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General Secretariat for
the Conservation of the
ARABIAN ORYX

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Arabian Oryx
(Oryx leucoryx)

Housing & Husbandry Guidelines
Version 1

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Arabian Oryx

(Oryx leucoryx)

Housing and Husbandry Guidelines
Version 1

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The guidelines are divided into five chapters as follows:

Chapter 1: In this chapter specific requirements of housing Arabian Oryx in captivity are outlined. These include optimal herd size, enclosure design, shading and substrate and other important aspects related to managing animals in fences.

Chapter 2: This chapter focuses on dietary requirements and ensuring optimal nutrition for the species.

Chapter 3: This chapter provides some veterinarian recommendations that are necessary to maintain Oryx health.

Chapter 4: This chapter provides recommendations on handling, transport, marking and identification based on experiences and case studies from the UAE.

Chapter 5: This chapter discusses conservation breeding for the species, including recommendations for ensuring genetic diversity.

These guidelines are kindly funded by EAD. Particular acknowledgments are due to H.E. Razan Khalifa Al Mubarak, Secretary General of EAD; Dr. Shaikha Al Dhaheri, Executive Director of TMBS, EAD, and Dr. Salim Javed, Acting Director of Terrestrial Biodiversity. Acknowledgments are also due to Al Ain Zoo, Al Bustan Zoological Centre and Marwell Wildlife for their generous and valuable expert contribution to authoring the guidelines.

The guidelines are available for download at www.arabianoryx.org

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Foreword

It is my sincere pleasure to share with you the first ever guidelines to be developed for the Housing and Husbandry of Arabian Oryx Collections in the United Arab Emirates. These guidelines are the result of concerted efforts by conservationists and collection managers in the United Arab Emirates, building upon the recommendations of the National Workshop on Standardizing Herd Management of Arabian Oryx Collections in UAE, held on 31st May 2016 in Abu Dhabi. The workshop was organized by the General Secretariat for the Conservation of the Arabian Oryx (GSCAO) and the Environment Agency - Abu Dhabi (UAE). GSCAO, hosted by EAD, is a regional initiative established thanks to the visionary leadership of the founder of our nation the late Sheikh Zayed (may God have mercy upon him), and his genuine love and concern for our natural heritage.

The key mission of the GSCAO is to facilitate the sharing of information and support capacity building in the range states. The aim of these guidelines is to provide field biologists, conservation managers, veterinarians, geneticists and researchers at Arabian Oryx institutions in the UAE, the region and beyond with best practices and minimum requirements in housing, nutrition, health, capture, transportation and conservation breeding. These guidelines were authored by biologists, scientists and conservation managers who generously volunteered their time and expertise to supporting the GSCAO in fulfilling this task. It is our hope that these simple recommendations, which are based on actual on the ground experience in managing Arabian Oryx collections, prove useful and beneficial to all. We urge collections to do their best to implement the minimum requirements of these guidelines, in order for all of us in the biodiversity conservation community to have a common ground and agreement on how best to manage and conserve this iconic Arabian species for current and future generations.

In this context, the Arabian Oryx housing and husbandry guidelines are not static and the GSCAO, in collaboration with its partners, will update them as new information and recommendations arise. Hence, we welcome your feedback on this version of the guidelines.

Finally, I would like to thank the authors and coordinators for their valuable contribution to the development of these guidelines. Without their support and in-kind contributions, this document would not have been possible. I hope this document will benefit all those of you in the UAE and beyond that are passionately dedicating your time, expertise and resources in the conservation of the Arabian Oryx, and wish you best of luck in your endeavors.

Preface

Arabian Oryx Housing and Husbandry Guidelines, Version 1.

The General Secretariat for the Conservation of the Arabian Oryx (GSCAO) was established in 2001 as a regional initiative to coordinate regional conservation efforts of the Arabian Oryx. GSCAO is hosted and funded by the Environment Agency - Abu Dhabi (EAD).

The guidelines represent one of the key outcomes of the National Workshop on Standardizing Herd Management of Arabian Oryx Collections in the UAE, which was held on 31st May 2016 at the Environment Agency - Abu Dhabi (EAD). At this workshop, a voluntary technical advisory group composed of key experts and collections managers in the country was formed to develop and agree on standardized requirements for captive collections of Arabian Oryx. This document aims to share these requirements and recommendations within the UAE and the region, as part of GSCAO's mission for the sharing and dissemination of best practice and for technical capacity building that helps serve Arabian Oryx conservation.

The UAE hosts the largest population of Arabian Oryx in the region with numbers exceeding 10,000 individuals. Most of these individuals are housed in captivity with various levels of management intervention. These guidelines are mainly set for intensively managed herds and have been prepared to provide conservation managers and zoo keepers with basic and necessary requirements on housing Arabian Oryx herds in the UAE.

The General Secretariat for the Conservation of the Arabian Oryx (GSCAO) is grateful to the following wildlife managers and experts for generously contributing their expertise, knowledge and time to writing up and coordinating the work of the guidelines:

Meyer E. de Kock, Al Bustan Zoological Centre

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Environment Agency - ABU DHABI

Marwell Wildlife

حديقة الحيوانات بالعين
AL AIN ZOO

Chapter 1
Housing guidelines

Meyer E. de. Kock & Kate Burns

Captive Arabian Oryx in the region are managed according to a range of different management strategies. Housing and husbandry guidelines are directly influenced by the management strategies of each institution.

Within the Middle East region, populations can be divided into three main groups of management:

- Intensely managed, selected zoo populations in the region that manage their population on an individual level
- Semi wild animals that are housed in large herds in relatively large camps where a form of group management is practised. These collections may be in private or governmental managed populations
- Re-introduced populations, where there is limited management
- These guidelines will focus on intensely managed popuations, while providing some information on semi wild population management. The user of these guidelines needs to select the correct recommendations as per his/her population management plan.

Table 1: Relationship between states of conservation and attributes of fully conserved species (reproduced from Redford et al., 2011)

States	Attributes					
	Representative	**Replicated**	**Self-sustaining**	**Healthy**	**Genetically robust**	**Resilient across range**
Self-sustaining	Fully conserved	Fully conserved	Fully conserved	Fully conserved	Fully conserved	Fully conserved
Conservation dependent	Fully conserved	Fully conserved	Partially conserved	Fully conserved	Partially conserved	Partially conserved
Lightly managed	Partially conserved	Partially conserved	Partially conserved	Partially conserved	Partially conserved	Minimally or not conserved
Intensively managed	Partially conserved	Partially conserved	Minimally or not conserved	Minimally or not conserved	Minimally or not conserved	Minimally or not conserved
Captive managed	Minimally or not conserved	Minimally or not conserved	Minimally or not conserved	Minimally or not conserved	Minimally or not conserved	Minimally or not conserved

Note: These are modal values that will vary on a species-by-species basis.

1. Intensely managed populations (zoo based populations)

There is a range of general minimum standards for housing zoo animals developed by global and regional zoo institutions. These main standards are available from the websites of the following associations:

- World Association of Zoos and Aquaria (WAZA): http://www.waza.org
- European Association of Zoos and Aquaria (EAZA): http://www.eaza.net

Accommodation

In order to provide adequate housing that ensures the health and welfare of Arabian Oryx in captivity, collection managers are advised to implement the below recommendations:

a) Ensure that physical space, preferably three dimensional, is sufficient to accommodate all animals. It should contain furnishings suitable for the species

b) Ensure carrying capacity of the enclosure is not exceeded

c) Design of the exhibit should be suitable for all species to demonstrate natural behaviour. Elements to consider include:

    i. Substrate

    ii. Shade

    iii. Furnishing

    iv. Privacy

    v. Welfare

    vi. Minimization of stress

d) Wherever possible, provide an isolation area as part of each exhibit

e) Ensure that the design is suitable for the day to day management, including:

    i. Enrichment

    ii. Training

    iii. Movement/capture

    iv. Cleaning/maintenance

f) Ensure that environmental conditions for the well-being and survival of the species are provided, for example:

    i. Appropriate life support system with back-up

    ii. Appropriate climatic conditions for the animal's needs

g) Maintain hazard and risk-free environment for all species

h) Internationally recognised husbandry guidelines should be followed in the housing of the species

i) Where necessary, all animal facilities should be cleaned/disinfected on a daily basis

j) All facilities should be maintained to the highest safety and animal welfare standards

k) Mixed species exhibits, which are encouraged, should take into consideration the species compatibility, group size and structure

l) Success and failure of mixed species exhibits should be shared amongst members

m) Free ranging species should have containment areas for veterinary and management procedures.

2. Breeding Arabian Oryx

Conservation breeding principles must be followed in any captive-breeding program. On an institutional level, herds need a clear plan, with an aim to add value to regional and international conservation goals. In some cases, conservation breeding may result in a decision not to breed a specific collection or herd. Genetic variety is as important as population size in a breeding program. A clear idea should be formed on where your collection fits in the bigger picture of this species' conservation. This institutional plan, in turn, will need a supporting infrastructure that includes an enclosure designed for the intended purpose e.g. breeding, or display enclosures.

3. Herd composition

Arabian Oryx are gregarious in nature, and housing individuals in isolation is not recommended for this social species.

3.1. Bachelor herds

Arabian Oryx is not known to have naturally occurring all male herds. In captivity, even in large areas, bachelor groups are generally unsuccessful, due to fighting and constant sparring. This results in aggressive behaviour and injuries.

3.2. Breeding herds

One male, several females (harem group)

Most zoos house Arabian Oryx in this way, where the sexually mature male offspring are removed to allow a single mature male to breed with the mature females. This allows managers to know 100% parentage, and therefore the genetic purity of the herd.

Several males, several females

In the re-introduced herds in the Dubai Desert Conservation Reserve, multiple herds consist of 1:1 sex ratio (G. Simkins, pers comm.). In non-zoo based areas, where semi-wild herds are kept in large camps, this is common.

Data received from the regional housing survey (De Kock, 2017) suggest success with the breeding herd in large enclosures (semi wild populations) with a sex ratio of 1.3 (J. Samour, pers comm.).

4. Gestation period

The gestation period is about 240 days. The females will leave the herd to give birth. The calf will join the herd between the ages of 15-45 days. Weaning of calves is about 150 days. Animals reach sexual maturity at approximately 2-years of age, and live up to 23-years in captivity.

Seasonal births

In captivity, there is no clear seasonal birth period, and populations need to be managed to reduce births between May to August during the hottest time of the year.

Figure 1-1: Arabian Oryx males sparring (©H.Ensling).

5. Mixed exhibits

Arabian Oryx is mixed with a range of species in the region, commonly with Arabian Sand Gazelle, Arabian Mountain Gazelle and Speke's gazelle *(Gazella spekei)*. Some institutions house Arabian Oryx with non-endemic species, such as:

Mouflon or Urial *(Ovis orientalis spp)*: 1 collection

Indian blackbucks *(Antilope cervicapra)*: 1 collection

Barbary sheep *(Ammotragus lervia)*: 1 collection

Nubian ibex *(Capra nubiana)*: 3 collections

Axis deer *(Axis axis)*: 1 collection

Fallow deer *(Dama dama)*: 2 collections

The success of mixed exhibits is usually limited to the minimization of competition in common areas like feeders, drinkers, shade and general space. Mixing Arabian Oryx with any other species of the same genus must be avoided at all times. This includes the following: Beisa Oryx, Galla Oryx, Fringe-eared Oryx, Gemsbok and Scimitar-horned Oryx. Close relatives to this genus may also pose a genetic risk and possible hybridization, like the Addax.

Enclosure design

Space available in institutions may be limited. Where space is limited, a maximum carrying capacity for the area must be the guide for the total number of animals housed. Ideally the enclosure design must consist of 3 main areas. Hardstanding area, indoor/stall area and a grazing area. There are limited publications on the housing of Arabian Oryx. Zoo based enclosures can follow general guidelines of similar species in captivity such as the husbandry guidelines for the Scimitar-horned Oryx (Gilbert and Woodfine, 2004).

6. Indoor areas

Because of the Arabian Oryx's gregarious nature, indoor areas must be large enough to house all individuals, with a separation stall within the indoor area to assist in handling and capture of individuals in intensely managed populations.

Separation area doors that can operate from the outside will be an advantage, so animals can be separated from the herd if needed. If animals are separated, it is recommended that they remain aware of the rest of the herd via smell. Visual gaps are not recommended, as this may encourage aggressive behaviour (Gilbert and Woodfine, 2004).

6.1. Flooring recommendations

There are limited reports of over-grown hooves if compared with other ungulates housed in the region, due to the natural soft fine sand that reduces hoof wear. However, smooth flooring may result in slipping and injury and therefore need a textured finish. The key recommendations for flooring include:

- Having a non-slip floor
- Ensuring easily cleanable surfaces
- Having a flat floor, with a slight slope to reduce water and urine buildup
- Covering the flooring with adequate bedding. If hay is used, it needs to be removed if wet and changed frequently to reduce the risk of mould.

6.2. Environmental conditions

The region's air quality during the windy months will be reduced as a result of the high dust concentration. Airflow is important throughout the year, and large air vents are recommended, including vents that can be closed if needed especially during sand storms.

Indoor areas are preferred by the species during these months. It is important to maintain good airflow within the indoor area if vents are closed due to air quality issues. High heat and high humidity during summer months will influence how we house this species.

Plain steel roofing is not recommended as this will heat up the indoor area. Natural roofing, shade net and insulated roofing panels are all good options. Large clear roof panels must be avoided due to the greenhouse effect that will heat the inside area. Smaller clear roofing can be added to enclosed areas to increase natural light.

Arabian Oryx can withstand natural extreme heat. Shade and cover from sunlight as well as hot winds are needed. Individuals will compete for the best shaded and sheltered spots within the enclosure. No institution in the region reports the need to use cooling systems for enclosures for this species.

7. Enclosure boundary

Arabian Oryx are well-equipped diggers. A relatively low fence >1.5 m high, will keep them in if this fence is extended and well secured below-ground level. Arabian Oryx would rather go underneath a fence than over it.

7.1. Fencing recommendations

The recommended design of fences for Arabian Oryx enclosures includes:

- Chainlink or welded mesh fencing
- Height above ground a min of 1.5 m - 2.1 m
- More important is the distance below ground. The distance varies from 30 cm to 50 cm with eight gauge line wire at 10 cm below ground to hold the chain link (D. O'Donovan, pers comm.)
- Gaps in fencing need to be small enough so head and feet cannot be pushed through and get stuck, but large enough so horns do not get stuck
- Electric fencing with a setting of 4KV or higher can be used. Care must be taken to provide a backup system to provide a barrier during a power failure.

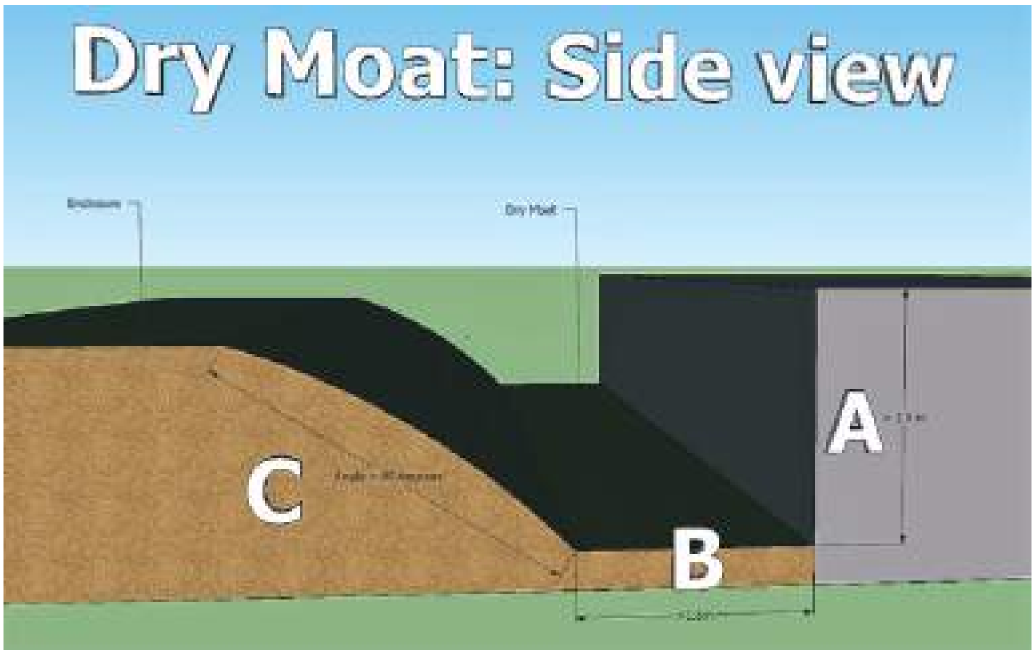

Figure 1-2: Dry moat guidelines

Table 2: Dry moat guidelines

Dry Moat	A: Moat Height	B: Moat Width	C: Moat Angle
Guidelines	> 1.8 meter	> 1.6 meters	< 60 degrees

7.2. Moats, wet and dry

Dry moats are common in zoos, but wet moats are rarely seen in use for Arabian Oryx enclosures.

Figure 1-2 and Table 2 indicate the guidelines for the dry moats housing Arabian Oryx.

The height (A) is calculated on 1.5 x the shoulder height of the species. The moat width (B) is calculated on the average total length of the species. The angles (C) are suggested to be lower than 60 degrees. Regular checks for the possible sand runoff from C to B, reducing the total clearing height, are needed, followed by adequate maintenance.

8. Feeding

To reduce aggression and competition for feed items that are presented as a broadcasted feed item, attention must be given to how these items are provided in the enclosure. Generally speaking, this will include a range of feeders that can accommodate all the individuals at the same time and more than one drinker per enclosure. Feeders and drinkers must be selected that can accommodate more than one individual at a time.

8.1. Hayracks and feeders

There is a range of types available. Selected racks and feeders need to be safe for use by this species.

It is recommended that composed feed feeders be:

- Lifted from the floor
- Long narrow feeders that will allow access from both sides
- Have a few drainage holes
- Non-porous material that can easily be cleaned
- If the feeder is made from galvanised sheet metal, do not paint the area that will be in contact with the pelleted food.

Figure 1-3: Hanging hayrack

Figure 1-4: Free standing hayrack

Recommendations for hayracks include:

- Hay needs to be suspended from the ground to reduce contamination
- Hayracks with vertical metal basket bars rather than horizontal metal basket bars need to be selected
- The space between individual basket bars as well as the type of material needs to be investigated
- The gaps must be smaller than a calf head width and made out of rigid material that doesn't bend or flex under normal use by the species
- Racks should allow access from both sides to feed. The paint can flake off over time and mix with the food items.

8.2. Drinkers

It is recommended to have more than one drinker per enclosure. Water points can be dominated by individuals and be a point of confrontation and aggression.

Guidelines for drinkers

- Must provide access from more than one side
- Must be able to accommodate more than one individual at any given time
- Shallow and easy for calves to get out if needed
- Shaded
- If automatic ball valves are used to automatically refill the drink, it is best to cover this system to reduce damage and breakage due to sparring.

Figure 1-5: Shaded shallow drinker

Figure 1-6: Feeding area on a concrete slab

9. Shade

Shade is critical for the species and can be natural or artificial. If trees are in the enclosure for shade, non-toxic trees that are protected against debarking by Oryx are recommended (Figures 1-7 and 1-8). Roofing needs to be designed in a way that reduces the risk of injury because of the structure or materials used.

Shade Recommendations:

- Multiple shaded areas within an enclosure to reduce competition for shade
- Shaded areas that will provide usable shade for all the individuals during the heat of the day
- Shaded areas over feeding and drinking area.

Figure 1-7: Naturally shaded area

10. Substrate

It can be challenging to keep the regional sandy substrate "clean". Removing build up of faecal matter is necessary for smaller areas with a high animal load and in intensely managed populations. Traditional cleaning techniques for areas around feeding stations can be seen in Figures 1-9 and 1-10.

Figure 1-8: Arabian Oryx under the shade of a Ghaf tree (*Prosopis cineraria)*

Figure 1-9: Barari Forest Management (BFM) team cleaning around feeding areas using traditional methods

Figure 1-10: BFM using a locally developed sifting system to clear high-density areas

11. Enclosure horticulture, irrigation lines

Arabian Oryx often dig to create bedding areas or to reach underground water or irrigation lines (AZA, 2017)

Figure 1-11: Arabian Oryx breaking and drinking from irrigation lines

Figure 1-12: Electric fencing is protecting plants in the enclosure

11.1. Poisonous plants

Poisonous plants in the enclosure must be removed, like the natural occurring Sodom's apple ***(Calotropis procera)***. The milky sap contains a complex mix of chemicals, some of which are steroidal heart poisons known as **"cardiac aglycones"**.

