bani Ma'arid to avoid rapid genetic loss.

Therefore, it is very difficult to assess the MVP in `Uruq Bani Ma'arid as:

- The effective number of founders cannot be assessed yet, and needs to be clarified with more field observations. Further addition of oryx will depend on population dynamics, disease outbreaks, other catastrophic events or significant poaching.
- The number of years per generation will be difficult to assess until many years have passed.
- The estimated N_e/N ratio, as well as growth rate, are of course not known yet.

To conclude, genetic loss is decreased by maximizing the growth rate of the reintroduced populations. It is suspected although not proved that the effective number of founders per reproductive cycle is lower in the wild than in captivity, as a dominant male is expected to mate with many females. The reproductive life of oryx in the wild is certainly shorter than in captivity given the general vulnerability of captive-bred released animals. A population of vertebrates smaller than 50 to 100 individuals may be particularly vulnerable to extinction due to random demographic causes. Among these causes, potential threats are loss of grazing through competition with livestock, infertility of dominant males, male-biased sex ratio, a period of rainless years, causing a reduction in breeding rate.

Therefore, we believe it is necessary to increase as quickly as possible the `Uruq Bani Ma'arid population to at least 250 animals through natural reproduction and immigration from the captive-breeding center. Another releases in 1998 and 1999 will bring new founder lineage to the herd, increase representation of "rare" blood lineage, increase the released population size through high growth rate, and bring the number of released animals to over 120 oryx.

3. *SUCCESS AND PERSPECTIVES OF RE-INTRODUCED POPULATIONS*

The number of oryx populations to re-introduce, as well as the degree of mixing; subpopulation versus metapopulations are important issues needing assessment.

a). Measuring success of Arabian oryx re-introduction

It is likely that the success of today's conservation efforts will be judged posthumously since the timescale of conservation exceeds our lifespan. We can define the success of re-introduction as the establishment of a self-sustaining population. But for the Arabian oryx, this is a long-range objective that exceeds the ten years of the Arabian oryx re-introduction programme in Saudi Arabia. Indeed, the length of time required before the biological success of a re-introduction can be assessed makes it nearly impossible for us to evaluate and use information deriving from the release to improve our methodology and techniques.

However, certain criteria can be estimated to assess the success of a re-introduction. Success for a species at the "*K*-selected" end of the continuum, i.e. with a long lifespan, late puberty, long interbirth interval and a small litter size, is better judged by post-release survival of re-introduced individuals in the first years of the programme, rather than by reproductive success. In contrast, success for an "*r*-selected" species is better defined by reproductive output and infant survival during the early years, rather than by post-release survival of captive-born adults. The Arabian oryx is considered as intermediate between the two extremes. Both post-release survival and reproductive output of re-introduced animals are very good in the Mahazat as-Sayd and `Uruq bani Ma'arid protected areas.

Therefore, we can conclude that after ten years of captive breeding, the Arabian oryx re-introduction is successful.

b). Population viability analysis

Populations which are re-establishing themselves resemble in many ways wild populations which are either naturally small, or declining towards possible extinction. Such populations are common subjects of conservation biology. The vulnerability of small populations (such as the Arabian oryx populations released in Mahazat as-Sayd and`Uruq Bani Ma'arid) to extinction is set by determined factors or stochastic events leading to the three extinction vortices of the population phenotype: environment, population structure and fitness. Oman's oryx population has demonstrated the operation of stochastic events such as male-biased sex ratio in calves, and a low effective population size due to herd dynamics and sex-ratio. These events have not yet been observed in Saudi wild populations, but will express themselves in only a few years if they exist.

c). Population genetics and metapopulation concept

Population genetics is of major importance in the long term management of the re-introduced herds. The population genetics in `Uruq Bani Ma'arid and Mahazat as-Sayd have been maximized through:

- Equalization of founder contribution;
- Management of inbreeding coefficient;
- Avoiding artificial selection;
- Increasing the effective population size;
- Reaching the minimum viable population size as quickly as possible.

In natural conditions deterministic and stochastic events act jointly on a population. If we consider a large population composed of several sub-populations (the future population model of the Arabian oryx in the Arabian peninsula) affected by similar factors, the systematic environmental pressures will tend to establish a stable equilibrium, and random pressures will tend to shift this equilibrium. A stable state is therefore a product of the action of systematic pressures and genetic drift. As soon as this stable state is reached, there should be a certain degree of differentiation between sub-populations, but the general distribution of the allelic frequencies will be the same as long as environmental conditions remain unchanged. The re-introduction programme of the Arabian oryx is a model of this process in reverse. Different sub-populations are being created as the base of a large oryx metapopulation in the Arabian Peninsula. However, we are only at the very beginning of the process. A network of subpopulations is necessary that will allow interaction and mixing between populations and prevent undesirable stochastic events having an impact on isolated populations. **The Arabian oryx population will be self-sustaining when stable metapopulations have been successfully created.**
Taking into consideration urban and agricultural development in the Kingdom two metapopulations are proposed for the future:

- An 'Empty Quarter" metapopulation, comprised of the subpopulations of `Uruq Bani Ma'arid, al-Hibakah and al-'Uruq al-Mu'taridah.
- A northern metapopulation, comprised of the subpopulations of al-Khunfah, Nafud al Uraq and possibly at-Tubaiq and Harrat al-Harrah.

