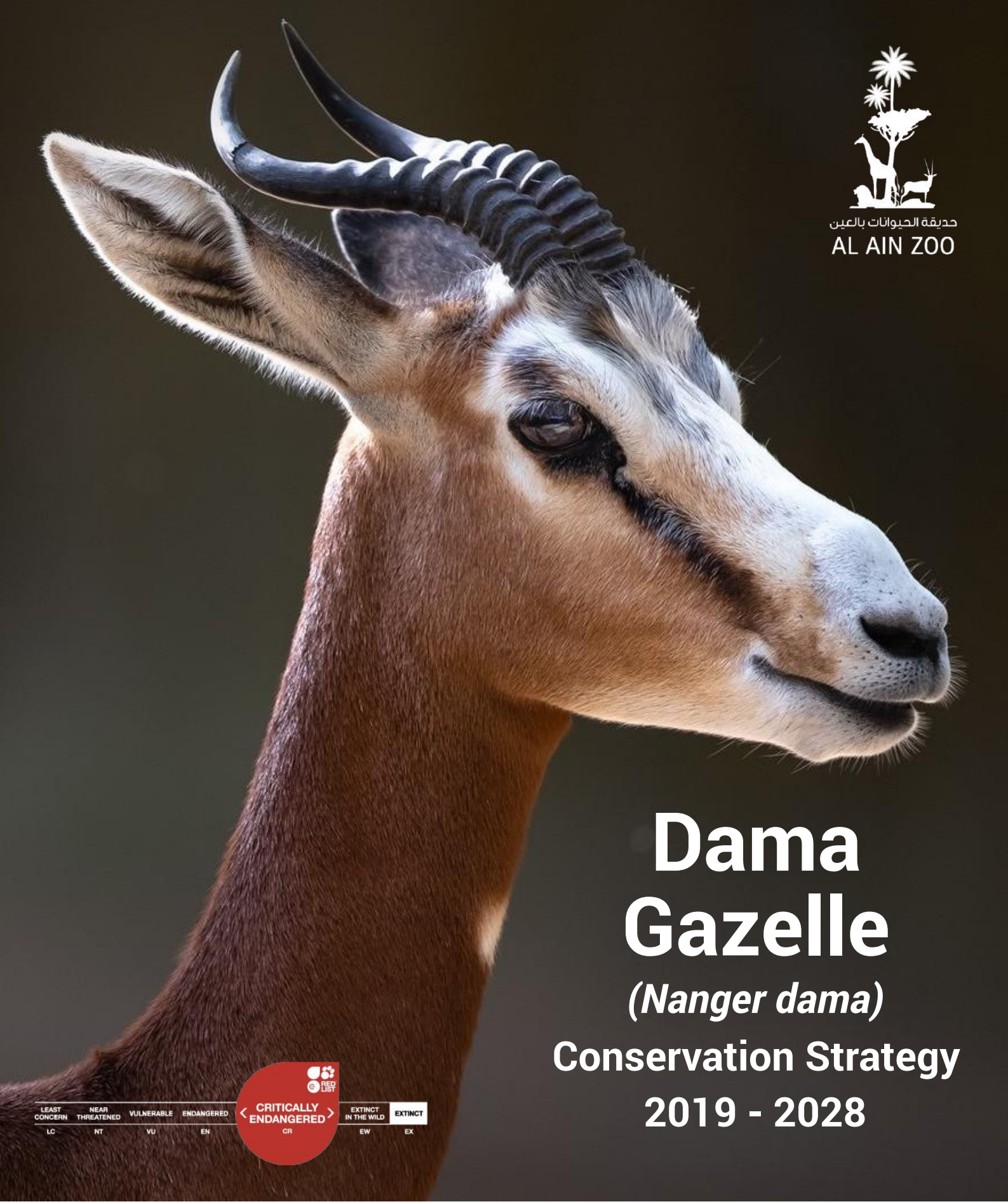

حديقة الحيوانات بالعين
AL AIN ZOO

Dama Gazelle

(Nanger dama)

Conservation Strategy 2019 - 2028

IUCN SSC Species Survival Commission

RZSS THE WILDLIFE CONSERVATION CHARITY

Dama Gazelle (*Nanger dama*) Conservation Strategy 2019-2028

Produced following the workshop hosted by Al Ain Zoo in Al Ain, United Arab Emirates, 11-13 December 2018.

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Foreword

As part of its commitment to the conservation of arid land biodiversity, Al Ain Zoo is proud to present this Dama Gazelle (*Nanger dama*) Conservation Strategy 2019-2028.