11.2. Seasonal / temporary capture systems

These systems usually consist of traditional game capture techniques that push the herd into a funnel shape holding area where individual animals are isolated to be handled or transported. The TAMER system, consisting of a panel system and sliding doors that are connected to a restraining device, is commonly used in the region.

11.3. Built-in isolation and management systems

An integrated isolation system can be as basic as separation areas (stalls) within the enclosure. If an enclosure is designed, this area can be integrated into the main structure.

A useful tool to add to this system is a weight platform to get weights of individuals passively.

Professional systems are available, and the TAMER Junior© (www.faunaresearch.com) is widely used in the region.

Figure 1-13: Capture techniques in large open areas

Figure 1-14: Internal isolation system with the sliding doors operating from the outside

12. References

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Chapter 2
Nutrition

Mohammad Al Faqeer, Stephen Chege, & Mayyas Al Qarqaz

1. Diet

1.1. Wild diet

Very little is known on the nutritional requirements of the Arabian Oryx *(Oryx leucoryx)* in its native environment. Stewart (1962), who was the first to study the species in the wild prior to its extinction, found that they fed mainly on such grasses as *Stipagrostis plumosa* and *Lasiurus hirsutus*, but also on foliage, fruits and roots (Asmode, 1990).

Oryx mainly eat grasses and the shoots of trees and bushes and may wander long distances in search of pasture. They can survive for long periods without drinking, apparently meeting their water requirements from succulent plants and occasionally from dew, but they drink freely when water is available. They feed mainly in the early morning, evening and possibly at night (EAD, 2010).

Results of a research performed by Jean-François Asmode at the National Wildlife Research Center, Taif, in 1990, showed that when given a choice, the Arabian Oryx are selective grazers. The grasses most consumed, like *Cynodon dactylon* and *Eragrostis papposa*, have the highest protein content found for grasses in the study area. It was also noticed that the young animals that grazed on natural vegetation from an early age ate a large amount of browse, while zoo bred adult animals took a long time to adapt to this kind of food when reintroduced in Oman (Stanley Price, 1989).

1.2.Diet in captivity

Successful feeding of wild mammals in captivity requires knowledge of basic nutritional concepts, an understanding of digestive physiologies, an appreciation of natural feeding behaviors, a familiarity with appropriate food sources and awareness of potential diet related diseases (Wild Mammals in Captivity, 2010).

Due to the availability of extensive information on diets & nutritional requirements of domestic ruminants, many of the well-managed Arabian Oryx populations in captivity have used this data as a foundation in the formation of their diets (Gilbert & Woodfine, 2004). A combination of bulk forage, in the form of grass hay and/or alfalfa hay, and concentrated feed or pellets, usually form a major component of the diet.

1.2.1. Hay

Hay (forages that are harvested & dried) is an important source of nutrients and often provides a major portion of dry-matter intake for captive mammalian herbivores and is usually provided on an ad libitum basis. Hay is especially valuable as a source of fiber in support of normal microbial fermentation and normal feeding behavior. In the wild, herbivores may spend many hours each day acquiring and consuming food. In captivity, animals fed relatively concentrated diets can consume them in minutes rather than hours and may develop behavioral vices, such as chewing on exhibit or stall materials and obsessive licking, grooming, or other stereotypic behaviors. Because consumption of hay requires prolonged periods of chewing, its use may help prevent these unusual behaviors (Oftedal et al., 1996).

Commonly used grass hays include plants in the family Poaceae, whereas legume hays include plants in the family Fabaceae. Examples of grass hay used to feed Arabian Oryx include: Timothy grass, Orchard grass, Bermuda grass, and Rhodes grass. The most commonly used legume is Alfalfa/Lucerne called Lucerne in Europe and Australia.

An important factor influencing the nutritional value of both legume and grass hay is the stage of maturity at cutting (Morrison, 1956 and Vans Soest, 1994), and this stage is an important criterion in establishing hay grades. The net result is a decrease in hay palatability, digestibility, and nutritional values as maturity at cutting advances (Vans Soest, 1994).

Harvesting and storage factors can influence hay quality. It is recommended that hay should be stored in a building or properly designed storage facility. General recommendations include ensuring that hay storage areas have adequate drainage, natural or fan ventilation, protection from precipitation and soil moisture, and protection from contamination by pests (birds, rodents and vermin). If hay is stored outdoors, it should be kept off the ground by placing it on pallets or other similar devices. The hay should be covered with a trap or plastic sheet to protect it from sand particularly when it is stored outside.

Proper drying and cutting of freshly cut forage is a critical step in producing high quality hay (Church and Pond, 1988; Van Soest 1994). If hay is too wet when it is baled, bacteria & mold can begin to grow. These microorganisms can reduce feed intake and may produce toxins that adversely affect animal health. If hay is baled when it is too dry, however, leaves may fracture and fall off the stems, reducing nutritional value. When over-dried hay is offered, feed intake also may be adversely affected. Minimum dry-matter content of hay should be 85% (Oftedal et al., 1996).

Figure 2-1: Fresh alfalfa is fed to Arabian Oryx herds in Al Ain Zoo. It is predominantly utilized as browse alternative for Arabian Oryx and other similar species.

1.2.2. Pelleted feed (concentrated feed)

Pelleted diets are manufactured from ground ingredients that are compressed into cylinder-shaped particles. A wide range of manufactured diets is available for feeding captive wild herbivores. The most common form of commercial herbivore diet is a pellet.

Pellet feeds offer a convenient method for ensuring that the Oryx's nutritional requirements are met (Gill & Cave-Browne, 1988; Oftedal et al., 1996).

1.2.3. Browse

Browse is used as a foraging food in many institutes. Browsing is defined as a type of herbivory in which a herbivore feeds on small bushes, twigs, sprouts, herbaceous plants, small trees and other vegetation (including buds, twigs, leaves, fruit, and flowers of woody plants). The plant material eaten is known as browse.

There may be behavioral benefits to providing Oryx with browse as it may increase time spent feeding and enable animals to exhibit a greater range of their feeding behaviors (Gilbert & Woodfine, 2004).

Fresh alfalfa is predominately used as alternative browse source to enhance the diet fed to the Arabian Oryx herds in many of the captive collections. However, it is preferable to offer a range of browse species rather than just one. Provision of fresh alfalfa should be properly introduced to the animals and adequately wilted before being fed in order to avoid the incidence of any associated dietary problems.

According to the classification of Hoffman & Stewart (1972) for the food choices of the ruminant herbivores, the definition of Bulk & Roughage Feeders or Grazers, are the herbivores that select diets containing less than 25% browse. However, provision of browse to the Arabian Oryx as a selective grazer is essential but should be offered in moderation.

1.2.4. Water

Although the Arabian Oryx is well known as a uniquely adapted species to the arid land environment, and equipped with a range of behavioral and morpho-physiological responses to high temperatures (Williams et al., 2001); in captivity a continuous supply of fresh, clean water should be available adequately within animals' enclosures.

1.2.5. Feed supplements

In their natural environment, wild species have little need for supplementary feeding as their free ranging habits enable them to pursue more nutritious grazing and therefore satisfy their requirements. With the advent of game farming, wild animals have been confined to limited areas and this has necessitated some form of supplementary feeding. In the case of captive populations their total feed requirements have to be met (Roosendaal et al., 2015). Specific requirements of vitamins & minerals supplements for Arabian Oryx are not yet available, thus it is sensible to base requirements on those of the domestic ruminants and to supplement the diet accordingly. Most of the commercially available concentrated feeds contain added vitamins and minerals, even though mineral salt licks are recommended as well as vitamin E & selenium.

1.2.6. Feed and water presentation

Hay can be placed on a raised feed trough (Fig. 2-2) or concrete foundation (Fig.2-3). Feeding location and access to feed should be well considered in a manner that accommodates the feeding behavior of species herds and individuals within those herds. In addition, feeder space should allow individuals within a herd to feed without excessive competition. The pellets can be sprinkled on the raised concrete floor (foundation) or placed in galvanized steel troughs, which should be evenly distributed in the enclosure. However, pelleted feed is recommended to be mixed with some hay (grass or alfalfa) rather than provided separately, or at least fed after animals have access to the roughage feeds, which may help to prevent some digestive disorders. To satisfy some grazing behaviors of the species and to attain specific herd management objectives, some local animal facilities are using rubber mats as a substitute for troughs or trays (Figure 2-4). Those thick mats can be rotationally relocated within the animals' enclosure to help avoid excessive accumulation of manure in the feeding location and simultaneously prevent ingestion of sand, which can help prevent sand impaction in the alimentary tract.

Figure 2-2: Tiled concrete drinkers & hay troughs in an Arabian Oryx mixed-enclosure

Figure 2-3: Feed placed on a concrete foundation. The advantage is that it allows animals to have normal feeding behavior, and can be cleaned easily. The disadvantage is that it easily gets contaminated with feces and urine as animals stand on them

Figure 2-4: Thick rubber mats can be used as substitutes for hay troughs &/or concrete foundation. They can be shifted rotationally within animals' enclosures & consequently help to minimize accumulation of animal waste in one area, particularly when cleaning is a challenge with sand substrate

Figure 2-5: Automatic drinker placed in the enclosure. This is preferred as it ensures good hygiene and minimal water loss

Automatic stainless steel drinking troughs (Fig.2-5) are one of the drinkers that can be used. They should be placed at a suitable height for easy access by all animals (around 100 cm) and to avoid contamination from organic matter, i.e. feces, urine or food. They should be safe enough to avoid the animals accidentally kicking and emptying, and should be designed to avoid horn trapping or damage. One of the common drinking facilities is the concrete trough (Fig. 2-2) which should be tiled with a cleanable surface. If ponds are used as drinking places, they should be clean and free from organic matter to avoid weeds and fungi developing (Smith et al., 1997).

Figure 2-6: Ponds may be used as drinking places if free from organic matter to prevent weeds and fungi from growing

Figure 2-7: Feed multi-sampler is used in Al Ain Zoo to take a representative sample of grass & alfalfa hays, for routine feed analysis

1.2.7. Feed testing

Each shipment of hay and pellets should be examined prior to acceptance. Hay quality can be evaluated by sight and smell upon arrival (Morrison 1956). The hay should contain minimal weed contamination and should not appear excessively bleached (bleaching may indicate improper field drying). Hays should appear leafy, and the leaves should not readily fall off the stems when the bale is opened. The amount of leaf may indicate the stage of growth at the time of cutting, but excessive leaf fall may also indicate that the hay is too dry. Stems should be pliable; stems that feel brittle or snap when they are bent may indicate that the hay is too dry or that the hay is too mature at the time of cutting. Excessive dustiness, a musty smell or a choking sensation when smelled closely suggests that mold growth may be a problem. Representative feed samples from each feed item should be obtained and preserved under suitable conditions (for nearly 6 months) to be used as reference for analysis whenever needed. Although the feed manufacturer gives guaranteed feed analysis of the pelleted feed it's important to perform random testing to ensure the minerals and other nutrients are within acceptable limits to prevent deficiency. Biannual testing is a good starting point.

1.2.8. Feeding the neonate

If a calf cannot be raised by its dam, hand rearing is labor intensive and requires early intervention to provide the calf with the best chance of survival. Neonatal ruminants acquire immune protection passively through ingestion of maternal colostral immunoglobulins (IgG) in the first 24 to 48 hours of life. The first choice for colostrum replacement should be oral administration of fresh or frozen intraspecific colostrum, followed by low-temperature pasteurized cow's colostrum, commercial freeze-dried cow's colostrum replacer, and commercial bovine plasma. Feed calves 10% of their body weight in colostrum, or 5 grams per kilogram (g/kg) colostrum replacer, over the first 24 to 48 hours. Milk composition varies considerably among species, and a formula's composition should mimic that of the dam's milk in protein, carbohydrate, fat, and total solids. Goat's milk is a good choice for many species, alone or in combination with a milk replacer. However, milk may be low in vitamin E, zinc, copper, and iron, necessitating vitamin and mineral supplementation. Probiotics may also be beneficial in establishing a healthy rumen flora. Calves should receive 8% to 15% of their body weight in formula every 24 hours, divided into four to six feedings per day. In the first 2 to 3 weeks of a ruminant's life, milk digestion occurs in the abomasum and small intestine. Milk deposited into the nonfunctional rumenoreticulum during this period is not digested and may lead to rumenitis and septicemia (Drackley, 2008). For this reason, tube feeding or force feeding a calf with a poor suckle response may be harmful. By 2 to 3 weeks, the ruminal papillae are stimulated, and the calf begins to take in small amounts of dry feed.

1.2.9. Feeding adults

Grazers are generally fed commercial herbivore pelleted concentrate diet containing 12% to 18% protein and 16% to 25% acid detergent fiber (refer to Table 2-1 and Table 2-2) at approximately 1% body weight per day in addition to adlibitum hay. Salt blocks should be available at all times. Fresh alfalfa or any other preferred browse should be offered. At Al Ain zoo the ratio of Timothy hay to pellets is 80:20 (an example of an adult Arabian Oryx diet record is shown in Table 2-3. below).

Table 2-1: Manufacturer's guaranteed analysis of an example of Diet 1 fed to Arabian Oryx at Al Ain Zoo

Analytical component	Quantity
TDN (min)	**60%**
Crude protein (min)	15%
Crude fat (min)	**2%**
Fibre (max)	12%
ADF (max)	19.5%
NDF (min)	34%
Calcium (min)	0.95%
Calcium (max)	1%
Phosphorus (min)	0.3%
Vit A (min)	15000IU
Vit D3 (min)	3000IU
Vit E (min)	240IU
Manganese (min)	150mg
Zinc (min)	140mg
Iron (min)	300mg
Copper (min)	22mg
Iodine (min)	20mg
Selenium (min)	240mcg
Cobalt (min)	500mcg

Table 2-2: Manufacturer's guaranteed analysis of an example of Diet 2 fed to Arabian Oryx at Al Ain Zoo

Analytical component	Quantity	Analytical component	Quantity	Analytical component
Crude protein (min)	15%	Digestible energy	3,050 kcal/kg	Pyridoxine 5.9ppm
Arginine	0.79%	Metabolizable energy	2,510 kcal/kg	Biotin 0.5ppm
Cysteine	0.25%	Ash	7.8%	Vit B12 22μg/kg
Histidine	0.37%	Calcium	1.2%	Vit A 8540 IU/kg
Isoleucine	0.84%	Phosphorus	0.75%	Vit D31140 IU/kg
Leucine	1.1%	Potassium	1.9%	Vit E 320 IU/kg
Lysine	0.67%	Magnesium	0.32%	Vit K 4.6ppm
Methionine	0.23%	Sodium	0.50%	Betacarotene 23ppm
Phenylalanine	0.7%	Chloride	1%	
Tyrosine	0.4%	Sulfur	0.24%	
Threonine	0.58%	Iron	430ppm	
Tryptophan	0.19%	Zinc	145ppm	
Valine	0.74%	Manganese	165ppm	
		Copper	21ppm	
Fat (Ether extract)	3.0%	Cobalt	1.8ppm	
Linoleic acid	1.1%	Iodine	1.9ppm	
Omega 3 fatty acid	0.49%	Selenium	0.20ppm	
Omega 6 fatty acid	1.1%	Thiamin	11ppm	
		Riboflavin	10ppm	
Fiber (crude)	23%	Niacin	62ppm	
Neutral detergent fiber	39%	Pantothenic acid	32ppm	
Acid detergent fiber	24%	Choline chloride	1810ppm	
Starch	9.5%	Folic acid	1.9ppm	

Special observations: Vitamin B complex can be administered in the case of neonatal weakness to stimulate the appetite. To prevent neuromuscular disorders, a Selenium and Vitamin E supplement can be given to neonates and before transport. All other vitamins are present in balanced proportions in the feeding formula and there is no need for further supplements, unless there is a severe avitaminosis.

Table 2-3. Al Ain Zoo Diet Record for an adult Arabian Oryx (average 75 kg body weight)

Food type	Quantity	Unit	Frequency	Comments
Timothy hay	1.6	Kg	Daily (adlibitum)	2-2.5%/kg BWt.
Pellets (Arabian Oryx pellets)	0.5	Kg	Daily	0.7-1%/kg BWt.
Fresh alfalfa	0.3	Kg	Daily	0.3-0.4%kg BWt.
Mineral salt- licks	1	Block (5Kg)	Adlibitum	Kept in shade
Copper bolus	-	-	-	Given once annually
Vit. E/Selenium				Dose 0.1mg/kg

2. Body condition scoring

Body condition scoring (BCS) is a method of measuring the general body condition of an animal, as an indication of its nutritional and energetic state (Millar & Hickling, 1990). Body condition scoring has been used in livestock husbandry for some time, but can also be useful for the assessment of fitness in zoo animals (Hosey et al., 2013).

Animal collections may hold upward of a thousand individual animals or even more. Hence, BCS as a noninvasive procedure can be utilized effectively as a possible indicator of an underlying health problem (i.e. loss of appetite, behaviors associated with ill health, changes in defecation or urination, posture, gait,etc.).

In animal management, many important decisions are based on the assessment of body condition. In case of species reintroduction projects, the assessment of body condition during pre-releasing and in the initial post-release period provides an indication of the response of an animal to the translocation and its new environment. Loss of body condition might be an indication of disease. Moreover, there is evidence that mammals may require a minimum level of body fat for adequate reproductive performance. Therefore, the provision of a standardized, reliable body condition scoring system for wild animals will enable management to be optimized and increase the speed at which several problems can be detected.

Body condition scoring can be determined by visual assessment or by handling an animal. Russel (1984) describes a commonly used method of condition scoring in livestock, in which a stockperson feels along the spine of an animal and assesses the level of body fat covering the spine. The stockperson then records a score for the animal's condition. A score of 1, for example, describes an animal with a prominent spine and very little body fat; a score of 5 indicates a good layer of fat over the vertebrae, under which the joints on the spine can hardly be distinguished.

BCS is a subjective method that can be a useful measure if scores are recorded regularly by the same keeper or stockperson, for the same animal over a period of time. When animals are losing condition, the fat reserves are mobilized and then muscle wasting sets into supplying the required energy demand. However, characteristics of each body condition score will help to minimize assessor bias (thus providing a standardized, reliable, and repeatable BCS system).

Several body regions are used in the BCS (Figure 2-9): they may include: the neck, shoulders (scapular region), ribs (costal region), spine (vertebral region), rump (gluteal region), abdominal region, tail base (caudal region).

Figure 2-8: Body condition score diagram by Edmund Flach, Zoological Society of London. Reproduced from 'The biology, husbandry and conservation of scimitar-horned oryx (Gilbert & Woodfine, 2004)'.

Therefore, the more detailed description of body regions the more reliable the BCS that can be gained. Observer scores of body regions can be calculated, then combined scores for regions can be produced.

Method of performing BCS system for Arabian Oryx (adapted from El Alqamy, 2013):

Before performing the BCS process, there should be an understanding of what is normal for the species or an individual animal, and this comes with knowledge and experience of behavior, body weight, physiological or health parameters). This system is based on visual assessment of the back posture of the animal and defining the BCS according to presence or absence of features like: musculature, fat deposition, spinal vertebrae, and caudal vertebra. However, it is general and has some bias and high personal variation.