This metapopulation strategy will prevent genetic isolation of separate populations, and secure the long-term survival of the species.

4. ORYX RE-INTRODUCTION SITE SCHEDULING

This issue is based on the "System plan of Protected Areas for Wildlife Conservation and Sustainable Rural Development in Saudi Arabia" published by the NCWCD and the "Oryx Management Plan in Saudi Arabia" produced by P. Seddon *et al.* (1995). The data are summarized in tables 2 and 3.

a). Arabian oryx re-introduction site responsabilities

Task	Responsability
Formalise borders	NCWCD
Assign rangers	NCWCD
Fence / protection core area	NCWCD
Erect facilities	NCWCD
Recruit research staff	NCWCD
Start baseline studies	NWRC
Start trial releases	NWRC
Start full-scale releases	NWRC
Undertake monitoring	NWRC

b). Assessment of NCWCD Protected Areas for Oryx Re-introduction

The proposed and existing NCWCD protected areas have been reviewed according to four criteria:

- Oryx present status in the protected area.
- Suitability of the habitat for Arabian oryx.
- Current state of protection from illegal hunting.
- Suitability for reintroductions of Arabian oryx.

Additionaly, we focused on existing protected areas or proposed sites which have interesting location in term of metapopulation design.
In total 12 areas have been assessed (Table 3). Nine are already protected areas and 3 are proposed areas. Two sites; 'Uruq Bani Ma'arid and Mahazat as-Sayd are the focus of on-going re-introduction programmes. Five sites would have a suitable habitat to welcome oryx back into the wild. Three sites; one in the Nafud desert and two in the eastern part of the Empty Quarter would need suitability surveys (topography, geology, vegetation cover, human activities) as they cover the former range of the species and present interesting geographic connexion with the reserves of 'Uruq Bani Ma'arid (Empty Quarter reserves) and al-Khunfah (Nafud reserve).
In summary, apart from Mahazat as-Sayd and 'Uruq Bani Ma'arid, there are three proposed NCWCD protected areas that could act as oryx reintroduction sites. These are Nafud al Uraq, al-Hibakah and al-'Uruq al-Mu'taridah. None of these areas have facilities nor have formal protection on the ground. However they present very interesting geographical location and at least for the last two ones a low population density.
Three NCWCD protected areas could also act as reintroduction sites. These are al-Khunfah, at-Tubaiq and Majami al Habd. All these sites are within the former range of the Arabian oryx distribution and benefit at least for the two northern areas of a reasonable conservation effort.

Protected Area	First protected	Oryx status	Habitat potential for Arabian oryx	Current protection from hunting	Suitability for reintroductions	Reintroduction site
Harrat al-Harrah	1988	none	unconfirmed	partial	unsuitable 2?	?
al-Khunfah	1988	none	suitable	partial	unsuitable 1	Yes
at-Tubaiq	1989	none	suitable	partial	unsuitable 1	Yes
Mahazat as-Sayd	1988	reintroduced population	suitable	adequate	suitable	Yes
Hawtat Bani Tamim	1988	none	unsuitable		unsuitable 2	No
Farasan Islands	1990	none	unsuitable		unsuitable 2	No
Raydah	1989	none	unsuitable		unsuitable 2	No
Majami al-Habd	1994	none	suitable	partial	unsuitable 1	Yes
'Uruq Bani Maarid	1994	reintroduced population	suitable	adequate	suitable	Yes
Nafud al Uraq	pending	none	suitable	none	unsuitable 1	Yes
al-Hibakah	pending	none	suitable	none	unsuitable 1	Yes
al-'Uruq al-Mugtaridah	pending	none	suitable	none	unsuitable 1	Yes

c). Arabian oryx scheduling

Seven re-introduction sites identified above are considered (Table 4). They are Mahazat as-Sayd, `Uruq Bani ma'Arid, al-Khunfah, at-Tubaiq, Nafud al-Uraq, al-Hibakah and al-Kidan. Different tasks have been identified. The table 4 sets out a timetable for these tasks for each of these seven protected areas.

ction site	1998	1999	2000	2001	2002
as-Sayd	release	review			
i Magarid	release	release	review		
nfah	protect core area pre-release enclosure baseline studies regulate grazing	regulate grazing start release	release	release	release
baiq	protect core area baseline studies re-assign rangers	pre-release enclosure baseline studies regulate grazing	regulate grazing start release	release	release
l-Uraq	formalise borders protect core area assign rangers erect facilities	protect core area regulate grazing start baseline studies	regulate grazing baseline studies release facilities	regulate grazing start release	release
akah	formalise borders	protect core area assign rangers erect facilities start baseline studies	protect core area regulate grazing baseline studies	regulate grazing protect core area release facilities	start release
dan	formalise borders	protect core area assign rangers erect facilities start baseline studies	protect core area regulate grazing baseline studies	regulate grazing protect core area release facilities	start release