The dama gazelle remains one of the three most threatened antelope species in the world and, despite extensive work by dedicated conservationists, it remains on the edge of extinction in the wild. It is, however, through the efforts of these few that the Dama Gazelle has not yet fallen over that edge and continues to survive.

In 2013, following a workshop hosted by the Royal Zoological Society of Scotland, the *Conservation Review of the Dama Gazelle* was published outlining the basis for a dama gazelle conservation strategy, a series of conservation actions that could be conducted in support of dama gazelles and a road map for moving these actions forward.

In 2018, Al Ain Zoo proudly hosted a second workshop leading to this Conservation Strategy for the Dama Gazelle 2019-2028. This document outlines the progress made towards completing conservation and research actions, provides an updated strategy and develops further updates on the conservation planning process.

Al Ain Zoo has one of the largest dama gazelle populations of any zoo in the world and views this as a great responsibility to maintain genetic diversity, undertake genetic and reproductive research and provide educational information to our visitors.

The dama gazelle is the first animal visitors see on entering the zoo and is an ambassador for our leadership in the conservation of arid land species. We have committed to a long-term One Plan approach for our conservation planning which links both in-situ and ex-situ conservation actions, required for the long-term survival of this most elegant antelope. Since 2013, we have therefore been supporting the in-situ conservation of the largest remaining wild dama gazelle population.

Our goal of conserving this species depends on the partnerships and collaboration of our regional and international colleagues. The combined input of these colleagues from 12 countries representing 21 different institutions during the Al Ain workshop provided the knowledge and expertise, commitment and resources to secure our strongest chance of saving the dama gazelle.

I sincerely thank all the workshop delegates for this great body of conservation work and look forward to working with you all and others in the future to meet our vision of saving the Dama Gazelle.

Thank you

H.E. Ghanim Mubarak Al Hajeri
Director General
Al Ain Zoo

Executive Summary

The dama gazelle (*Nanger dama*) is one of the most threatened antelopes in the world and perhaps fewer than 100 remain in the wild.

A conservation planning workshop took place on 11-13 December 2018 in Al Ain, United Arab Emirates, with the theme of "*Increasing the resilience of the dama gazelle*". The workshop brought together for the first time all key stakeholders, including government agencies, NGOs, research institutes and representatives of the ex-situ community. The aims of the workshop were:

1) to review and update the objectives and actions published in the *Conservation Review of the Dama Gazelle (Nanger dama)* 2014 and the *Regional Action Plan* of 2017, and

2) to identify and agree concrete actions to reduce the extinction risk of the dama gazelle both in-situ and ex-situ.

Key outcomes of the workshop were:

- An updated current status of the species, in-situ and ex-situ, with all recent information.
- The global population of dama gazelle (wild, semi-captive and captive) is estimated at 2865-2915.
- A review of progress 2014-2018 concluded that many actions have been achieved but that the programme was overambitious given the resources available.
- Critical research requirements were documented.
- Training and capacity needs in range states were identified.
- Demographic and genetic issues in the captive population were addressed.
- Agreement was reached that in the absence of captive *Nanger dama dama,* that *N. d. ruficollis* is the most appropriate substitute.
- All possible conservation options were discussed including capturing wild individuals to conserve their genetic diversity, the reinforcement of wild and semi-captive populations with captive-bred animals, translocation of animals and the management of the three proposed subspecies.
- The risks and opportunities associated with each option were identified and discussed.
- Potential reintroduction and reinforcement sites were reviewed, highlighting the limited number of possibilities.
- It was recommended that attempts should be made to capture any animals remaining in Manga to conserve their genetic diversity before the population most likely becomes extinct.
- A framework of objectives and actions for 2019-2028 was developed.