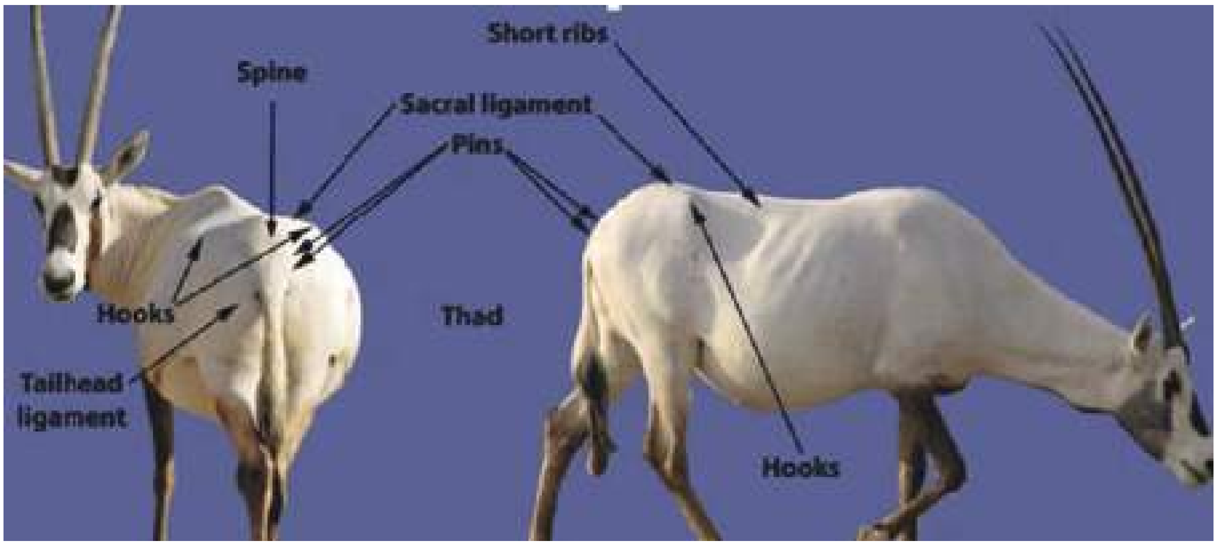

Figure 2-9: External body parts or regions used in the BCS scheme of the Arabian Oryx herd in the Arabian Oryx Protected Area, Abu Dhabi. The scheme is modified after Gilbert & Woodfine (2003) using the dairy cattle body condition scoring developed by University of California (Davis) veterinary medicine extension

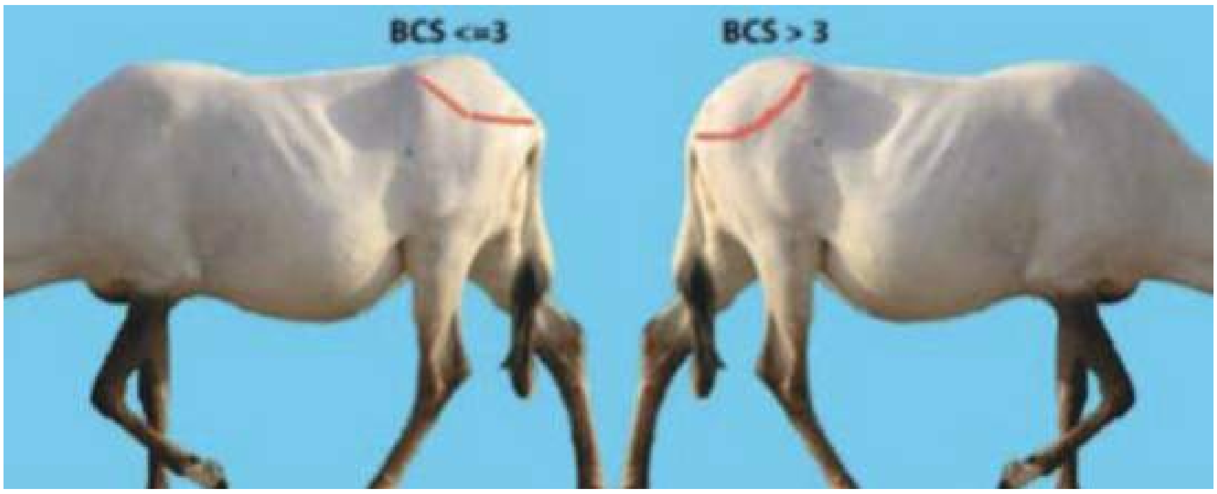

Figure 2-10: Assessing the thurl line

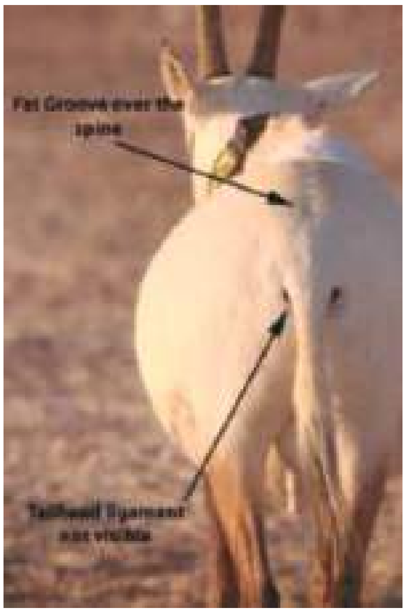

Figure 2-11: Assess the fat deposit

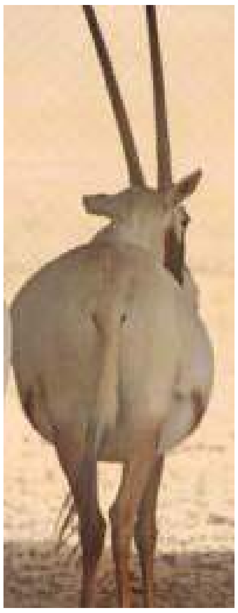

Figure 2-12: Assessing the hooks

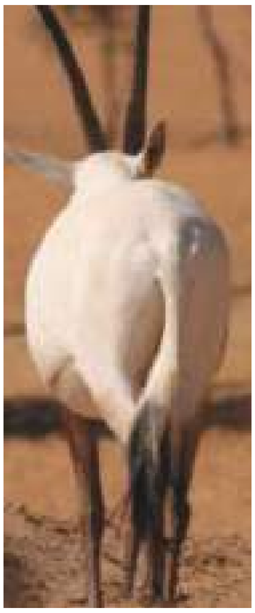

Figure 2-13: BCS=2

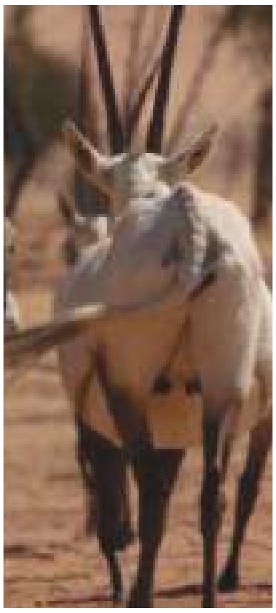

Figure 2-14: BCS=0

- Assess thurl line (line between hooks, thurl, pins (Fig. 2-10)

  - Thurl line is circular forming a crescent --> BCS>3
  - Thurl line is V-shaped --> BCS<=3

- Assess the fat deposits at the spine over the tail head (see Figures 2-11, 2-12 & 2-13)

  - Spine is fully covered in fat but tail head ligament is visible --> BCS=4
  - Spine is covered with fat forming a groove over the spine & tail head ligament is not visible -->BCS=5

- Assess the hooks (Figure 2-13)

  - If the hooks are circular in outline --> BCS=3
  - Hooks are angular in outline --> BCS=4

- Assess the fat cover over the pins:

  - If the fat cover is poor and only upper pins are visible or slightly visible -->BCS=2
  - Fat cover over pins is poor and 2 pairs of pins are visible -->BCS=5

- Assess the fat cover over the pins

  - Spine showing, 2 pairs of pins visible and shallow groove around tail head ligament, but caudal vertebrae not visible -->BCS=1.
  - Spine strongly visible, 2 pairs of pins prominently visible, deep grooves around tailhead ligament, and caudal vertebrae are visible -->BCS=0. Figure 2- 14 shows an emaciated animal with a condition score of "0".
  - An average grade of a group of animals around the value of 3 is optimum, expressing a fit and healthy population. On the other hand a value around 4 indicates fattened population and 5 is for obese animals. The other end of the scale shows animal in poor condition where 0 means emaciated condition, 1 is thin animal and 2 is an indication of malnutrition.

3. Enrichment (dietary enrichment)

Ungulates, while not exempt from developing stereotypic behavior, are not as well documented for producing some of the more undesirable or self-mutilating behaviors as seen in some of the primate, bird or carnivore species. Captive ungulates can often be viewed chewing cud, interacting with conspecifics or watching for unseen predators, much like their wild counterparts. Initiating an enrichment program is essential in creating a stimulating environment (changing the animals' daily routines and providing them with time consuming and complex activities). This can encourage species-typical behavior (Burgess, 2004).

When considering dietary enrichment, it is important to analyze new additions to the diet with supervisory and veterinary staff, in order to prevent digestive problems that can be associated with ungulates. When appropriate amounts of enrichment foods are determined, gradual introduction of each item should be scheduled.

4. Nutrition-related diseases

4.1. Obesity

Obesity can lead to other health problems such as reduced fertility. It is more common in captivity compared to the wild or semi-wild populations due to many factors: lack of opportunities for physical activity, dominance of some animals with greater chance of monopolizing the feeding areas which leads to overfeeding, feeding of energy-dense commercial feeds and maintaining the same diet over a relatively long period without adjustments & overlooking the seasonal and physiological changes of the dietary requirements (Hosey, 2013).

4.2. Bloat

Bloat is a digestive disorder characterized by an accumulation of gas in the first two compartments of a ruminant's stomach, exerting pressure on the diaphragm and restricting breathing (Kleiman et al., 2012). Animals can bloat due to variety of factors such as finely ground feeds, high grain diets, or commonly when immature legume is fed. When bloat is observed animals should be offered dry hay.

4.3. Ruminitis

Ruminitis is an inflammation resulting from irritation of the rumen wall. It is a typical consequence of rapid ruminal fermentation of dietary carbohydrate with subsequent increased acidity of the ruminal fluid. Diets with high level of carbohydrates can be a primary cause, but the texture of feed and the method of feeding can be contributing factors. Additionally, it has been suggested that ruminitis (and acidosis) may be associated with heat stress (Wren, 2003).

4.4. Mineral deficiency

Essential mineral for ruminants are: calcium (C), phosphorous (P), sodium (Na), cobalt (Co), copper (Cu), iodine (I), selenium (Se) and zinc (Zn). Mineral deficiencies have been associated with the following disorders in animals: reproductive disorders (miscarriage, placenta retention); health disorders (bone fragility, diarrhea, bone deformation, rickets, osteo-malacia) and behavioral disorders: anxiety, stereotypies, i.e. pica (licking walls and metal surfaces, eating sand, stones or bones).

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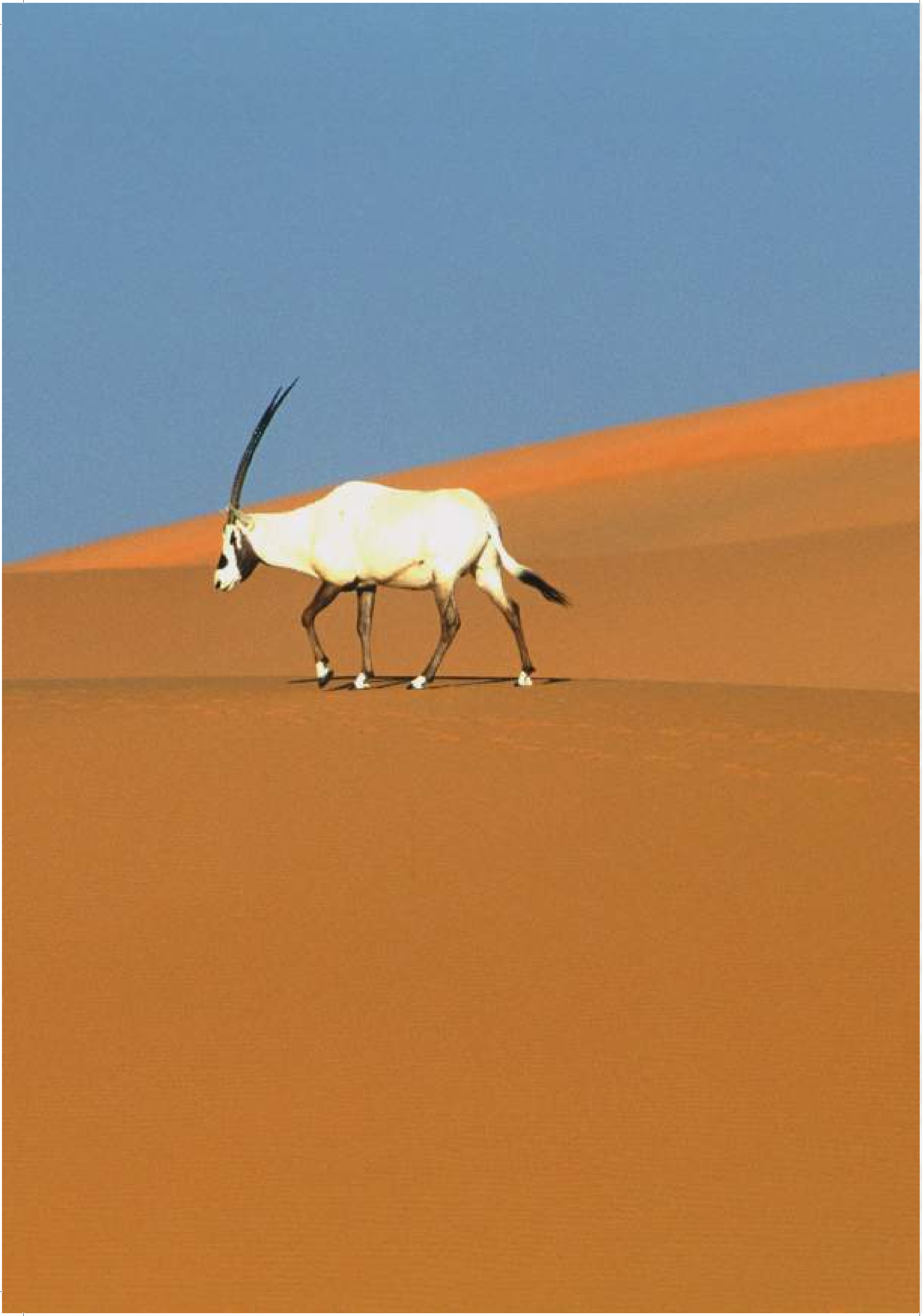


Chapter 3
Veterinary guidelines

Chris Lloyd, Cedric Tutt, Kate Burns, & Meyer E. de Kock

1. Body Condition Scoring (BCS) for health assessments

BCS is a useful non-invasive management tool in assessing general health. Herd BCS can be used to assess general nutrition and as an early warning system for identifying increasing parasite loads and disease screening. It is also a useful tool for comparing individuals of concern with the general herd (see Chapter 2: Nutrition & El Alqamy, 2013).

2. Infectious diseases

These guidelines are not intended to be a comprehensive review of all diseases to which Arabian Oryx are susceptible. For such information, the Arabian Oryx disease survey conducted regularly by the GSCAO since 2011 serves as a reference. The regional disease survey covers a range of diseases that have been reported in the species throughout the Middle Eastern region (Lignereux and Alkharusi, 2013).

The epidemiological risks of disease are increased by:

- Insufficient biosecurity protocols including quarantine procedures and staff / vehicle movements
- Lack of vaccination protocols
- Presence of Oryx / domestic livestock interface
- Lack of proper fencing systems
- Increased inbreeding coefficient
- Increased stocking densities
- Poor institutional hygiene
- Nutritional stress or stress related to inappropriate herd dynamic.

3. Disease surveillance

Disease surveillance is an integral part of herd health. While practical and financial considerations may limit extensive testing of the herd, careful archiving of material can be crucial in disease detection retrospectively or can provide evidence for the health status of the herd for movement or reintroduction.

A minimum database should include:

- Animal identification database
- Frozen (-20C or preferably -70C) serum samples with animal ID and date of collection, collected opportunistically or at annual herd vaccination
- Frozen tissue / fluid samples, which may be used in future viral/ bacterial disease outbreak investigations
- Tissue samples preserved in 10% formalin for future histopathological exam

The following sections list potentially important infectious diseases in Oryx with information to assist in diagnosis.

3.1. Brucellosis

While over 75% of the population is captive bred, less than 25% of this population is screened for Brucella sp. Common practice suggests that all animals whether captive bred, imported, exported or reintroduced to the wild should be checked (see Table 3). Brucellosis screening should be done annually at vaccination using a consistent serological method. Threats are increased by the domestic/wildlife interface.

3.2. Q fever

This is a zoonotic disease that has been recently investigated and found in Arabian Oryx in the UAE (Chaber et al., 2012). All captive bred animals, especially those living close to domestic livestock and those reintroduced to the wild should be checked (Table 3).

3.3. Mycobacteriosis

None of the collections in the region report veterinary testing for Tuberculosis (avian or bovine). All captive bred animals, especially those that are imported, exported and reintroduced to the wild, should be checked annually or opportunistically. Mycobacteriosis is potentially zoonotic and notifiable in many countries. An inexpensive triage test is the intradermal tuberculosis test, using tuberculin purified protein derivative. Automatic syringes (Mc Lintock) are available and are designed to accurately inject the tuberculin intradermally. Animals should be appropriately marked or identified in order to "read" the results 72 hours after initial injection. Animals testing positive should be retested using confirmation tests such as tracheal wash cultures. Lateral flow tests for TB and interferon gamma testing should also be considered as they are quick and effective.

3.4. Karyotype

Cribiu et al. (1991) described what is called the 17:19 Robertsonian translocation in the Arabian Oryx. It is a chromosomal abnormality that can be detected with karyotyping. The animals are phenotypically normal and therefore healthy, but their progeny can inherit a form of trisomy. No information has been found as to its implications for the health of the Arabian Oryx population. Karyotyping can be performed once in a lifetime.

3.5. Fecal analysis

Fecal analysis is by far the most common test performed across the Middle East Arabian Oryx population. This is performed over a variety of times during the year, but not less than twice a year. Fecal testing targeting pre- and post calving periods is most likely to detect the highest number of fecal ova. Worming at this time is likely to reduce the parasitic burden on the enclosure. Well irrigated, grassed enclosures are likely to carry heavy nematode burdens if not managed correctly. The most commonly used Avermectins used for deworming are Ivermectin and Doramectin. These are given by injection once or twice a year. They are effective against arthropods (including dung beetles) and most of the common intestinal worms, excluding tapeworms. Benzimidazoles, such as Fenbendazole, is the most widely used, dissolved in water. This can also be used as a feed additive which may be preferable in a species used to arid environments such as the Arabian Oryx. Alternating classes of anthelmintic, together with "pasture" rotation is likely to reduce the nematode burden and the possibility of drug resistance.

3.6. Blood values

Normal reference values for the Arabian Oryx are shown in **Appendix 1.**

4. Prophylaxis

When establishing a vaccination program, the following background information is key:

- Prevalence of disease in the wild and in contact with domestic animal populations, ideally with strains or serotypes
- Target species sensitivity to prevalent infectious diseases
- Vaccines available
- Efficacy of the vaccine and side effects in target species

In non-domestic species including the Arabian Oryx, information is lacking on vaccine efficacy and many vaccination protocols are based on assumptions. Most vaccines used are designed for domestic livestock and there is a lack of data for most wildlife species on seroconversion levels, duration of immunity and protection provided to field exposure. Serum banking in vaccinated collections, if widely practiced, would go some way to providing this initial data and would be an extremely valuable collaborative project for the conservation community.

It is recommended to carry out a regular vaccination protocol on all captive bred populations. As a general guideline, to confer a good level of protection, at least 75% of a population should be vaccinated. If less than 75% are vaccinated, the population is considered as being at risk. A regular vaccination program involves a primary vaccination, consisting of two injections with a maximum one month interval, followed by an annual booster. A primary vaccination of only one injection will not result in a good immune response.

4.1. PPR vaccination

PPR vaccine is a live attenuated vaccine. While the disease has not been described in the Arabian Oryx, and there is anecdotal evidence of animals being unaffected in the face of a zoological outbreak of the disease, it is still recommend to vaccinate. A recent study published by Sa et al. (2013) shows that a locally available vaccine confers an appropriate immunity level, consistent with protection.

4.2. FMD vaccination

While the Arabian Oryx is sensitive to this disease, the vaccines available today (according to studies conducted on domestic livestock) do not confer a long immune response, and therefore must be injected twice with one month apart and then every six months to be effective. This protocol is likely impossible to implement in wildlife collections. Double Oil Emulsion (DOE) based vaccines seem to provide longer protection. No cross protection exists between the different serotypes.

4.3. Sheep and Goat Pox vaccination

Arabian Oryx are susceptible to the disease that is enzootic in the region. It is recommended to vaccinate on a regular basis but there is a lack of information on this topic: vaccines are live attenuated and it is unknown how safe and effective they are for this species.

4.4. CCPP vaccination

Although only one case of CCPP in Arabian Oryx is reported, it is nevertheless important to consider this disease in animals with compatible respiratory lesions to avoid under diagnosis. Further studies on CCPP vaccines will be required if more cases of CCPP were to be discovered on the Arabian Oryx.