In summary, only a very small release is to be carried out in 1998 in Mahazat as-sayd to complete the founder representation of the herd (Table 2). Releases are to continue in `Uruq Bani Ma'arid in 1998 and 1999. Preparation of the five other sites can begin in 1998/1999. Trial releases could start in al-Khunfah in 1999 and in at-Tubaiq in 2000.

Exact timing of the preparation of each areas depends on fundings and manpower. The captive breeding unit in Taif will be able to provide suitable numbers of oryx to any planned re-introduction programme within the next ten years. However, as it takes 45 months to produce a mature C-generation animal there is a strong need of future planning. The schedule sets out in the present document intends to be realistic and present a certain degree of flexibility.

CONCLUSIONS

The NWRC herd today comprises the most diversified pool of genes in existence for the species, and maintains a high standard of health through the three generation management programme. Although some genetic lineages are still under-represented in the herd, and substantial breeding of these founder lineages is still necessary, captive breeding of second generation animals has had to be reduced since June 1995 as new release sites are not yet ready to welcome oryx. The NWRC minimal viable population (population needed to conserve 90% of the genetic polymorphism after 100 years) has nearly been reached. Although maintenance of such a large herd is time consuming and of course expensive, the need for more "genetically fit" animals to be released in `Uruq Bani Ma'arid and hopefully very soon in al-Khunfah protected areas, justifies the maintainance of a captive herd until the released populations have become self-sustaining. Additionally, the risk of catastrophic losses in the released herds due to drought, unexpected disease or significant poaching events is still possible. For these reasons a solid herd of oryx should be kept at the Taif breeding Center until a sufficient number of released populations are considered self-sustaining. The recent poaching of the Omani oryx population, released since 1982 (nearly 15% of the wild population has been poached in 1996), demonstrate that even after 25 years of success this charismatic species remains vulnerable.

Conclusions in seven steps

- The captive breeding programme at the NWRC has achieved expected goals;
- The captive herd needs to be maintained in order to support further re-introductions;
- After seven years, the Arabian oryx re-introduction in Mahazat as-Sayd is a success. Further development of the population within the reserve needs to be consider in a management plan;
- After three years, the Arabian oryx re-introduction in 'Uruq Bani Ma'arid is successful;
- It is too early to assess the log term self-sustainability of the re-introduced populations;
- The Arabian oryx re-introduction programme will be self-sustaining when stable metapopulations will be created;
- Two metapopulations can be envisaged in view of the development of the country, one in the 'Empty Quarter' and one regrouping Northern/Nafud areas.

LITERATURE CITED

Flamand J.R. B., Greth A., Haagsma J., and Griffin, F. 1994 Veterinary Record 134, 115.

Fowler M.E. (Ed.). 1986. Zoo and Wild Animal Medicine. W.B. Saunders Company, Philadelphia. 1127pp.

Greth A., Flamand J.R.B., and Delhomme A. 1994. Veterinary Record 134, 165.

Griffin J., and Cross J. 1986. Proceedings of the New Zealand Veterinary Association, deer branch. vol 3. p71.

Haagsma J., and Poilane J.F. 1989. Wildlife Conservation and Development in Saudi Arabia. Proceedings of the 1st Symposium on the Potential for Wildlife Conservation and Development in Saudi Arabia. Eds A. H. Abuzinada and others. Riyadh, National Commission for Wildlife Conservation and Development. p349.

Haque M.N., and Smith T. 1996. Reintroduction of Arabian sand gazelle Gazella subgutturosa marica in Saudi Arabia. *Biological conservation* 76(2): 203-207.

Kirkwood J.K., Gaskin C.D., and Markham J. 1987. Perinatal mortality and season of birth in captive wild ungulates. *Veterinary Record* 120: 386-390.

Seddon P.J., Saint-Jalme M., van Heezik Y., Paillat P., Gaucher P., and Combreau O. 1995. Restoration of Houbara bustard populations in Saudi Arabia: Developments and future directions. *Oryx* 29(2): 136-142.

Seitre, R. 1989. Wildlife Conservation and Development in Saudi Arabia. Proceedings of the 1st Symposium on the Potential for Wildlife Conservation and Development in Saudi Arabia. Eds A. H. Abuzinada and others. Riyadh, National Commission for Wildlife Conservation and Development. p320.

Smith T., and Haque M,N. 1994. Re-introduction of red-necked ostriches in Saudi Arabia. *Re-introduction news* 9:5.

LIST OF FIGURES AND TABLES