Wild dama gazelles, Ouadi Rimé-Ouadi Achim Faunal Reserve in Chad © T. Wacher

List of Abbreviations

AAZ	Al Ain Zoo (UAE)
ABZC	Al Bustan Zoological Center (UAE)
ANN	National Agency for the Conservation of Nature (Algeria)
APN	African Parks Network
ASG	Antelope Specialist Group
ATNNN	Aïr and Ténéré National Nature Reserve (Niger)
AZA	Association of Zoos and Aquariums (US)
AZAA	Arabian Zoo and Aquarium Association
C2S2	Conservation Centers for Species Survival (US)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CSIC	Spanish National Research Council
DCFAP	Directorate for Wildlife Conservation and Protected Areas (Chad)
DFCPR	Directorate of Wildlife Hunting and Parks and Reserves (Niger)
DGF	General Directorate of Forests (Algeria)
DPN	Directorate of National Parks (Senegal)
EAD	Environment Agency-Abu Dhabi
EAZA	European Association of Zoos and Aquaria
EEZA	Experimental Station of Arid Zones (Spain)
EWA	Exotic Wildlife Association (US)
HCEFLCD	High Commission for Water and Forests and the Fight against Desertification (Morocco)
IUCN	International Union for the Conservation of Nature
NMS	National Museum of Scotland
OROA	Ouadi Rimé-Ouadi Achim Faunal Reserve (Chad)
PCBR	Partnership for the Conservation of Sahelo-Saharan Biodiversity of the Nature Nature Reserve of Termit and Tin-Toumma (Niger)
POROA	Project Ouadi Rimé-Ouadi Achim
RZSS	Royal Zoological Society of Scotland
SAF	Second Ark Foundation (US)
SCF	Sahara Conservation Fund
SSC	Species Survival Commission
SBCI	Smithsonian Conservation Biology institute (US)
SPA	Source Population Alliance (US)
SPSC	Standards and Petitions Sub-Committee
SWS	Sudanese Wildlife Society
TAG	Taxon Advisory Group
TTNNR	Termit and Tin-Toumma National Nature Reserve (Niger)
TWCS	Tunisian Wildlife Conservation Society
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WHC	World Heritage Centre
ZAA	Zoological Association of America
ZSL	Zoological Society of London

Countries: ALG - Algeria; MLI - Mali; NGR - Niger; SEN - Senegal; TCH - Chad; TUN - Tunisia.

Site Designations: ABC - Acclimatization and Breeding Centre; BR - Biosphere Reserve; CP - Cultural Park; FR - Faunal Reserve; NCR - Natural and Cultural Reserve; NNR - National Nature Reserve; NP - National Park; PA - Protected Area; RR - Royal Reserve; SWR - Special Wildlife Reserve; WR - Wildlife Reserve.

Acknowledgements

We are grateful to H.E. Mr Ghanim Mubarak Al Hajeri, Director General of Al Ain Zoo, for hosting the workshop and to the Royal Zoological Society of Scotland, Sahara Conservation Fund and Al Bustan Zoological Center for sponsorship. We also appreciate the time and commitment of all workshop participants and those who have provided data, information and images and whom commented on the strategy.

Figure 1. Above: Dama gazelle workshop participants © Al Ain Zoo. Below: Dama gazelle workshop participants at Al Ain Zoo's mhorr gazelle exhibit © E.C. Mungall

1. Introduction

1.1. The dama gazelle

The dama gazelle (*Nanger dama*) is one of three species in the genus *Nanger*. It is the largest of all the gazelles with a striking appearance due its chestnut-brown and white coloration. Variations in coat pattern have been used to identify three subspecies, corresponding approximately to the west, centre and east of the distribution (Cano 1984; see revision by Kitchener 2018). Recent genetic analyses based on mitochondrial DNA sequences, however, do not support the traditional subspecies arrangement (Senn et al. 2014, 2016).

The dama gazelle was originally distributed across the Sahelian steppe zone from the Atlantic to the Nile (Figure 2). Its occurrence in subdesert steppes north of the Sahara is less well established. This historic range has been greatly reduced (Jebali 2008, 2009, Durant et al. 2014) and only six small fragmented populations, at most, remain. The wild population is estimated at <250 adults but may be as low as 85-120 (RZSS and IUCN SSC Antelope Specialist Group 2014; IUCN SSC Antelope Specialist Group 2016). There is also one released population (c.15) in a fenced reserve within range and several captive and semi-captive populations in government, public and private collections in North Africa, North America, Europe and the Arabian Peninsula, totalling about 2,500. Updated information on the status of all populations is provided in section 2 of this report. Summaries of the biology, taxonomy and ecology of the species are available in Scholte (2013) and RZSS and ASG (2014) and more detailed accounts of the biology, management and history in Mungall (2018a).

Dama gazelle appears to be shyer and more fragile than other species of gazelle. It has proved more difficult to establish new populations of dama gazelle than other Sahelo-Saharan species. The species is close to extinction in the wild and without full consideration of all the available conservation options there is little hope of improving the current situation.