4.5. Enterotoxaemia

Clostridial vaccines are some of the most commonly administered vaccines in ruminant collections. It is usually multivalent and gives protection against enterotoxaemia (*Clostridium perfringens),* Tetanus (*Clostridium tetani*) and blackleg (*Clostridium chauvoei*). Six Arabian Oryx died of enterotoxaemia in 2011 in herds that were regularly vaccinated (Lignereux et al., 2013). This emphasizes that extra care should be taken to minimize risk factors, such as an excessively rich or inappropriate diet, conditions that slow the motility of the gastrointestinal tract, heavy infestations of gastrointestinal parasites, and recovery from illness.

4.6. Pasteurellosis

Pasteurella multocida and *Mannheimia haemolytica* are a main cause of respiratory disease in ungulates. These opportunistic agents will take advantage of the deleterious effects of stress: handling, transportation, parasitism, viral infection and overcrowded housing, predisposing animals to infection (Brodgen et al., 1998). Different serotypes of both *P.multocida* and *M. haemolytica* exist, and vaccinating against one serotype does not always guarantee cross-protection. Extensive published literature exists on domestic ruminants, without very clear conclusions: some research suggests that vaccination has no effect, yet other research (Smith, 2008) indicates that vaccination can reduce the risk of disease. If it seems important to vaccinate against these pathogens, removing and/or reducing the predisposing factors is also an effective way to minimize the risk associated with these diseases.

4.7. Colibacillosis, Rota and Coronavirosis

Escherichia coli, Rota and Coronavirus vaccination is done on late pregnant females. The second injection of primary vaccination is done two to four weeks before the expected parturition date to increase the antibody level in their colostrum. This will give a passive immunity to the offspring if they drink the colostrum within 24 hours of birth.

5. Tranquilisation and transfers

There are occasions where individual animals may have to be chemically immobilized instead of physically restrained. Some drugs and dosages are:

1. 2mg/kg tiletamine-zolazepam with 0.2mg/kg xylazine given together. Antagonise with 0.125mg/kg yohimbine
2. 0.03mg/kg etorphine with 0.3mg/kg xylazine given together. Antagonise with 0.06mg/kg diprenorphine and 0.125mg/kg yohimbine
3. 0.05mg/kg etorphine with 0.05mg/kg medetomidine given together. Antagonise with 0.1mg/kg diprenorphine and 0.025mg/kg atipamezole
4. 0.5mg/kg xylazine. Antagonise with 0.09mg/kg atipamezole or 0.125mg/kg yohimbine. This can only be used on calm animals
5. 0.06mg/kg medetomidine. Antagonise with 0.25mg/kg atipamezole
6. 0.05 – 0.5mg/kg medetomidine with 1.5 - 15mg/kg ketamine given together (ZIMS). Antagonise with Atipamazole at a ratio of 5:1 (Kreeger and Franzmann 1996)

Chemical immobilisation and restraint guidelines are addressed in detail in Chapter 4.

<table>
<tr><th colspan="2">Calculating drug dosages:</th></tr>
<tr><td rowspan="2">Volume of drug</td><td>Body weight of animal x Dose</td></tr>
<tr><td>Drug concentration</td></tr>
</table>

5.1. Different delivery systems

There is a wide range of remote delivery systems with regards to darting equipment. Make sure you are familiar with the system you are using before working with it. Used incorrectly it can present a danger to you, others, and the animal.

5.2. Health and safety while working with dangerous drugs

There are a range of chemicals used in animal anaesthesia that are harmful and potentially deadly to humans. Accidental exposure can occur in many ways and could prove life threatening. To minimize the risk, ensure the following:

- Only authorized users are allowed to use scheduled drugs, these laws and regulations may change depending on your location.
- Obtain competent training in chemical immobilization of wild animals
- Be trained in basic first aid and CPR
- Always work in pairs
- Always have appropriate antagonists immediately available
- Wear protective clothing
- Work carefully
- Cover darts when pressurizing or do not use pressurized darts
- Know what drugs you are using
- Ensure that your facility has a standard operating procedure for handling schedule drugs and identify responsible persons to handle emergency situations.

If accidental exposure occurs

- Do not panic
- Tell someone
- Wash the site
- Administer the appropriate antagonists
- Note the time
- Transport person to nearest emergency center.

5.3. Governmental law on schedule drugs

The legalities surrounding the purchase, storage and use of schedule drugs used for immobilization vary from country to country. Compliance with governmental law is mandatory.

5.4. Parameters to monitor on anaesthetized animals and correct positioning

As soon as the animal becomes recumbent and is safe to approach, ensure the following:

- Nothing is impeding the breathing and the neck is straight and nose is clear
- Position in sternal if possible, with head higher than thorax and nose pointing towards the floor
- Place an IV catheter
- If the animal will be immobilized for more than 1 hour, roll animal over onto other side to restore circulation to legs
- Cover the eyes and place cotton wool in the ears. Remember to remove when immobilization is finished.

Basic vital signs to monitor:

- Respiration
- Temperature
- Pulse

6. Stress management

"There is no way to eliminate stress from any form of animal capture, however capturing the animal quickly and efficiently and releasing it as soon as possible can minimize stress" (Kreeger and Franzmann 1996).

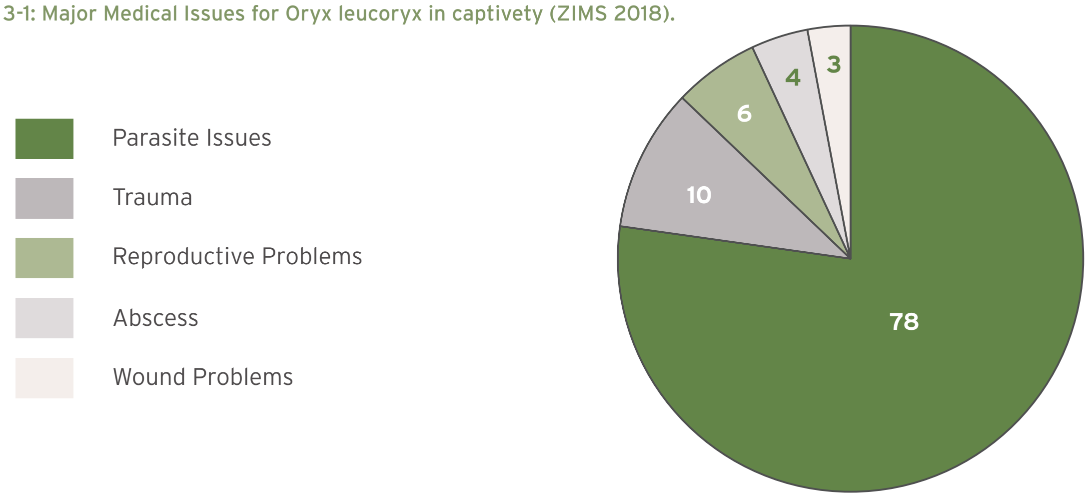
This is accomplished by:

- Using the correct drug at the right dose
- Processing the animal quickly – being organized
- Using drugs capable of being antagonized
- Giving vitamin E and Selenium: these vitamin supplements are used mainly to prevent stress related diseases (Lignereux, 2013).

Common medical problems

ZIMS (Zoological Information Management System, Species 360) provides information on the common medical issues and causes of death in registered captive collections (Figure 3-1).

Figure 3-1: Major Medical Issues for Oryx leucoryx in captivety (ZIMS 2018).



Another issue found in the region is impaction. This usually occurs from the animal ingesting foreign objects, such as irrigation pipes and fittings, plastic rope and plastic bags. Arabian Oryx are curious animals and will investigate foreign objects as possible food sources.

Morphometrics

General morphometrics from an Arabian Oryx herd are provided in Table 1, including body measurements, total live weight and body temperature for different age groups (O'Donovan, 2015).

Table 3-1: Average morphometrics and body temperature from mentioned age-groups.

Sample size: 136 individual Arabian Oryx (O'Donovan, 2015).

(This table has been reproduced from O'Donovan, 2015 with the permission of the author)

Age	Weight	Body length	Shoulder height	Body temperature
1 w - 6 m	19.56 Kg	56 cm	60.52 cm	39.95
6 m - 1 y	F - 43.81 Kg M - 45.80 Kg	F - 74.30 cm M - 78.57 cm	F - 77.43 cm M - 80.85 cm	40.49
1 y - 2 y	F - 65.27 Kg M - 69.43 Kg	F - 86.82 cm M - 87.76 cm	F - 86.19 cm M - 85.85 cm	40.02
2 y - 5 y	F - 82.92 Kg M - 93.36 Kg	F - 90.73 cm M - 95.50 cm	F - 88.92 cm M - 91.70 cm	40.01
> 5 y	F - 87.99 Kg M - 93.70 Kg	F - 93.64 cm M - 94.13 cm	F - 88.72 cm M - 90.17 cm	39.87

7. Dental

The Arabian Oryx is a member of the Bovidae family of which the domestic bovine is also a member. The dental formula of the Arabian Oryx is:

2 I0C0P3M3 I3C1P3M3 giving a total in the adult animal = 32 teeth; and

2 I0C0P3 I3C1P3 giving a total in the young animal = 20 teeth.

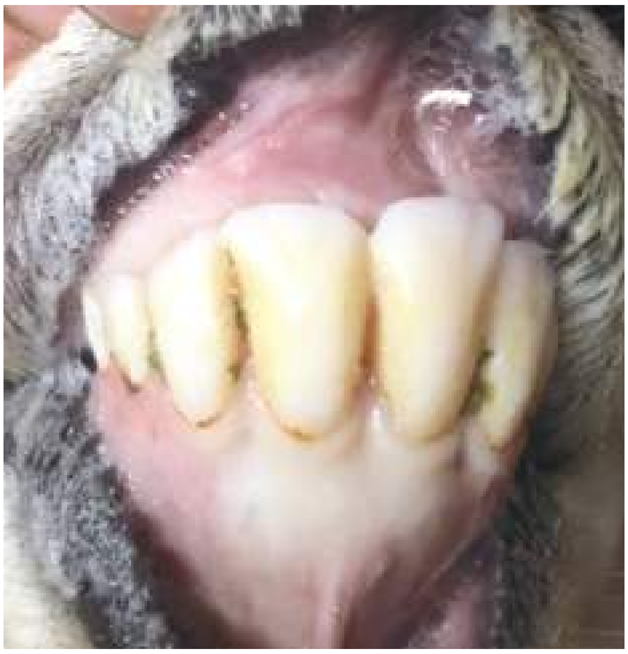


Figure 3-2: 4-year-old Arabian Oryx dental front view.

The dentition is defined as hypsodont, selenodont and radicular. This means that the crowns are comprised of the clinical crown – visible in the mouth, and the reserve crown – that part which will erupt in time but is currently below the gingival margin. These teeth will form roots eventually. Selenodont describes the crescent shaped cusps on the crowns. The maxillary and mandibular molars have two infundibula each, the maxillary premolars have one infundibulum each and the mandibular premolars do not have infundibula. An infundibulum is a structure visible on the chewing (occlusal) surface of some teeth that is enamel lined and often has cementum on its inner surface. This structure provides enamel on the occlusal surface, increasing the endurance of the grinding capacity of the tooth. The occlusal surface has enamel, dentine and cementum exposed.

The infundibula in the young animal are deep but as the teeth erupt and wear, the infundibula will become smaller and shallower.

The adult Arabian Oryx does not have maxillary incisors or canines but instead has a dental pad, a fibrous structure onto which fodder and grazing are pressed by the mandibular incisors and held there while a head and neck action facilitates the cutting of the food by the mandibular incisors. There are three mandibular incisors on each side and one canine on either side that has become aligned with the incisors and "incisorised". In other words, the two mandibular canines have taken on the shape and function of incisors. This has effectively widened the prehension area of the mandibles.

There are three premolars and three molars in each quadrant. The premolars have become molarised taken on the shape and function of molars and work together with the molars to form the "cheek tooth battery". The six cheek teeth in each quadrant grind the food as a unit.

Figure 3-3: Arabian Oryx top jaw.

8. Problems that may be encountered

- Where animals are fed a commercial diet or short hay, the incisors are not required to prehend food and this may result in their overgrowth
- Infundibula are initially very deep and can trap food. If pelleted diets are fed, the carbohydrates in the diet can become impacted in the infundibula and undergo fermentation, forming acids which may damage the cementum and enamel lining the infundibula resulting in tooth decay (caries)
- Tooth fractures occur when animals chew on objects. These include bones and horns of other animals, often sought after by animals displaying pica
- Periodontitis with secondary osteomyelitis of the jaws is also possible, although this appears to be rare.

Table 3-3: Common practice suggests that all animals whether captive bred, imported, exported or reintroduced to the wild should be checked for the following:
Reproduced with permission from O'Donovan, D. (2005).

Disease	Comment	Serological test	Comment	Pathogen identification	Comment
Brucella abortus / B melitensis	Zoonosis affecting a wide range of mammalian species. B.melitensis species of main concern in Middle East	Rose Bengal test and c ELISA testing	No blood test will determine the species of Brucella involved	Bacterial culture	Gold standard diagnostic test. Samples from aborting females,milk, infected joints, mammary glands and testicular infections should be tested
	The main source of Brucella bacteria are aborting animals or animals that have recently given birth		RBT and cELISA are commonly used	PCR	PCR testing from pus or tissue samples not considered reliable by OIE or APHA Brucella reference laboratory (UK)
	The bacteria can spread vertically from dam to calf. A small percentage of these calves may be persistent carriers (5%)		Both have high sensitivity and poor specificity and subject to cross reactions with common bacteria such as Yersinia. Thus commonly used as herd prevalence screening methods with further diagnostics being used on positive animals		
	Horizontal spread is through contact with the mucosal surfaces of a susceptible animal: i.e. from placentas, vaginal secretions, aborted foetus		Both unvalidated in wildlife with no established cut off for positive and negative		
	Horizontal transmission more apparent in high population density situations	Rose Bengal test and c ELISA testing	Intial screening with RBT quick and economical. Positives can be cross tested with cELISA. Animals positive for both should be isolated for further antemortem or post mortem diagnostics		
	Main clinical sign in the female is abortion or retained placenta; in the male infertility, orchitis and lameness result. Most females will only abort once				
	The bacteria localizes in the uterus and mammary tissue of females and the joints and testicles of males				
Coxiella Burnetti (Q-Fever)	Zoonotic bacteria responsible for epizootics of later term abortion in a wide range of mammals	Indirect ELISA (Chekit Q-Fever)	There is an inconsistent relationship between serologic status and C. burnetii shedding in nondomestic animals. Confirmed aborting Q fever animals may be seronegative	PCR	Useful on foetal membranes and body fluids
	Bacteria shed heavily in aborted material and placental tissue. Also present in milk, semen, urine and feces (rarely)			Histopatholo-gy and immunohist-ochemistry	For aborted material, especially cotyledons
	Usually only causes abortion once after first exposure				

Disease	Comment	Serological test	Comment	Pathogen identification	Comment
Tuberculosis					
Pestes de Petite Ruminants	A paramyxo virus, responsible for high mortality in domestic and some wild small ruminants. Transmitted mainly through close contact orally and through aerosol. Endemic in the Middle East	cELISA antibody test	Commercial PPR C-ELISA Kit (Biological Diagnostic Supplies (BDSL) prepared by the Institute for AnimalHealth (IAH) (Pirbright, UK)) on serum	PCR or virus isolation	PCR using swabs from nasal discharges or oral swabs. Also used on tissue such as lymph nodes and spleen
	Fever, anorexia, depression, nasal and ocular discharges, difficult respiration, necrotic lesions on gum, lips and tongue resulting in salivation, erosions on the nasal mucosa and finally diarrhoea			Sandwich ELISA ("ID Screen" PPR Antigen capture) or Agar Gel immunodiff-usion (AGID)	As Above
Contagious Caprine Pleuropn-eumonia (CCPP)	Caused by Mycoplasma species	Serological tests	Of little practical use due to cross reactions	PCR or Bacterial culture	Organism susceptible to inactivation in a few minutes by UV light and high temperatures (over 60C). Specialised media and laboratory often required for culture and vitally important samples remain frozen at -20C prior to testing. PCR considered most practical diagnostic tool. Samples of lung and thoracic fluid and lymph nodes can be used
	Highly infectious respiratory disease, traditionally of goats but also can affect other small ruminants. High mortality rate in goats and related species			Histopatholo-gy and immunohist-ochemistry	Samples should be taken from interface between consolidated and normal lung
	Infection through aerosol. Chronic carrier animals may exist				
	Recorded disease of Middle East				
	Can be confused with Pasteurella complex and PPR				

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Chapter 4
Handling, transport, marking & identification

Mohammad Al Faqeer, Stephen Chege, & Mayyas Al Qarqaz

1. Handling and restraining

Several herd management objectives can be achieved through the animal restraining & handling process. Some of these benefits are: applying animal identification techniques, performing animal treatment & health care (hoof trimming, blood sampling, vaccination, deworming, etc.), animal relocations, and in research projects.

All ruminants are prey species and flight is likely their first response to any threat. To get "hands on" most exotic small ruminants will require physical restraint using a hydraulic squeeze or drop floor chute or immobilization. The approach to restraint and anesthesia for these species will be governed by the level of habituation to handling and human contact, the handling facilities (holding pens, raceways and squeeze chutes) available, and the animal handling expertise of the caretakers (Peregrine L. Wolff, 2009).

1.1. Physical restraint

Calves up to about four to five months of age can be caught manually and restrained for examination, identification, sampling and/or treatment, but this should only be done by trained and experienced personnel. A minimum of two handlers should perform the capture, depending on the size and the temperament of the animal, and handlers should wear protective clothing, footwear, eyewear and gloves. Animals less than 5kg can be done by a single handler (Flach, 2004).

1.2. Mechanical restraint

For older animals they can be restrained in a hydraulic crush. The crush systems were originally designed for deer farming (Fowler, 1995), but have been adapted successfully for Scimitar-horned Oryx (Atkinson et al., 1999), & other similar ungulates.

A properly set up chute and squeeze system is often the most economical, efficient and safest method for handling exotic small ruminants (Peregrine & Wolff, 2009). However, this system is enhanced with a drop floor chute where, after entering the chute, the floor is dropped leaving the animal suspended. The drop floor chute decreases struggling and allows the animal to be safely handled with minimal stress. The width of the drop floor chute can be adjusted to accommodate the variation among animals at different stages (young, adult) or to suit a variety of similar species. Most chute systems allow access to the front and rear of the animal and also the back and legs, thus enabling the producer or clinician to perform routine husbandry procedures, disease testing, and reproductive manipulations. The tops of the chutes are wide to allow for horns. Once in the chute the animal should be blindfolded to reduce visual stimulation. If the head, ears, or horns are manipulated, then a halter or a rope can be applied and the head tied.

The design of the sorting and holding pens and runways leading to the chute have incorporated principles developed for safely moving farm animals. A circular pattern layout with non-slip solid footing, adequate lighting and appropriate visual barriers is recommended for decreasing stress during the handling operation. Elevated catwalks facilitate animal handling and observation in the sorting pens but should never go over the top of chute area as animals will become distracted by what is above them and reluctant and fearful to move forward. Animals should be restrained and handled gently but firmly and it is important that they feel secure and balanced in the squeeze.

In this section of the guideline, some examples of the equipment used for a physical restraining system (used currently in Al Ain Zoo) are provided. This system has been developed and sourced by Fauna Research Inc. and is called "Tamer System".

1.3. Chemical immobilization

New discoveries and developments in drugs have made the use of immobilization drugs safer and economically feasible for exotic animals' restraint. The use of chemical restraint is effective, relatively easy, and often faster and more efficient than traditional restraint methods. It also helps meet the particular objectives of the animal restraint (Rice & Kalk, 1996). Chemical restraint should only be performed by a trained and experienced veterinarian.

When physical or behavioural restraints are inadequate to maintain control of an animal for the length of time or invasive nature of the desired procedure, chemical restraint is necessary as an adjunct or sole method of restraint. Extremely tame (hand raised) animals may allow administration of anesthetic agents by hand syringe either intramuscularly (IM) or intravenously (IV). Pole syringes or jab sticks can be utilized on animals that can be confined to small pens or stalls. Remote delivery systems involving darts ("flying syringes") delivered by blow pipe, dart pistol or rifle are available and can be utilized for animals in large pens or pastures.

An important factor for successful immobilization, whatever the drug combination, is reducing the amount of stress on the animal at the time of darting. A stressed animal will need a higher dose of drug for the same degree of sedation, and is more likely to suffer later from capture myopathy. On a practical level, stress can be reduced by keeping to a routine as much as possible, and so it helps if Oryx are used to being shut in races or yards as part of their daily routine. It is also useful, if an animal has to be confined for darting, if one or two other animals can be kept with it, and then released when the drugs start to take effect. Animals should not be immobilized in very hot weather, except in emergencies when they should be moved quickly into the shade and cooled down. Once recumbent and sufficiently deeply sedated, the animal can be positioned for the procedure. If at all possible it should be kept in sternal recumbency with the head raised and the muzzle lower than the pharynx.

Anaesthetic monitoring should include, as a minimum, regular measurement and assessment of the pulse rate, respiratory rate, rectal temperature, mucous membrane colour and capillary refill time. Respiratory and cardiac monitors can assist, but should not replace a trained member of staff with responsibility for the care of the animal whilst immobilized.

1.3.1. Planning chemical immobilization

Attention to detail in preparing for a capture or immobilization may be the greatest predictor of a successful outcome. Fear, anxiety, perception of danger, novel environments and crowded conditions all cause stress in animals and are usually present to varying degrees during a capture or immobilization event. Every effort should be made to reduce these stressors by providing visual barriers (blindfolds), decreasing extraneous noise, having an adequate number of well-trained animal handlers, and utilizing proper equipment and facilities. Animals should be confined to the smallest enclosure in which they can be safely worked. Multiple gates to separate herd mates once the animal has become heavily sedated or immobilized should be available. If the enclosure is small then a visual barrier should be in place so that the person shooting the dart is able to remain outside of the animal's flight zone thereby reducing agitation of the animal and the herd prior to immobilization. If the immobilization area is a field or open area then it should be assessed for potential hazards such as bodies of water, ditches, steep terrain and dense tree cover or brush and contingency plans made to remove or deal with animals in the event that they become recumbent in such areas. As much focus should also be placed on the recovery phase of the immobilization. Ideally the animal should be held in a quiet, small, secure area with level footing. Animals should be separated from herd mates until they regain consciousness as individuals that act abnormally may be attacked and injured.

1.4. Monitoring and emergencies

Hyperthermia is a common problem during the immobilization of exotic ruminants and body temperature should be monitored throughout the procedure. An animal's internal temperature may increase from physical exertion as well as psychological stress and fear and the response of the thermoregulatory center to changes in temperature is decreased by immobilization agents such as tranquillizers and sedatives. Hyperthermia may predispose the animal to metabolic complications such as capture myopathy, or if the body temperature increases above 43°C death may occur. As the ambient temperature increases it becomes more difficult for animals to dissipate heat and ideally a capture or immobilization should be planned for a cool, cloudy day with temperatures less than 25°C.

Animals should be fasted for 12 to 24 hours to decrease the incidence of regurgitation and bloat; however, in a free-range setting this may be difficult. Thus during the immobilization, care should be taken to protect the airway by maintaining the animal in sternal whenever possible (which will decrease the pressure of the abdominal viscera on the diaphragm) and by placing the head with the nose and mouth below the level of the ears to allow saliva or regurgitated rumen contents to drain. If the terrain is not level then the animal should be positioned with the thorax above the level of the abdomen to decrease pressure from the abdominal viscera. Horns and antlers can complicate head placement but make useful handles for positioning the head. Capture myopathy is a syndrome that is not infrequently seen during capture and handling events in exotic small ruminants. However, the pathogenesis of capture myopathy not only includes muscular activity but the sympathetic nervous and adrenal systems as well as perception of fear. Capture shock is the acute manifestation of capture myopathy in which the animal develops tachypnea, tachycardia, hyperthermia, hypotension, and depression usually followed by death within 1 to 6 hours. Treatment is usually unsuccessful and prevention is the most effective way to manage capture myopathy (Peregrine & Wolff, 2009).

Table 4-1: Chemical tranquilizing agents used in Arabian Oryx

Suggested tranquilizing agents and their onset and duration of action		
*Drug, dosage and route of administration	Onset of action	Duration of action
Azaperone 0.5mg/kg bwt I.M	30 minutes	6 hours
Haloperidol lactate 0.1-0.2mg/kg bwt I.M or IV	< 5minutes (iv), <15minutes (im)	8-18 hours
Zuclopenthixol acetate 0.5-1mg/kg bwt I.M	I hour	3-4 days
Perphenazine enanthate 0.5-1mg/kg bwt I.M	hours	7-10 days

* These are suggested dosages based on published information (Ebedes, 1993; Curro, 2007; Fowler, 2008).

Table 4-2: Drug protocols for sedation and anesthesia used in Arabian Oryx

Suggested regimen for general anaethesia in Arabian Oryx	
**Drug & dosage (mg/kg)	Antidote & dosage
Carfentanil (0.03-0.04) + Xylazine (0.25)	Naltrexone (100mg/mg carfentanil I.M)
	Atipamazole 0.1 mg/kg (or 1/10 of xyl)
Etorphine (0.03-0.04) + Xylazine (0.3)	Naltrexone (50mg/mg etrophine I.M)
	Atipamazole 0.1 mg/kg (or 1/10 of xyl)
Etorphine (0.04) + Medetomidine (0.005)	Naltrexone (50mg/mg etrophine I.M)
	Atipamazole 5mg/mg medetomidine I.M
Ketamine (1.2-2) + Medetomidine (0.03-0.06)	Atipamazole 5mg/mg medetomidine I.M
	Ketamine is not reversible

** These are suggested dosages based on published information (Ancrenaz, et al. 1996; Ebedes & Raath, 1999; Fowler, 2008).

Figure 4-1: Capture of Arabian Oryx through the Tamer system.

1.5. Behavioral conditioning

There are certain situations where husbandry training, desensitization, and/or operant conditioning are used to facilitate or perform a procedure. Training and desensitization should always be the first consideration in developing a restraint plan (to reduce stress). For example, an animal may be trained to enter a restraint device voluntarily where it can then be mechanically restrained or chemically immobilized.

1.6. Release and recovery

In many cases of restraint events, release and recovery are considered as the most critical and dangerous point of the procedure. Transition from controlled situation (physical restraint or complete immobilization) to a state of freedom must be done carefully. Fight or flight response and injuries should be anticipated and controlled. All personnel should be aware of the likelihood of the response upon release. Escape routes should be discussed. As an animal is being released, it should be directed towards an area that minimizes the risk of injuries to it or others. Maintaining a quiet, calm environment, that allows the animal to act rather than react is essential to good release and recovery.

1.7. Considerations when deciding or performing restraint method

- Goals of restraint should be clarified, and should be clear in everyone's mind (although the goal may change during a restraint)
- Physical condition of the restraint location: climate, terrain, facilities, equipment,etc.
- Resources availability
- Chemical restraint should only be performed by a trained vet
- Safety: the choice of whether or not to restrain animal and the method of choice should always put safety as the first consideration (primary consideration to personnel safety, safety of animals next)
- Reduction or removal of unwanted stimuli. Visual and acoustic stimuli should be controlled and minimized (using blindfold during handling is highly recommended)
- Use of voice, body language, and posture could be critical. Animals are very sensitive to our expressions!

- Confident staff members with an ability to convey it to the animal! This cannot be taught but can be developed through experience. Lack of comfort and confidence is immediately perceived by the animal and can result in an increase in its anxiety and stress
- Plans for contingencies
- Release and recovery is one of the most critical procedures in the restraint event, particularly following the chemical immobilization. The animal should be crated until fully recovered, after which it can be returned to its enclosure or social group
- Any design should incorporate facilities to allow training and behavioral conditioning of the animal
- Husbandry training should be safe for staff and animals. Animal managers with restraint experience should be involved in the design process
- Following chemical immobilization, staff must be careful to prevent the animal from being injured during recovery.

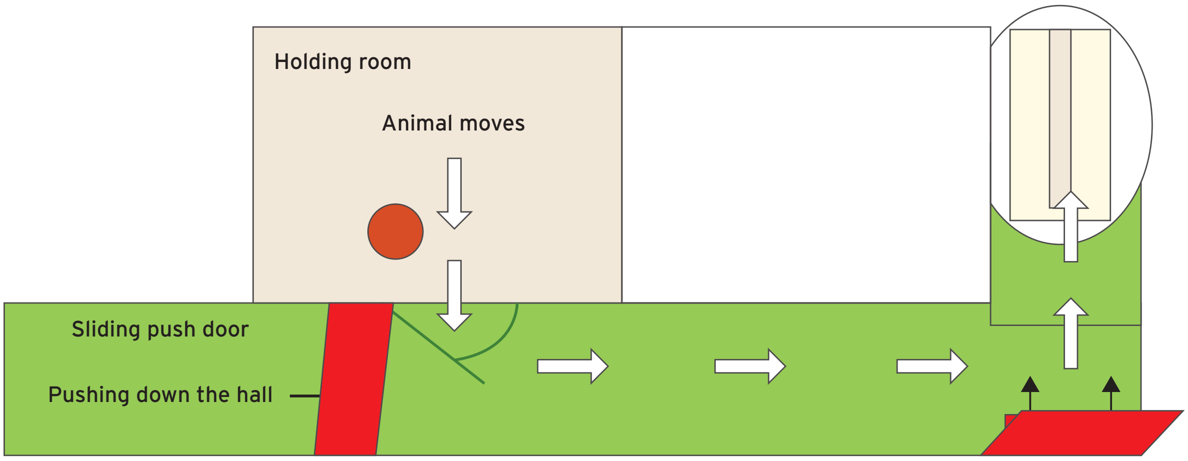

Figure 4-2: Diagram of L-shaped hallway with push board doors. As the animal enters the hallway, the push boards moves the animal while closing its enclosure door at the same time. When the animal reaches the end of the hallway, the second push board door pushes the animal into the Tamer. Reproduced from (Cisneros, 2012)

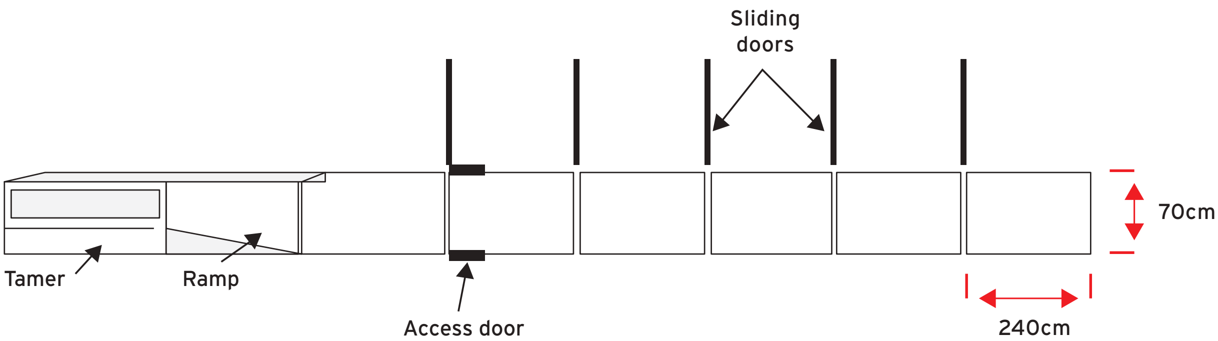

Figure 4-3: Layout of crush system with animal sorting pens and Tamer system; reproduced from O'Donovan & Bailey, 2006.

Figure 4-4: Animal capturing team of Al Ain Zoo, while having a small meeting just prior to the initiation of an animal restraining operation

Figure 4-5: While an animal is being checked & health screened in the Tamer, a number of animal caretakers are observing other animals in the sorting pens

Figure 4-6: Health care team preparing animal blood sampling tools and other medical equipment at the site of animal vaccination

Figure 4-7: Steps for handling Arabian Oryx inside the crate for transport or veterinary procedures

Figure 4-8: Sorting pens enhanced with "Catwalk" to ease animal observation and sorting

2. Transport

2.1. Single animal and group transports

Arabian Oryx can be transported individually or in social groups depending on the purpose of the translocation, the number, the sex, and the age of the Oryx and the strength of the social bond of the group (Molcanova & Gilbert, 2004).

There are advantages and disadvantages for transporting Oryx in individual crates and in multi-animal crates (or mass-crates), and the pros and cons of the method of transport need to be carefully weighed in each individual case (Molcanova & Gilbert, 2004).

Key Considerations:

- Due to the strong social nature of Oryx and particularly when the animals are allowed to establish a social hierarchy prior to transport, it is recommended to transport them in groups. This is an important consideration to prevent, or at least reduce, the possibility of fighting or increased stress levels during transport. Nevertheless, additional thought should be given to the sex ratio of the animals, to ensure that aggression is kept to a minimum
- It is also important that IATA guidelines are met, regardless of whether Oryx are being transported individually, or in a group
- Availability of emergency access to the Oryx during long transports for veterinary reasons. It is easier to control and give veterinary treatment to an individually crated animal, than it is for a group of animals in a crate
- Facilities for unloading crates at the destination need to be taken into account. Problems have been encountered with unloading individually crated Oryx including maneuvering the forklift truck on the sandy substrate. A larger crate, containing several animals, would be even more difficult to unload under such conditions.

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Container construction

- Material: The container or crate should be made of wood or metal and rubber, burlap or canvas for padding and light reduction, if required
- Dimension: The height and width of the container must allow the animals to stand erect with head extended. The size of container must sufficiently restrict movement so that the animal cannot turn around and in doing so trap or injure itself. Additionally, it should not have the space to kick or damage the container. However, the animal must have enough space to lie down, lie comfortably and stand up. The dimension will vary according to the age and sex of the animal being shipped
- Frame: The frame must be made of a minimum of 2.5cm solid wood or metal parts, bolted or screwed together. When the weight of the container plus the animal exceed 60 kg, additional metal bracing must be present around the whole container
- Sides: Suitable plywood or similar material need to closely line the frame to a level slightly above the animal's eye over which there must be a louvered or slatted area for ventilation extending to the roof. The interior must be completely smooth
- Floor: The base must be solid and leak-proof, there must be either pegboard or slats bolted to the solid base to give a firm foothold. A dropping tray must be provided under the pegboard or slats to prevent excreta escaping
- Roof: The roof must be slatted at a width that horns cannot become trapped between the slats. If padding is required, soft material such as shavings can be stuffed under the rubber, canvas, or burlap covering
- Ventilation: Ventilation louvers or slots, with 2.5cm spacing between the louvers/slats or holes, with a minimum diameter of 2.5cm, must be present, above eye level, on all four sides and the roof of close boarded containers. Slots and holes must be covered with a fine wire mesh that will not allow any part of the animal, including horns, to protrude. If the mesh is on the inside of the container all edges must be protected to prevent injury
- Spacer bars/handles: Handles must be made to a depth of 2.5cm, and formed from the framework of the container
- Feeding and watering in the containers: Food and water containers must be provided with outside access from a hinged bolted flap that must be large enough for the entry of a large water dish and /or quantities of appropriate food such as grass hay, roots, vegetable, etc.
- Special requirements: Plastic or rubber piping can be placed over the horns, and the roof of the container must be padded with rubber or other suitable material in order to prevent the animals from hurting themselves.

2.2. Preparations before transport

The condition of the container (interior and exterior) must be checked before the shipment. Any defects must be corrected to prevent any injury of the animal while it is being transported. For the comfort of the animal during the long/short-term shipment, it is important to provide the right bedding inside the container. Good absorption of excrement is necessary. For this purpose it is recommended to staple polythene sheeting to the sides of the container to prevent spillage of excreta, and an absorbent such as wood shavings should be placed underneath the container. Additionally, straw and hay should be placed on top to help keep the animal sufficiently dry. Normal rations should be fed before transport, but care should be taken not to overfeed the animals. The Oryx should be watered not less than two hours prior to loading in the container. In case of immobilization, veterinary instructions must be followed (IATA, 2018).

2.3. General care, loading, transport

Animals do not normally require additional feeding or watering during 24 hours following the time of dispatch. However, the shipper's watering instructions must be followed. If feeding is required due to an unforeseen delay, fodder must be provided but care must be taken not to overfeed the animals.

Some of the animals may require tranquillizing for transportation. The name of the medication and time of administration must be provided to the shipper and affixed to the container. The information must also be accompanied by the shipper's certification. The transport contractor must be instructed about the general care during the shipment. During the transport the container with the animal must be placed in the freight space (lorry, train, ship, and airplane) on a horizontal plane, strictly avoiding placing the container at an angle. The container must be located in an area with good air ventilation, to ensure a good supply of oxygen to the animal. Animals must be checked regularly while in the container (IATA, 2018).

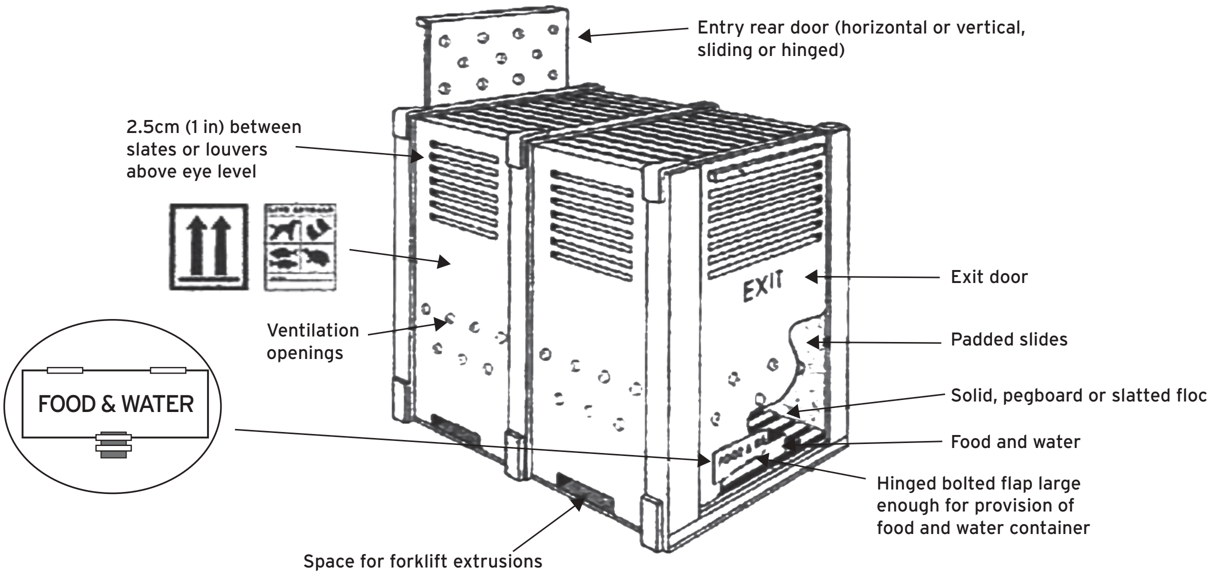

Figure 4-9: A layout of ungulate transport crate, reproduced from the IATA guidelines on the transport of live animals (IATA, 2000)

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3. Marking and identification

Identification of individual herd animals is necessary to facilitate routine animal management, captive breeding programs and scientific studies. There are a number of methods available for identifying individual animals. These include: use of natural markings; ear tagging; ear notching; implanting sub-cutaneous transponders or microchips; tattooing; and freeze branding. These techniques vary in their suitability for use with Arabian Oryx, and this section sets out recommendations for the most appropriate methods for this species based on practical considerations and experience.

3.1. Factors to consider when selecting identification techniques

(Rice & Kalk, 1996) suggest the following criteria for marking animals:

- Markings should be permanent and last the lifetime of the animal to which it is applied (see also Reuther, 1968; Jarvis, 1968)
- The technique should be inexpensive so that it can be applied to the entire collection without incurring excessive costs
- Visible markings should be readable at a distance so that animals can be identified without the need for restraint
- Markings should be humane, and it should be possible to apply them quickly and easily to prevent the animals from becoming unduly stressed.

Ideally, the animals should be marked using an established technique, so that anyone who is unfamiliar with the collection can identify the individuals. In some circumstances, it may also be desirable to use marking techniques that are inconspicuous.

3.2. Marking techniques Natural markings

Identifying individuals using natural marks such as pelage pattern, horn structure and permanent scars might be suitable for Arabian Oryx. This approach is non-invasive, inexpensive, permanent, and can be used to identify animals at a distance. The use of naturally occurring features is reliant on detailed and accurate records and must take into account the fact that differences between individual Oryx may be very subtle. This can be achieved with the aid of photographs, drawings and written descriptions of the animal. However, each identifying trait or combination of features must be unique to that animal and must be permanent. Features such as the animal's size and small wounds are subject to change, and are therefore not suitable as identifying marks (Rice & Kalk, 1996). Care must be taken to update records if other physical characteristics change (e.g. horn loss).

In relatively small collections, animal keepers who are familiar with their Oryx will be able to identify some individuals visually without the need for an applied marking technique. However, identification using the individual characteristics of the animal is susceptible to human error (Jarvis, 1968), and a person who is unfamiliar with the animals is likely to have difficulty in telling individuals apart. Hence, use of natural markings should be complemented with an additional method of identification.

Ear tags

Ear tagging is one of the most common methods for marking ungulates in general (Ashton, 1978; Dietlein, 1968; Griner, 1968) and for Arabian Oryx in zoos. Ear tags are inexpensive, quick and easy to apply, relatively inconspicuous (Ulmer, 1968; Rice & Kalk, 1996), and facilitate identification without the need for animal restraint (Rice & Kalk 1996). Identifying animals with tags is quicker and easier than relying on natural markings to distinguish individuals (Ashton, 1978).

Plastic ear tags are readily available in a variety of sizes, shapes and colors, and can have numbers printed on them (Rice & Kalk, 1996). Consequently, they can be used to distinguish individuals, their age and sex according to the marking protocol.

Common approaches include:

- Use of numbers for individual identification
- Use of different colored tags to identify year of birth (Davis, 1968; Rice & Kalk, 1996), or different sizes
- Tagging of different ears to distinguish between sexes i.e. right ear for males, left for females or vice versa (Ulmer, 1968; Deitlein, 1968; Rice & Kalk, 1996).

However, loss of one tag may lead to confusion. Colored tags that fade to the same or similar colors (e.g. red and orange) should not be used for any of these tagging strategies (Rice & Kalk, 1996).

Tags are applied using a special tool that can be obtained from the tag manufacturer. For both adult and young animals, tags should be placed in the thick cartilage on the anterior edge of the ear where it is less likely to tear out (Ulmer, 1968; Rice & Kalk, 1996). Care should be taken to avoid any major blood vessels (Rice & Kalk, 1996). Different institutions tag animals at different ages from infants on the day of birth to adults that have been recently transferred to that institution or are restrained for veterinary care (Griner, 1968; Davis, 1968). Oryx can be tagged on the day of birth, however there is a risk of rejection by its mother. Ulmer (1968) recommends waiting for four days after the birth, so the mother can develop a bond with the infant.

The main disadvantage of using ear tags is their lack of permanency. Plastic tags swing freely on a perforating pin, but they can still be caught on fences or branches and be either ripped from the ear, or fall apart when the animal pulls away (Davis, 1968; Griner, 1968; Ulmer, 1968; Rice & Kalk, 1996). Dirt and fading may reduce the effectiveness of ear tags over time (Ashton, 1978) and numbers on some tags are difficult to read at a distance (Ulmer, 1968).

Transponders

The use of transponders for marking individual animals is increasing in popularity amongst many zoos and animal collections. Transponders are small, rod-shaped and encased in a glass capsule. They range in size from 2mm x 10mm to 3.5mm x 30mm with the smaller transponders having a range of less than 8cm and the larger transponders having a range of 16cm (Gilbert, 2004).

Transponders are quick and easy to apply, permanent and inconspicuous. Each transponder is programmed with a unique code during manufacture and this code can then be read using a microchip reader (Rice & Kalk, 1996). Transponders are implanted under the skin or in the muscle, by first cleaning the site with alcohol to avoid infection. At Al Ain zoo, as a standard protocol transponders are implanted behind the left ear of all the ungulates (immediately at birth or upon receiving a new animal that had not been microchipped before). The disadvantages of using transponders for identification is that they are relatively expensive compared to other methods of marking, the performance is not always reliable and they need to be read in close proximity to the animal which usually entails physical restraint. As a result, the use of transponders offers a suitable backup to visual markings such as ear tags, and therefore it is advisable to combine the two techniques to ensure that the Arabian Oryx are permanently marked in an appropriate manner and all the criteria of the ideal marking are fulfilled.

Figure 4-10: A female Arabian Oryx, ear-tagged on the right ear. The bent horn can also be used for identification (left). A universal reader may be used to read the transponder (right). At Al Ain zoo, the standard procedure is to tag females on the right ear and males on the right ear.

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Chapter 5
Conservation breeding

Tania Gilbert & Myyas Al Quarqaz

1. Introduction

The Arabian Oryx *(Oryx leucoryx)* was endemic to the Arabian Peninsula and Sinai until its extinction in the wild in 1972 (Stanley Price, 1989) due to habitat degradation and overhunting (Abuzinada et al., 1988). However, the species was maintained in private collections and zoos around the world, and in 1963 'The World Herd' was created to save the species from complete extinction. The World Herd was founded when nine Arabian Oryx were sent to Phoenix Zoo in the Unites States of America, seven of which became founders (three wild-caught, three from Riyadh Zoo, and one from London Zoo (Homan, 1988). This was followed by a number of programs in the Middle East in the 1970s and 1980s that aimed to reintroduce Arabian Oryx back to the wild.

This chapter reviews the importance of genetic and demographic management of ex-situ Arabian Oryx herds in relation to maintaining long-term sustainable populations and providing animals for reintroduction projects.

2. Conservation breeding

Many ex-situ populations are regarded as 'assurance populations' or an 'insurance policy' to protect against extinction if the species is extirpated in the wild (Bingaman Lackey, 2010; Conde et al., 2011a; Frankham, 2008; Mace, 1989). These can make a valuable contribution to the conservation of species, subspecies, varieties and populations (Ballou & Lacy, 1995; Caughley, 1994; IUCN/SSC, 2014; Philippart, 1995) in their own right or when used as a source for reintroductions, as exemplified by the Arabian Oryx. It is therefore crucial that ex-situ populations of species like the Arabian Oryx are appropriately managed to ensure that they retain the characteristics necessary for long-term persistence in both ex-situ conditions and if they are reintroduced to their natural habitat.

Ex-situ breeding presents its own challenges and captive species can experience genetic and behavioural adaptation to human-dominated environments, loss of genetic diversity, and alterations in the morphological, physiological, ecological, genetic and behavioural characteristics that define the species i.e. species integrity (Balmford et al., 1996; Frankham, 1995a; Lacy, 1994; Mcphee, 2004; Philippart, 1995; Snyder et al., 1996). The ecological interactions between animals and their environments are also disconnected (Junhold & Oberwemmer, 2011). These factors may operate individually or in combination, to result in the expression of deleterious traits, or maladaptation, which might become particularly apparent when they are released to the wild (Campbell, 1980; Frankham, 2005b; Lacy, 1994; Montgomery et al., 2010), but also affecting ex-situ breeding success (Bowkett, 2009; Lacy, 1994; Mathews et al., 2005; Ralls & Ballou, 1992; Rosatte et al., 2007; WAZA, 2005; Zafar-ul Islam et al., 2010).

Whilst these concerns are all valid, ex-situ breeding has made the difference between extinction and survival for a number of species; 34 animal species are currently 'Extinct in the Wild' and only persist because of ex-situ conservation-breeding programmes (IUCN, 2018). Furthermore, ex-situ breeding and reintroduction can be an effective conservation strategy, and has played a major role in the recovery of 17 of the 68 species whose IUCN Red List threat status has been reduced, including the Arabian Oryx (*Oryx leucoryx)* (Gusset & Dick, 2011; IUCN, 2018).

3. The importance of a population management for ex-situ populations

There are a number of factors that influence the success of a reintroduction project, but a viable, well-managed, sustainable ex-situ population with substantial genetic diversity is a pre-requisite when utilising ex-situ populations (Kleiman, 1989; Lees & Wilcken, 2009; Ralls & Ballou, 1992; Wisely et al., 2003). Ex-situ populations are often small, fragmented and closed (Ballou & Foose, 1996; Ballou & Lacy, 1995; Williams & Hoffman, 2009) and more vulnerable to extinction than large contiguous populations subject to migration (Ballou & Foose, 1996; Lacy, 1993; 2000a). Generally, small populations lose genetic diversity faster than large populations, and on average retain less overall genetic variation (Frankham, 1995a; Thompson, 2004).

The minimum population size needed to ensure persistence will vary depending on the biological characteristics of the population (Pollak et al., 2005; Ralls & Ballou, 1992; Reed et al., 2003), but essentially, the larger the population size (census size), the better the chance of survival (Foose et al., 1995; Lees & Wilcken, 2009). However, merely ensuring a large census size may not be adequate to retain essential genetic variation (Briscoe et al., 1992).

Small population dynamics and viability are impacted by both deterministic (predictable) and stochastic (random) factors that operate simultaneously (Hedrick et al., 1996; Lande et al., 2003; Mace, 1989; Reed & Hobbs, 2004). Deterministic factors are intrinsic to the population and largely independent of population size. Stochasticity includes genetic, demographic and environmental factors, all of which, individually and combined, can determine population viability (Ballou, 1992; Frankham, 2003; Hedrick et al., 1996; Mace, 1989; Reed & Hobbs, 2004; Snyder et al., 1996). The magnitude of stochastic threats depends on population size with stochasticity having a greater impact on smaller populations (Ballou et al., 2010; Holsinger, 2000; Lande, 1993). Genetic stochasticity, the changes in genetic variation caused by genetic drift and mutation, can exert a substantial influence over the genetic diversity and therefore persistence of ex-situ populations (Ballou & Cooper, 1992; Ballou & Lacy, 1995). Drift is defined as the loss of alleles due to random fluctuations in gamete sampling from one generation to the next (Frankham et al., 2010).

Genetic diversity is measured in both individuals and populations, and can be described in terms of allelic diversity and heterozygosity (Ballou & Foose, 1996; Ballou et al., 2010). Allelic diversity is important for a population's long-term ability to adapt to environmental change, and therefore represents evolutionary potential (Ballou et al., 2010; Briscoe et al., 1992; Frankham, 2003). It is sensitive to population bottlenecks, such as those encountered by the founding of ex-situ populations (Amos & Balmford, 2001). Heterozygosity is important for individual health and response to selection (Reed & Frankham, 2003). It is described either as observed heterozygosity, which is the proportion of genetic loci for which the average individual in a population is heterozygous, or expected heterozygosity also frequently referred to as Gene Diversity (Höglund, 2009; Lacy, 1994; Pollak et al., 2005). Gene Diversity is the probability that two homologous genes randomly drawn from the population are distinct alleles (Höglund, 2009; Lacy, 1994). It is the mean heterozygosity that would exist in a population if it were in Hardy-Weinberg equilibrium. Furthermore, the rate at which a population responds to selection is related to Gene Diversity (Lacy, 1994). Gene Diversity is one of the key genetic measures that population managers assess in the management of the genetic diversity of pedigreed ex-situ populations (Lacy et al., 2012).

The amount of genetic diversity in an ex-situ population is determined by its founders (Mace et al., 1992). Many ex-situ populations are founded with relatively few, possibly related, individuals representing only a small fraction of the genetic diversity of the wild population (Ballou & Lacy, 1995; de Boer, 1989; Mace, 1986; Ralls & Ballou, 1992). For example, the 'International Studbook for Arabian Oryx' records 18 founders for the current global ex situ population, although 26 individuals had wild-caught parents (Hatwood, 2015). Some of these individuals might also be identified as additional founders if more of the pedigree were complete. The international studbook records 1,459 living Arabian Oryx in 58 global institutions in April 2015, but there are several thousand more animals in zoos and zoological collections in the Arabian region (GSCAO, 2016), and approximately 500 in private collections in the USA (Mungall pers comm., 2018). It is possible that the number of actual global founders exceeds that recorded in the studbook.

Founders to ex-situ populations are often collected from small or declining populations of threatened species (Conde et al., 2011b; Lyles & May, 1987; Traylor-Holzer, 2011a; Williams & Hoffman, 2009), and threatened species typically have much lower levels of genetic variation than comparable non-threatened species (Frankham, 2005a; 2005b; 2006; Reed & Frankham, 2003; Spielman et al., 2004). The number of founders, and their relatedness to each other, determines the amount of genetic diversity that can be retained in the ex-situ population (Frankham et al., 2010; Mace et al., 1992; Senner, 1980; Willis & Willis, 2010). Loss of genetic variation from a population is a serious threat to its long-term viability (Lacy, 1997; Willis, 1993).

Small closed ex-situ populations encounter four types of genetic change which can impact long-term population viability and reintroduction success (Armstrong & Seddon, 2008; Arnold, 1995): 1) loss of genetic diversity; 2) accumulation of new mildly deleterious alleles; 3) inbreeding and; 4) genetic adaptation to human-dominated environments (Ballou & Lacy, 1995; Frankham, 1995a, 2008; Princée, 1995).

3.1. Loss of genetic diversity through genetic drift

Closed populations lose neutral genetic variation (allelic diversity and heterozygosity) through genetic drift (Ballou & Foose, 1996; Reed & Frankham, 2003; Wilcken & Lees, 1998) at a rate dependent on the effective population size (*Ne*) (Nunney, 2000). The *Ne* is the size of an idealised population that would give rise to the same variance of gene frequency, or rate of inbreeding, as observed in the actual (census) population under consideration (Frankham, 1995b), and is often much smaller than the census size (Frankham et al., 2010). The theoretically smallest *Ne* where the mutation rate balances genetic drift is *Ne* = 500 (Lees & Wilcken, 2009; Vogler et al., 2009), although some authors suggest that an *Ne* in the region of 1000-5000 is needed to achieve this (Lynch & Lande, 1998). Most ex-situ populations are too small for mutation to have a noticeable effect (Lacy, 1987), and population size is limited by available space (Vogler et al., 2009). Drift overwhelms natural selection in small closed ex-situ populations, and is the dominant force in determining allele frequencies (Höglund, 2009; Lacy, 2000a; Lande, 1995). Genetic drift can be reduced by increasing *Ne* and extending generation length, because each generation is a genetic sampling of the previous one (Lacy et al., 1995; Taylor & Barlow, 1995).

3.2. Accumulation of new mildly deleterious alleles

As populations become smaller, genetic variation increasingly becomes 'nearly neutral', and genetic drift replaces selection as the dominant force (Lacy, 1997; Nunney, 2000). The consequence of this is that mildly deleterious alleles become selectively neutral, and their fate is then determined by genetic drift. Over sufficiently long periods of time, mildly deleterious alleles can accumulate in the population and reduce overall fitness. The accumulation of deleterious variants speeds up as the population size decreases, and these alleles can drift to fixation, resulting in a negative feedback loop. Eventually, this can cause the population to decline to extinction. Such events are termed 'mutational meltdown' (Frankham, 2005a; Höglund, 2009). Mildly beneficial alleles are also subject to drift as they become 'nearly neutral', and the probability of any allele reaching fixation increases as the population size decreases (Franklin, 1980; Lacy, 2000a; Nunney, 2000; Peterson & McCracken, 2005).

3.3. Inbreeding

Inbreeding (consanguineous matings) is inevitable in small closed populations (Ballou et al., 2010; de Boer, 1989; Höglund, 2009; Lacy, 1992). It is measured by the inbreeding coefficient *F*, which is defined as the probability that two alleles at any one genetic locus will be identical by descent from common ancestors (Ballou et al., 2010). The *F* of an offspring is equal to the kinship between its parents (Lacy et al., 2012), and is proportional to the loss of heterozygosity in the population (Lacy, 1992; 1997). Inbreeding often leads to inbreeding depression, characterised by increased juvenile mortality, decreased longevity, lower reproductive success, greater susceptibility to parasites and disease, and a higher rate of developmental defects (Ballou & Ralls, 1982; Frankham, 2006; Lacy, 1992; 1997; Ralls et al., 1980). A minimum short-term *Ne* of 50 has been recommended to avoid the immediate deleterious effects of inbreeding in a population (Franklin, 1980; Lacy, 1994). Inbreeding depression has been well-documented in experimental, wild, ex-situ and domestic populations (Boakes et al., 2007; Crnokrak & Roff, 1999; Höglund, 2009; Lacy, 1992; Reed & Hobbs, 2004), including the Arabian Oryx (Marshall & Spalton, 2000), and is more severe under stressful conditions such as those found in the wild (Crnokrak & Roff, 1999; Höglund, 2009; Kalinowski & Hedrick, 1999). Inbreeding depression can have a severe impact on the viability of threatened populations and may increase extinction risk (Frankham, 2005a; 2006; Höglund, 2009; Reed & Frankham, 2003). It can be more difficult to detect under benign ex-situ conditions (Charpentier et al., 2006; Crnokrak & Roff, 1999; Frankham, 1995a; Kalinowski & Hedrick, 1999), although Boakes et al. (2007) did detect inbreeding depression for neonatal survival across 119 ex-situ populations.

If a population is inbred, or suffering from the effects of inbreeding depression, the immigration of just one unrelated individual can substantially reduce its impact (Frankham, 1995a; Höglund, 2009). This has been demonstrated for Scandinavian wolves *Canis lupus* suffering from increased juvenile mortality and hereditary blindness caused by inbreeding, where genetic rescue restored pre-inbreeding growth rates (Höglund, 2009). This is only an effective strategy if there are alternative populations with unrelated individuals. Whilst an evaluation of the genetics of global Arabian Oryx populations has not taken place in recent years (but see Marshall et al., 1999), it is possible that geographically isolated global populations will exhibit some genetic differentiation either due to different founding individuals or differential drift between populations over time (El Alqamy et al., 2012; Frankham et al., 2010). This means that it may be possible to mitigate inbreeding depression, if it is present, in some Arabian Oryx populations by translocating individuals between unconnected populations from within the region or from around the world.

If this approach is taken then some consideration must be given to the potential impact of outbreeding depression, the reduction in reproductive fitness due to the crossing of two populations, that may arise from mixing together Arabian Oryx from genetically differentiated populations (Frankham et al., 2010). Whilst it is rare to detect outbreeding depression in mammals and birds (Frankham et al., 2010), Marshall & Spalton (2000) found inbreeding and outbreeding depression acting simultaneously on juvenile survival in a reintroduced population of Arabian Oryx in Oman.

4. Genetic adaptation to ex-situ conditions

Genetic adaptation to ex-situ conditions has been documented for a wide range of taxa, including mammals, birds, fish, plants, insects, and bacteria (Frankham, 2005b; Frankham et al., 2010; Leus et al., 2011; Montgomery et al., 2010; Witzenberger & Hochkirch, 2011), and may present a serious problem for populations that are undergoing ex-situ breeding for reintroduction to the wild (Frankham et al., 1986; Frankham & Loebel, 1992; Leus et al., 2011; Montgomery et al., 2010; Robert, 2009). When an ex-situ population is isolated the mean phenotype of the population may shift away from that of the wild population. When individuals are later reintroduced to the wild, they may exhibit a decline in fitness compared to their wild counterparts (Arnold, 1995). A number of factors influence the rate of adaptation to ex-situ conditions, including the similarity of captive and wild conditions, the number of generations under ex-situ conditions, the *Ne*, and the intensity of selection (Ford, 2002; Frankham, 2008; Haig et al., 1990; Leus et al., 2011; Williams & Hoffman, 2009). Selection in the ex-situ environment is often unconscious on the part of animal managers, for example more docile animals may reproduce better or are easier to handle, and are more likely to pass their genes onto the next generation (Snyder et al., 1996; Williams & Hoffman, 2009). Additionally, the benign ex-situ environment relaxes selection and individuals survive and reproduce that would not have survived in the wild (Hakånsson & Jensen, 2005; Junhold & Oberwemmer, 2011; Robert, 2009).

Adaptation to ex-situ conditions can be minimised by reducing the time populations spend ex-situ, immigration from the wild, increasing the generation length, decreasing the *Ne*, and fragmenting the population, so genetic drift reduces the genetic diversity available for selection in individual populations, whilst theoretically retaining it at the species level (Frankham, 1999; 2008; Frankham & Loebel, 1992; Lande, 1995; Leberg & Firmin, 2008; Princée, 1995). However, these last two methods present a dichotomy. Decreasing the *Ne* reduces adaptation to ex-situ conditions, and therefore enhances the probability of survival of reintroduced populations. At the same time reducing *Ne*, either directly or through population fragmentation, increases stochasticity and the extinction risk for small ex-situ populations (Earnhardt, 1999; Frankham, 2005a; Johnson & Schoen, 1994). The different demographic and genetic factors interact in small, closed, ex-situ populations, leading to greater instability and a further decrease in population size, in turn leading to further demographic and genetic problems (Ballou et al., 2010; Lacy, 2000a). This process is termed the extinction vortex (Ballou et al., 2010; Foose et al., 1995; Lacy, 2000a).

5. Coordinated ex-situ programmes

In order to address these issues, many ex-situ populations are managed in coordinated programmes that are designed to maximise the prospects of the species survival over the long-term within the limited resources available (Mace, 1989). Coordinated programmes involve managing ex-situ species as multi-institutional biological populations, and this is often, but not exclusively, achieved through regional zoo associations (Ballou et al., 2010).

Coordinated ex-situ programmes aim to develop self-sustaining populations that maintain demographic stability, maximise genetic diversity, minimise inbreeding and genetic adaptation to ex-situ conditions, and provide animals for reintroduction projects if it is appropriate for the species (Ballou & Foose, 1996; Ballou et al., 2010; Frankham et al., 1986; Hedrick & Miller, 1992; Leus & Traylor-Holzer, 2008; Montgomery et al., 2010). Ex-situ management is designed to minimise changes in the genetic composition of the population whilst it is in an ex-situ environment, so it will resemble, as closely as possible, the genetic characteristics of the original founding population (Ballou & Foose, 1996; Ballou & Lacy, 1995; Ballou et al., 2010; Foose et al., 1995; Lacy, 1994).

Many ex-situ programmes require accurate and current data in a standardised format in order to evaluate the genetic and demographic characteristics of a population, predict future trends, and model the effect of different management strategies (Ballou et al., 2010; Bingaman Lackey, 2010; Wilcken & Lees, 1998). The best source of compiled data is a studbook (Ballou et al., 2010). Studbooks contain a complete chronology of the ex-situ population listing information on individual identities, location, sex, parentage (pedigree data), relationships between individuals, cause of death, and birth, translocation, and death dates (Ballou et al., 2010; Bingaman Lackey, 2010; Lacy et al., 1995; Vasarhelyi, 2002). Studbooks can be local, regional or global (international studbooks) in scope.

6. Pedigree analysis

Coordinated ex-situ programmes often use pedigree analysis as the basis of population management for ex-situ populations. Pedigree analysis assumes a starting population where the wild-caught individuals (founders) are unrelated, or equally related, to each other (Ballou & Ralls, 1982; Lacy, 1994; Lacy et al., 1995). Information is often lacking on the geographic origin and relatedness of the founders (Gautschi et al., 2003; Witzenberger & Hochkirch, 2011), and whilst the founder assumption of non-relatedness is necessary for pedigree analysis, it may not accurately describe the true relationship between founders, and therefore subsequent generations (Lacy, 1994; Vasarhelyi, 2002; Willis, 1993; Witzenberger & Hochkirch, 2011).

Pedigree analysis involves estimating the relatedness of individuals in the population by tracing the pedigrees back to the founding generation (Lacy et al., 1995; Wilcken & Lees, 1998). This provides a method of accurately estimating how much Gene Diversity has been lost between the founders and the living descendant population (Lacy, 1995). It also provides an efficient method for calculating inbreeding and kinship coefficients (Ballou, 1983; Boyce, 1983; Lacy et al., 1995), and estimating founder contribution in the living populations in large, complex pedigrees (Hedrick & Miller, 1992).

A number of software programs have been developed for managing studbook databases and analysing pedigree data for population management, including PMx available from http://www.vortex10.org/PMx.aspx (Ballou et al., 2011). PMx carries out detailed genetic and demographic analyses using pedigree and/or molecular genetic data to model population management options and goals.

7. The management of ex-situ populations

Population management attempts to maintain a stable population size and structure in order to minimise temporal fluctuations and reduce extinction risk (Ballou & Lacy, 1995; Mace, 1989). Demographic analyses provide managers with the necessary information on how many animals need to breed and when they need to breed. The results of the genetic analyses provide information on which animals should breed, and with whom, to maximise the retention of genetic diversity, and minimise inbreeding (Wilcken & Lees, 1998).

Specific genetic and demographic goals are established for each ex-situ programme (Lacy, 1995; Ralls & Ballou, 1992). Once the genetic goal has been set, the number of animals required can be calculated from life tables, data on current genetic diversity levels, and estimates of *Ne* (Ballou et al., 2010; Lacy & Ballou, 2002). The amount and complexity of data obtained from pedigree analysis can be formidable, and different strategies have been developed to identify and rank individuals according to their genetic importance within the population (Ballou & Lacy, 1995). The Mean Kinship (*MK*) method, which quantifies the relationship between any one individual and all living individuals in the population, is a measure of the rareness of an individual's alleles in the population; it is the most effective strategy for retaining gene and allelic diversity in populations with complex pedigrees and unequal founder representation (Ballou & Lacy, 1995; Ivy & Lacy, 2012; Montgomery et al., 1997). Consequently, contemporary population management within regional zoo associations use the *MK* method to assign breeding priority to individuals within a population with a known pedigree (Wilcken & Lees, 1998).

Individuals with low *MK* coefficients (*MKi*), represent genetically important animals (Ballou & Lacy, 1995; Ballou et al., 2010; Ralls & Ballou, 1992). Minimising kinship in a population is directly related to maximising Gene Diversity. It also equalises family sizes, and that increases *Ne* and reduces the loss of Gene Diversity through drift (Ballou & Lacy, 1995; Ballou et al., 2010; Borlase et al., 1993; Frankham, 2005b; Ralls & Ballou, 1992; Williams & Hoffman, 2009). *MK* is calculated from pedigree data using the additive relationship matrix method given in Ballou (1983) and Boyce (1983) (Ballou & Lacy, 1995; Lacy et al., 1995).

Ex-situ programme managers select breeding pairs where males with low *MKi* are paired with females of similar and low *MKi*, excluding pairings between close relatives to avoid inbreeding (Ballou & Lacy, 1995; Ballou et al., 2010; Frankham et al., 2010; Lacy, 2000b; Vasarhelyi, 2002). The optimal pairings, based on both demographic and genetic criteria, are often modified due to behavioural, veterinary, geographic, social, financial and political considerations (AZA, 2004; Ballou & Cooper, 1992). Modified recommendations are then issued to participants in the ex-situ programme in the form of breeding and transfer recommendations or a population management plan (Ballou & Cooper, 1992).

7.1. Incomplete pedigree data

Detailed pedigree analysis including the calculation of kinships, inbreeding coefficients and frequency of founder alleles in the living population are critically dependent on good quality records and complete pedigrees (Ballou & Lacy, 1995; Lacy et al., 1995), and the application of population management models are limited by the quality of pedigree data (Ballou & Cooper, 1992; Princée, 1995; Russello & Amato, 2004; WAZA, 2005). The identity and parentage of every individual since the inception of the ex-situ breeding programme must be known in order to construct complete ancestries for each living animal (Ballou & Cooper, 1992). However, historical record keeping is often poor resulting in incomplete pedigree data (Ballou & Cooper, 1992; Ballou & Lacy, 1995; Mace et al., 1992; Princée, 1995).

Intensive population management cannot be implemented for populations with large proportions of missing pedigree data (Mace & Pemberton, 1990; Princée, 1995), but management still needs to proceed for ex-situ populations to ensure sustainability (Ballou et al., 1995; Princée, 1995). To address this, individuals with missing pedigree data may be excluded from population management (Ballou & Cooper, 1992). However, excluding individuals may also reduce the *Ne*, and therefore increase the loss of genetic variation through drift (Foose et al., 1995; Willis, 1993), as well as potentially increasing inbreeding due to a reduced number of breeders (Ballou & Lacy, 1995; Lacy et al., 1995). Alternatively, multiple parentage can be assigned to individuals with uncertain parentage, resulting in proportional parentage being included in the pedigree analyses (Ballou et al., 2011). This resolves the challenge of unknown parentage, but introduces an element of known error into the analyses. Furthermore, the population manager must hold information on possible alternative parents and include those data in the pedigree. In cases such as the Arabian Oryx, where the pedigree in the international studbook has only 30% completeness (Hatwood, 2015), removing a large proportion of the population from population management would probably have a detrimental effect on the overall retention of genetic diversity. Alternative management solutions that do not rely on a high level of pedigree completeness should be explored.

8. Managing populations using molecular genetic analysis

Molecular genetic analyses can help resolve uncertain parentage (Ivy et al., 2009) or can provide an alternative solution to pedigree-based population management when pedigree data are incomplete (Ballou et al., 2010). They can also be used to construct a pedigree if viable samples for DNA analysis are available from all current individuals in the population, and all individuals are individually identifiable. The identification of a large number of variable genetic markers will be required to do this, and this can be challenging in populations with low levels of genetic diversity due to inbreeding. The resolution of the pedigree will be improved if all historical, as well as all current, individuals within the population can be analysed. This is often not possible, and in the absence of historical samples, the pedigree will likely need to be approximated beyond a few generations, unless the genetic dataset is very powerful. Pedigree-based population management can be implemented if these conditions can be met and a pedigree constructed.

Alternatively, empirical kinships calculated from molecular data can be imported into PMx (Ballou et al., 2011) and used as the basis of population management in a comparable manner to mean kinships derived from pedigree data. Under this scenario, empirical kinships are needed for every living individual in the population; again all individuals must be individually identifiable with a high standard of record keeping.

Whilst empirical kinships are calculable from molecular data, the number and type of markers used may influence the results with more markers leading to more accurate results. Pedigree-based management is more effective than molecular-based management in maximising genetic diversity when data based on few molecular markers are used to manage the genetic diversity of populations (Fernandez et al., 2005). Pedigree analyses effectively estimate diversity across the whole genome but rely on the assumptions that the pedigree is accurate and that the founders are unrelated, whereas molecular analyses generally estimate diversity across a limited number of loci (i.e a limited fraction of the genome), unless more comprehensive techniques such as ddRAD analysis are used where genetic diversity can be estimated across thousands of markers (Ballou et al., 2010).

9. Using group management strategies for populations without pedigrees

Group management strategies can be used for populations when it is not possible to record and maintain data on individuals' key life history events such as births and deaths, where pedigree data are largely incomplete, or it is not possible to obtain empirical data for all individuals using molecular genetic techniques to reconstruct a pedigree (Jiménez-Mena et al., 2016; Leus et al., 2011). These groups-based populations encounter the same challenges as all ex-situ populations, and it is important for population viability that they are managed to retain their genetic diversity and reduce inbreeding (Jiménez-Mena et al., 2016). The group management strategy employed will depend on available information and practicalities, but a rigorous and consistent record keeping system remains a necessity (Leus et al., 2011) and it may be beneficial to periodically sample the genetic diversity of the population to monitor the management strategy and inform the introduction of new founders to the group.

9.1. Combined molecular genetics and group management

Molecular genetics may be useful where the conditions of individual management cannot be met and blood or tissue samples for every living individual in the population are not obtainable. Under these circumstances a sub-set of individuals can be genetically sampled and the results extrapolated to the whole group. Repeating the process for all groups in a country or region provides measures of genetic divergence between groups (Ballou et al., 2010). This enables the formulation of a population management plan using group management to maximise retention of genetic diversity across the region.

9.2. Maximum Avoidance of Inbreeding

The Maximum Avoidance of Inbreeding (MAI) scheme for group management is a simple, low-intensity form of genetic management that aims to slow down the accumulation of inbreeding in closed populations with multiple groups (Princée, 1995). It can be applied when detailed life-history data are largely missing and translocations of individuals between groups in a specified format can take place (Princée, 1995). Certain criteria need to be met to ensure that MAI schemes are effective: 1) The number of groups should be a power of two (e.g. four (22), eight (23), 16 (24) groups); the population should start with unrelated animals; 3) generations should be discreet; and 4) the offspring of one sex from one generation can be moved to another group. Inbreeding cannot be avoided beyond the third generation (Princée, 1995), but the scheme performs better than random breeding in retaining Gene Diversity within the population (Ballou & Lacy, 1995; Montgomery et al., 1997).

MAI can also be applied to populations that are divided into sub-populations in a nested approach to management e.g. sub-populations in a country within a regional population. The MAI scheme is applied within each sub-population and then also between sub-populations (Princée, 1995).

This approach to group population management includes several assumptions that may not be easily met for large-bodied social species like Arabian Oryx in already established groups e.g. moving all male offspring in one generation from one group to another, and the number of groups is to the power of 2. Traditional MAI management schemes may impact on social stability, and it is unknown how effectively inbreeding is delayed when a more relaxed form of MAI is applied (Leus et al., 2011).

9.3. Maintaining a high and constant effective population size (*Ne*) across generations

Retention of genetic diversity per generation is dependent on the *Ne* (Frankham et al., 2010), and this is influenced by a number of factors that can be manipulated through management actions (Ballou et al., 2010). *Ne* is optimised when the number of breeding animals is at its maximum, sex ratio of breeding animals are equalised, family sizes are equal, fluctuations in population size are avoided, and discreet generations are maintained (Frankham et al., 2010). Practically applying this to antelopes like the Arabian Oryx is challenging because of restraints posed by social structure and management requirements (Gilbert, 2011), but breeding management to maintain an equal sex ratio amongst breeders, ensuring that all females produce an equal number of offspring, rotating males in and out of breeding groups on a regular basis, maintaining a constant population size and moving 4-5 effective migrants per generation between breeding groups will help to maximise the *Ne* of the population (Ballou et al., 2010).

9.4. Group management using PMx

The genetic management strategies based on minimising kinship that are successfully applied to individual-based species management can be extended to group-living organisms (Jiménez-Mena et al., 2016; Leus et al., 2011; Traylor-Holzer, 2011b). The average inbreeding and mean kinship values of groups (average relatedness of one group to all groups in the population) can be calculated using data on group-size changes and movement between groups in a multi-group population. Similar to the mean kinships of individuals, these calculations enable population managers to identify which groups should move individuals between them for breeding purposes (Ballou et al., 2010). Group MK strategies may be applicable when individual-based management is a challenge or when there is less control over the patterns of group formation and the criteria for MAI cannot be met (Jiménez-Mena et al., 2016; Leus et al., 2011).

PMx is a software program primarily used for individual-based population management, however, it also has the capacity to analyse group pedigrees for group-living species. This process is augmented with a group pedigree data entry sheet and converter program (group2PMx) that enables the importation of group datasets in PMx (Jiménez-Mena et al., 2016). For the program to be effective, two assumptions must be met: discrete (non-overlapping) generations are maintained, with new individuals born removed to form an offspring group; and deaths or emigrations are recorded by designating the changed group as a new group formed by the sampling of individuals from the larger original group (this can be done after the removal or death of a number of individuals when the genetic calculations need to be updated). If these assumptions cannot be met then estimates of *MK* and inbreeding will over-estimate genetic diversity within groups, but not between groups (Jiménez-Mena et al., 2016).

Whilst this provides a method of managing the genetic diversity of group-living species beyond only managing inbreeding, group *MK* genetic management may not be as effective as individually minimising kinship (Leus et al., 2011).

10. Metapopulation management and the One Plan Approach

Metapopulation management is a developing approach that can assist regional ex-situ management programmes in meeting long-term viability goals for threatened species (Leus et al., 2011). A metapopulation is a group of populations of the same species that are partially geographically isolated from each other that undergo local extinctions and recolonisations (Frankham et al., 2010). This can apply to numerous situations, including discretely managed regional or global ex-situ populations i.e. each individual institution or country; wild populations where wild-to-wild translocations or migration takes place between populations; or management where animals are exchanged between ex-situ, wild and semi-wild populations.

Metapopulation management can provide a solution for the long-term viability of populations where individual population sizes are small or genetic diversity is limited. In instances where regional programmes are unable to achieve long-term population sustainability, global programmes may provide an answer (Leus et al., 2011). However, few species have successfully been managed on a global scale (inter-regional metapopulation management) e.g. lion tamarins *Leontopithecus spp* (Ballou et al., 2002), okapi *Okapia johnstoni* (Leus, 2004), and red panda *Ailurus fulgens* (Glatston & Leus, 2005).

Simulation models, including population viability analysis, can help to evaluate potential benefits of metapopulation management for a species (Leus et al., 2011). Population Viability Analysis (PVA) can simulate various scenarios in metapopulation management incorporating genetic data and can evaluate a mixed-approach to population management to account for different management approaches in different countries or regions where data and resources vary.

10.1. One Plan Approach

The historical practises of ex-situ breeding with reintroduction (IUDZG/CBSG, 1993) has continued to evolve into a more holistic approach to biodiversity conservation as exemplified by the One Plan Approach (OPA) promoted by the IUCN Species Survival Commission (SSC) Conservation Planning Specialist Group (CPSG) (Traylor-Holzer et al., 2018). OPA 'supports integrated species conservation planning through the joint development of management strategies and conservation actions by all responsible parties to produce one comprehensive conservation plan for the species' (Byers et al., 2013). Applying this principle to Arabian Oryx would involve the development of an integrated management plan that would encompass reintroduced, semi-wild, and global ex-situ populations for the long-term conservation of the species.

11. Global Arabian Oryx populations

When considering the management of Arabian Oryx ex-situ populations in the Arabian Peninsula, it is worth reviewing the role of the regional population within a global context. The Arabian Peninsula holds a far larger ex-situ population than any other region, with an estimated 6,000 Arabian Oryx in 2016 in the United Arab Emirates alone, most of which are managed in ex-situ facilities (GSCAO, 2016). Additional ex-situ populations exist across the Arabian Peninsula, and in 2010, free-ranging populations and those in fenced-managed reserves were estimated at around 2350 individuals (EAD et al., 2010). This puts a conservative estimate of Arabian Oryx populations in the Arabian Peninsula at approximately 8,300 individuals, although the actual number is likely to be considerably higher.

In comparison, the international studbook records 1,459 living Arabian Oryx in 58 global institutions in April 2015 (Hatwood, 2015) and ZIMS (Zoological Information Management System), a database containing information on species held by more than 1000 zoos, aquaria and wildlife organisations in over 95 countries worldwide (Species360, 2018a), reports approximately 1,890 Arabian Oryx held in ex-situ facilities around the world (Species360, 2018b), although most of these (approximately 1,670) are in seven institutions in the Arabian Peninsula. The remaining individuals are located in 17 European zoos (~60) where group size varies between 1-7 oryx per group; three institutions in Africa (~20) where group sizes vary between 3-14 oryx per group; Ten zoos in North America (~95) where groups consist of 1-19 oryx; and five zoos in Asia, outside of the Arabian Peninsula (~40), where group size vary between 2-14 (Species360, 2018b).

Additional unregistered ex-situ groups are held in private collections and ranches in Texas and Florida in the USA. The total population size in these collections is estimated to be approximately 500 individuals, with most being held on ranches in Texas where the climate is drier than that of Florida. Most herds consist of 10-20 individuals, but several herds are small with only 4-5 animals in each group (Mungall pers comm., 2018). Arabian Oryx first appeared on the State Wildlife Department's census of exotic animals in 1984 with 10 animals registered; unfortunately this census no longer takes place, so precise numbers are no longer available (Mungall pers comm., 2018). Two circumstances presently prevent numbers of Arabian Oryx from increasing as much as they otherwise might on ranches; first, political restrictions (required permits etc) present a problem; and secondly, females are difficult to acquire (Mungall pers comm., 2018). Overall, there are at least 9-10,000 Arabian Oryx around the world, with the vast majority located in the Arabian Peninsula.

Coordinated ex-situ breeding programmes operate for the European population (EEP: European Ex-situ Programme) under the auspices of the European Association of Zoos and Aquaria (EAZA), and the North American population (SSP: Species Survival Plan) under the auspices of the Association of Zoos and Aquariums (AZA). The rest of the global populations are currently not managed under coordinated population management to meet to population viability goals, making them vulnerable to the genetic and demographic factors that contribute to population extinctions.

Whilst most of the global Arabian Oryx population is located within the Arabian Peninsula, there may be some unrepresented genetic diversity in populations outside of the region, either because founders were not shared between regions, or genetic drift has operated over a number of generations to cause a differential retention of alleles and lineages in each population (Frankham et al., 2010). The development of an integrated management strategy for the region, if not globally, would benefit the long-term conservation of the species in the Arabian Peninsula. Such a strategy could encompass the different populations (ex-situ, fenced-managed, and wild), different management approaches and variable data standards across collections to implement a coordinated population management plan that is practicable for the collections within the Arabian Peninsula. The aims of the plan would be agreed at a regional level, but would seek to maximise genetic diversity and demographic stability to ensure the long-term persistence of the species within the region.

12. Breeding Arabian Oryx in individual collections

Arabian oryx breed well under ex-situ conditions and can live up to 23-years, although very few individuals live beyond 18-years (Hatwood, 2015). They are more suited to drier conditions where hoof problems and parasite burdens are less problematic than they are for Oryx kept in wetter climates (Mungall pers comm., 2018).

Female Arabian Oryx are polyestrus (Wilson & Mittermeier, 2011) and males will follow and attempt to breed with the females throughout the year leading to births across all months (Figure 1.), if males and females are permanently kept together (Wilson & Mittermeier, 2011). The gestation period for Arabian Oryx is 240-270 days (8-9 months) (Castelló, 2016; Hatwood, 2015; Wilson & Mittermeier, 2011), and a female Arabian Oryx can produce a calf every year without breeding management (Castelló, 2016; Wilson & Mittermeier, 2011). Most births recorded in the international studbook (99.7%) were of single calves, but 0.3% of births were twins (Hatwood, 2015).

In the wild, females separate from the herd to give birth and are accompanied by the dominant male during the first month. The male then mates with the female during the post-partum estrus (Castelló, 2016; Wilson & Mittermeier, 2011), as occurs with other Hippotragine antelopes (Densmore and Kraemer, 1986; Dieckman, 1980; Gill and Cave-Browne, 1988). No data have been recorded about the influence of lactation, which usually prevents ovulation in mammals, on the timing of the postpartum estrus. In cervids, estrus is delayed if males are not present (Verme et al., 1987).

Behaviour indications suggest that Arabian Oryx exhibit an estrous cycle between 25 and 32 days (Turkowski & Mohney, 1971). However, an estrous cycle of 22 days was hormonally determined in Scimitar-horned Oryx (Durrant, 1983). The timing of reproduction in mammals may be influenced by the energy available during gestation and lactation. In a seasonal environment, females give birth in spring, but in equatorial conditions they tend to breed throughout the year (Spinage, 1986). In captive populations, with ample water and food, one factor possibly influencing reproduction would be removed. Sempere et al., 1995 studied the length of estrous cycle and gestation in the Arabian Oryx and the importance of the male presence for induction of postpartum estrus, and found that environmental factors such as temperature or/and rain and social factors (i.e. the presence of a male) could affect the fertility of the postpartum estrus in Oryx, with the presence of the male having a stimulating effect on the first postpartum estrus. Moreover, although in captive conditions, most of the females are mated at their first postpartum estrus, and some females failed to be fertilized at their first estrus, which would suggest that environmental factors could also be implicated in the seasonal patterns of body condition of females.

In the wild, calving was observed throughout the year, implying a lack of seasonality, similar to the inter-birth interval and the birth period observed in Addax *(Addax nasomaculatus)* (Densmore and Kraemer, 1986). Wacher (1988) indicated that as in Scimitar-horned Oryx (Durrant, 1983) and Addax (Densmore and Kraemer, 1986), births for captive Arabian Oryx were not synchronized with the seasons. However, global ex-situ populations produce more calves from December through to May (see figure 5-1). In contrast, Stewart (1963) reported that in the wild, births were more frequent in the late spring and summer or in winter.

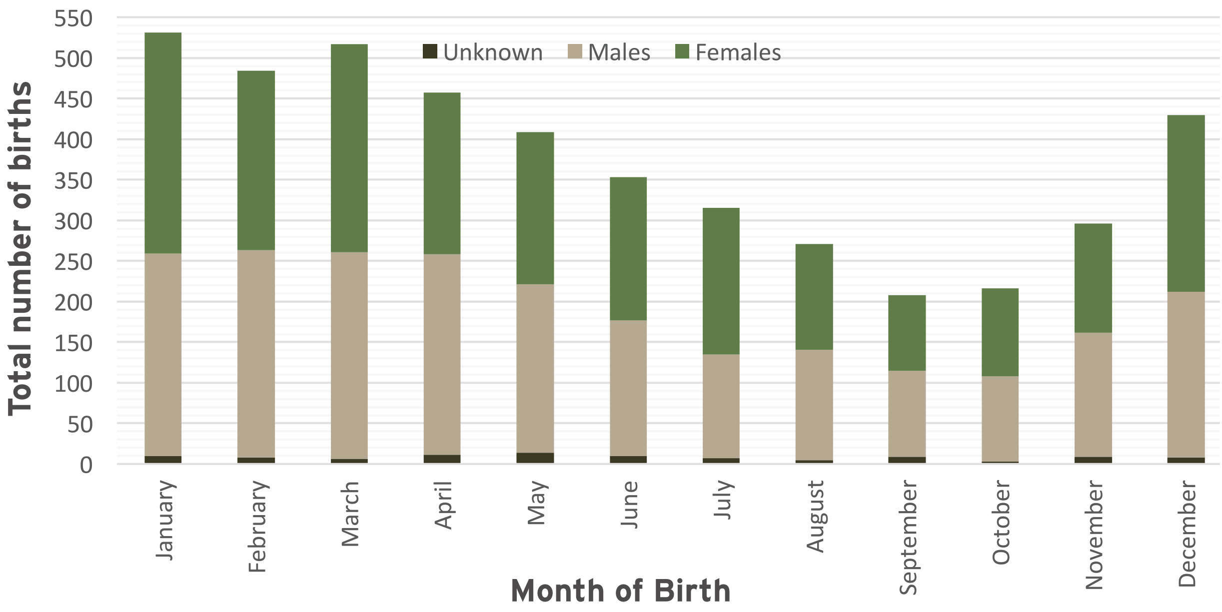

Figure 5-1: Birth seasonality for global captive Arabian Oryx based on data held in the International Studbook (Hatwood, 2015).

In conditions where breeding is controlled under a population or collection management plan, the male may need to be separated from the females during this period to limit the number of births. In this event, the ex-situ facility will need to have an adequate enclosure for the male during the period of separation from the females. Alternatively, if the collection or population management plan calls for the cycling of breeding males between a bachelor group and the breeding group, individual males can be introduced to the females for a period of time before being returned to the bachelor group. Under these circumstances, there may be a period where males reintroduced into the bachelor group will aggressively attempt to resolve their position within the group hierarchy.

Calves should be ear tagged and microchipped to enable individual identification within a few days of birth when they are relatively easy to catch and handle. Juveniles are weaned at 3.5 - 4.5 months (Castelló, 2016; Wilson & Mittermeier, 2011), and sexually mature at approximately 13 months (Castelló, 2016; Hatwood, 2015).

The mean age at first reproduction for females is approximately 3-years 2-months, and the median age at first reproduction is approximately 2-years 8-months (Hatwood, 2015). Males have a mean age at first reproduction of approximately 3-years 6-months, and a median age at first reproduction of around 3-years, although both males and females are capable of siring and producing offspring at a much younger age (Hatwood, 2015). Young males will therefore need to be removed from mixed-sex groups in their second year to prevent them from breeding with the females, especially if the dominant breeding male is not present. Males will spar when competing for females and these fights may end in injury or death (Castelló, 2016), so holding multiple-males in with females may be problematic both in terms of practical management and recording parentage of offspring.

In the wild, Arabian Oryx form herds typically of around 10 individuals, but herds as large as 100 have been observed. Groups usually contain one dominant adult male, several adult females, and their young with group size varying under different environmental conditions (Wilson & Mittermeier, 2011). Ex-situ group sizes vary between single animals and 20 individuals, with variable group compositions including harem groups, with one male held with a group of females and their offspring; single-sex groups, both male and female; bachelor groups of neutered males; solitary individuals, although this is not preferable for a group-living species; and pairs of Arabian Oryx, with their offspring (Hatwood, 2015; Species360, 2018b). Ideally, the ex-situ management of Arabian Oryx should replicate the group composition of wild populations as closely as possible to reduce risks associated with adaptation to captivity (Frankham, 2008).

As with other captive species, group management of Arabian Oryx should focus on producing calves from parents with the most appropriate genetic profiles, in order to meet the goals of the managed group or population. This may involve the temporary suspension of breeding, managed reproduction between specific individuals, and/or the translocation of individuals between groups, ideally coordinated by a breeding programme manager.

13. Disease management

Any population or collection management plan for Arabian Oryx will need to carefully consider, monitor and manage the health and welfare of the animals. Moving animals between enclosures, collections, countries or regions risks the spread of transmittable diseases that can severely impact population viability, and population managers will need to take this into account when developing management plans for the species.

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Appendix 1

Normal physiological reference values for the Arabian Oryx

Baseline values:

Arabian Oryx *(Oryx leucoryx)*

Samples contributed by 15 institutions.

Sample selection criteria:

- No selection by gender
- All ages combined
- Animal was classified as healthy at the time of sample collection
- Sample was not deteriorated.

Physiological Reference Intervals for *(Oryx leucoryx)*

Test	Units	Reference Interval	Mean	Median	Low Sample[a]	High Sample[b]	Sample Size[c]	Animals[d]
White Blood Cell Count	*10^9 cells/L	2.85 - 11.48	6.39	6.08	1.20	16.40	342	160
Red Blood Cell Count	*10^12 cells/L	5.04 - 13.91	9.67	9.99	3.50	14.80	235	123
Hemoglobin	g/L	79 - 201	147	150	54	214	220	114
Hematocrit	L/L	0.225 - 0.576	0.420	0.428	0.170	0.740	374	183
MCV	fL	34.7 - 62.3	45.4	44.2	29.1	73.5	219	114
MCH	pg	12.5 - 19.0	15.5	15.4	11.8	20.6	213	107
MCHC	g/L	279 - 396	343	345	220	443	203	105
Segmented Neutrophils	*10^9 cells/L	1.66 - 9.19	4.55	4.27	0.81	11.10	340	158
Neutrophilic Band Cells	*10^9 cells/L	0.01 - 0.07	0.03	0.03	0.00	0.10	326	156
Lymphocytes	*10^9 cells/L	0.36 - 3.41	1.50	1.38	0.01	4.52	341	159
Monocytes	*10^6 cells/L	34 - 465	170	141	17	650	273	146
Eosinophils	*10^6 cells/L	31 - 533	164	121	21	648	211	122
Basophils	*10^6 cells/L	0 - 193	85	62	11	270	52	46
Platelet Count	*10^12 cells/L	0.000 - 0.548	0.303	0.271	0.034	0.723	103	61
Glucose	mmol/L	3.33 - 15.08	7.72	7.22	0.66	18.32	286	144
Blood Urea Nitrogen	mmol/L	2.0 - 13.0	7.7	7.9	1.4	17.5	246	120
Creatinine	µmol/L	53 - 236	136	132	27	309	256	125
BUN/Cr ratio		6.0 - 25.8	14.5	13.7	3.8	35.0	237	113
Uric Acid	µmol/L	0 - 24	6	5	0	30	45	38
Calcium	mmol/L	1.73 - 2.95	2.27	2.23	1.55	3.38	253	124
Phosphorus	mmol/L	1.44 - 4.34	2.60	2.54	1.00	5.49	235	117
Ca/Phos ratio		0.6 - 2.1	1.2	1.2	0.4	2.9	231	116
Sodium	mmol/L	139 - 158	147	146	136	160	225	122

Physiological Reference Intervals for *(Oryx leucoryx)*								
Test	Units	Reference Interval	Mean	Median	Low Sample[a]	High Sample[b]	Sample Size[c]	Animals[d]
Potassium	mmol/L	3.3 - 8.0	4.9	4.5	3.1	10.7	227	123
Na/K ratio		18.8 - 44.3	32.1	32.5	16.5	46.3	227	123
Chloride	mmol/L	95 - 114	104	104	91	118	222	121
Total Protein	g/L	39 - 81	61	62	32	95	253	125
Albumin	g/L	20 - 59	37	37	13	62	226	113
Globulin	g/L	10 - 45	25	24	7	47	226	113
Fibrinogen	g/L	0.00 - 6.28	2.78	2.40	0.00	7.14	51	42
Alkaline Phosphatase	U/L	23 - 732	176	62	5	776	222	107
Lactate Dehydrogenase	U/L	0 - 2501	1129	640	351	3703	74	49
Aspartate Aminotransferase	U/L	33 - 115	61	56	8	137	231	121
Alanine Aminotransferase	U/L	4 - 55	23	22	3	67	176	96
Creatine Kinase	U/L	36 - 690	216	159	1	763	198	104
Gamma-glutamyltransferase	U/L	3 - 36	18	18	0	39	154	87
Amylase	U/L	1 - 44	22	23	6	58	42	33
Total Bilirubin	µmol/L	2.0 - 56.8	17.4	11.5	1.7	65.0	242	119
Direct Bilirubin	µmol/L	0.0 - 9.6	4.0	3.6	0.0	12.0	92	55
Indirect Bilirubin	µmol/L	0.0 - 34.3	12.0	7.1	0.0	51.3	91	53
Cholesterol	mmol/L	0.89 - 3.10	1.65	1.56	0.49	3.65	188	101
Triglyceride	mmol/L	0.00 - 0.62	0.30	0.26	0.09	0.86	94	56
Bicarbonate	mmol/L	*	23.9	26.0	11.0	33.0	32	21
Magnesium	mmol/L	0.478 - 1.153	0.835	0.816	0.411	1.356	62	34
Carbon Dioxide	mmol/L	8.9 - 41.0	25.5	24.9	10.0	52.5	59	39
Body Temperature	C	*	38.8	38.8	37.1	40.9	34	22

[a] Lowest sample value used to calculate the reference interval

[b] Highest sample value used to calculate the reference interval

[c] Number of samples used to calculate the reference interval

[d] Number of different individuals contributing to the reference interval

[*] Sample size is insufficient to produce a valid reference interval

Species360 (2013). "Arabian Oryx *(Oryx leucoryx)* Baseline values." ZIMS.

Appendix 2
Transportation guidelines

1. Pre-transportation guidelines

a. An inspection of the receiving institution facility should be carried out by the shipping institution to ensure that the quarantine and holding facilities are adequate for Arabian Oryx and that adequate resources are available to properly care for and manage the animals to be shipped. Take a facility inspection form with you to the inspection and fill it out (see Sample Site Evaluation Form for an example).

b. Select animals based on health, pregnancy status, genetic makeup and reproductive history. Healthy animals that have no injuries and are not close to parturition are selected.

c. Physical exam - each animal should be physically examined by a qualified veterinarian. A general body condition assessment, dental examination, treatment for ectoparasites, fecal samples, blood samples should be taken to assess the animals overall health. The two institutions should mutually agree upon the infectious diseases tests, parasite screening and vaccinations that should be considered. Hoses or pipes should be placed on horns for shipping duration.

d. Animals should enter into quarantine for at least 30 days to prevent the introduction of pathogens to the receiving institution (see the quarantine guidelines derived from conference). Males and females should be housed separately.

e. Obtain CITES permit for both export and import if an crossing an international border.

f. Ensure that all border crossing paperwork is in order if travelling by land.

g. Crates that are the proper size for the animals being shipped need to be constructed. Refer to the IATA guidelines for transporting animals by air. Animals should have enough room to lay down and get up but not enough room to turn around. All interior surfaces should be hazard free and adequate ventilation should be included.

2. Loading and transportation

a. Moving the animals into crates via proper animal loading facilities is of the utmost importance. This first step of loading the Oryx into their crates without stress, injury or overheating is a vital step in a successful translocation. Serious complications can arise (including capture myopathy) if animals are overheated and stressed as they are loaded.

b. Animals should be accompanied by qualified animal care management personnel and veterinarian during transportation.

c. It is generally not recommended to transport animals from April through September in the Gulf region due to the problems associated with transporting in extreme temperatures. If it is necessary to transport animals when the weather is hot it is recommended to do all travelling that is not air conditioned at night and keep air flowing through the crates. Transporting by air conditioned truck is recommended during the summer months.

d. Arabian Oryx should be shipped in individual crates to avoid injuries and hoses or pipes are recommended on the horns to prevent injury.

e. Arabian Oryx are prone to renarcotization therefore they should not be shipped or put into a crate less than 36 hours after anesthesia.

f. Animals should not be fed concentrated pellets 24 hours prior to shipment.

g. Crates should be lined with hay for forage and bedding.

h. Water should be provided for animals as duration and weather dictate. A remote system for watering the animal needs to be incorporated into crate design in case of unforeseen delay.

i. It is not recommended that Arabian Oryx be sedated during transport as the risk to benefit ratio does not justify it.

j. Animals should be loaded into the crates for shipment using a boma and a chute system, utilizing a pushboard, which will be much safer for the animals than anesthesia prior to shipment.

k. Proper planning should be considered so that animals are in the crates for the shortest duration possible. Refer to IATA guidelines for acceptable durations based on conditions.

l. Animals should be regularly checked and monitored for the duration of the transportation.

3. Arrival at receiving institution

a. Animals should be unloaded as quickly as possible in a quiet environment without disturbance for a recovery period.

b. Incoming animals should enter a quarantine where they have no contact with any other animals for at least 30 days.

c. Males and females should be housed separately when in locations with limited space.

d. A veterinary examination should be undergone only after the animals are recovered from the shipping procedure

Sample Site Evaluation Form:

Name of person/s evaluating: ....Date: ....

Name of Site being evaluated: ....

Location and description of site: ....

....

SPECIES: ....

Approximate number of animals: ....

SPECIES: ....

Approximate number of animals: ....

SPECIES: ....

Approximate number of animals: ....

EVALUATION:

Husbandry standards (food,water, shade) ....

Condition of site: ....

....

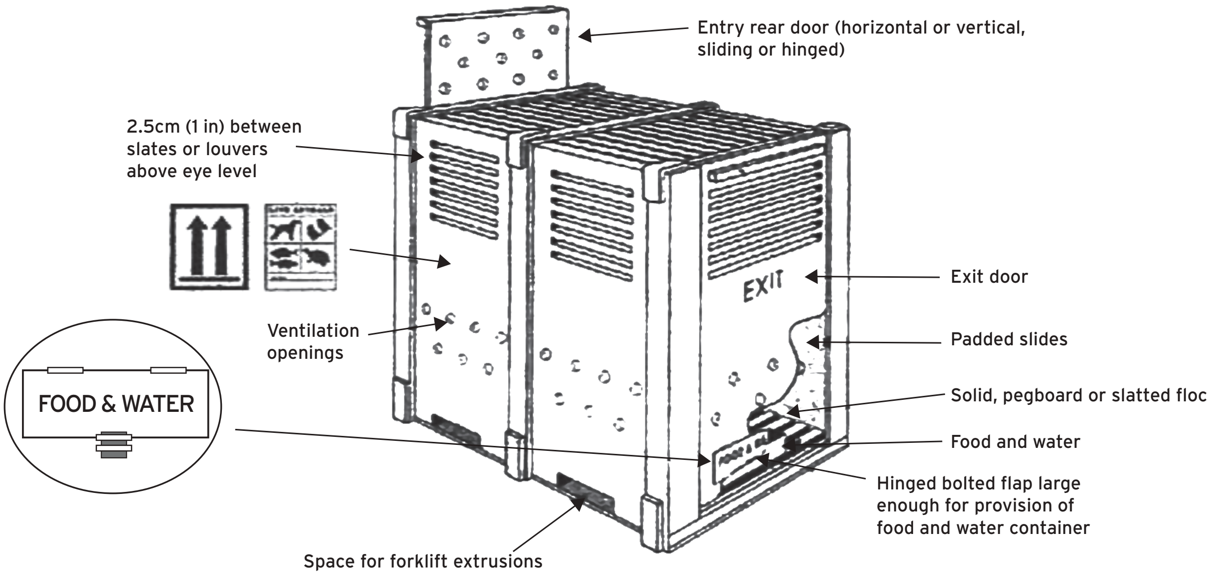
....

Condition of holding pens if applicable: ....

....

Name of contact person: ....

Appendix 3
Crate design recommendations for animal transport



Frame

- Additional strengthening braces must be present on the sides of the crate.

Sides

- Ventilation openings, 1" (2.5cm) in diameter, must be provided at the top and bottom half to provide adequate ventilation. Must be covered with shade cloth or burlap from the outside.

Front and back doors

- Doors must slide from the top and be within the frame of the crate providing adequate strength. Both doors must have a locking mechanism. A feed and water door consisting of a hinged door with a locking mechanism must be at the included in the front door.

Roof

- Solid plywood with a minimum thickness of 3/4 ". Meshed ventilation openings, 1" (2.5cm) in diameter, must be provided.

Floor

- The base of the container must consist of a narrow slatted floor allowing waste to end up in a leak-proof droppings tray.

Ventilation

- All the ventilation openings must be 1" (2.5cm) in diameter and must have exterior mesh screening.

Handling spacer bars/handles

- Must be provided along the length of container, not as shown in the diagram.

Space for forklift extrusions must be provided

FSC

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