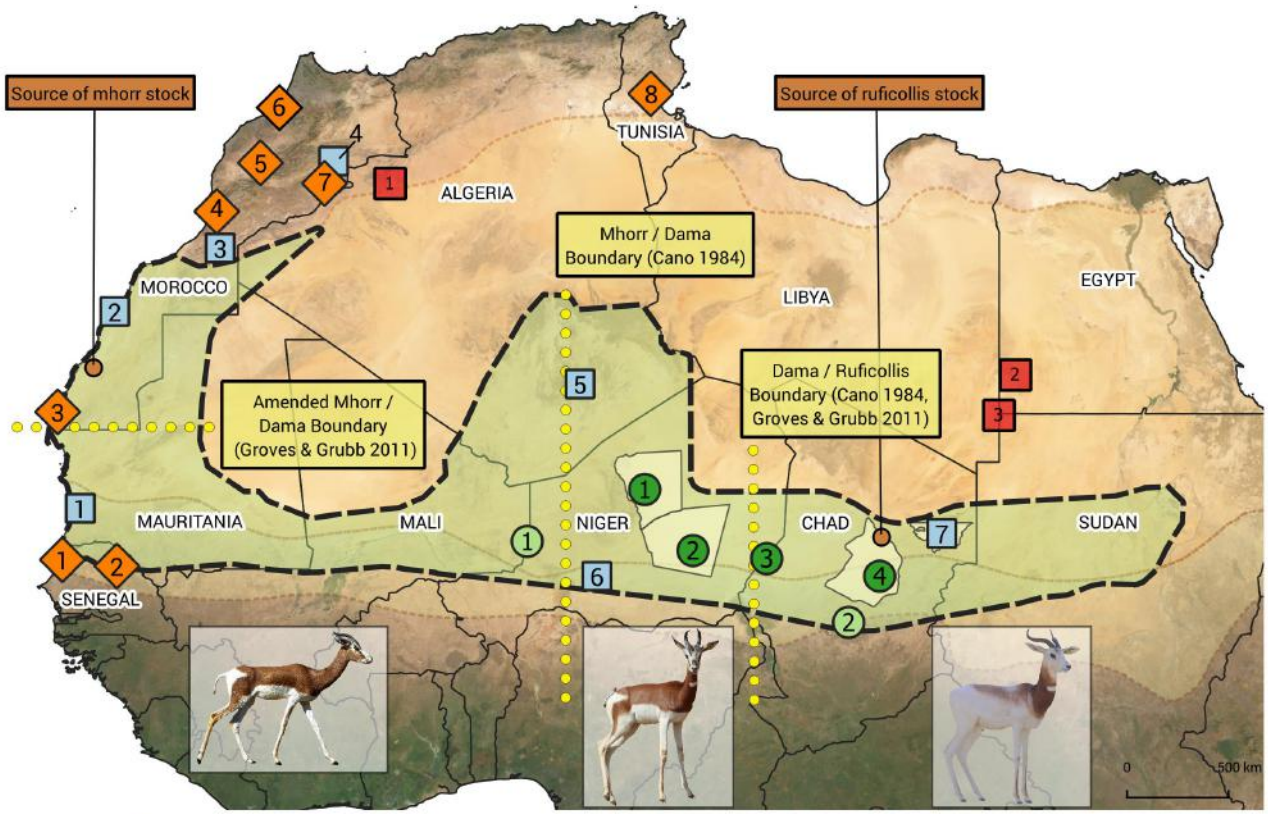
Dama gazelle is listed on Appendix I of CITES and Appendix I of CMS and is included in the CMS Concerted Action for Sahelo-Saharan Antelopes (Beudels-Jamar et al. 2005). A workshop was held in Edinburgh December 2013 to develop a conservation review, including a long-term vision and a set of objectives and actions, published in English and French versions (RZSS and ASG 2014). In March 2017 a workshop took place in N'Djamena, Chad to recommend conservation measures for the remaining wild populations of addax and dama gazelle in Niger and Chad (DCFAP et DFCPR 2017). A global planning workshop was convened in December 2018 by Al Ain Zoo in Abu Dhabi, UAE.

1.2. The 2018 workshop

The workshop took place on 11-13 December 2018. It was hosted by His Excellency Mr Ghanim Mubarak Al Hajeri, Director General of Al Ain Zoo, and organized by Al Ain Zoo, the Royal Zoological Society of Scotland and IUCN SSC Antelope Specialist Group. It was supported by the Sahara Conservation Fund and Al Bustan Zoological Centre. The workshop brought together for the first time all major dama gazelle stakeholders – representatives of current and former range states, NGOs, international experts, veterinarians and ex-situ population managers (a list of participants is in Appendix 1).

With the overall theme of "*Increasing the resilience of the dama gazelle*", the main aims of the workshop were to review and update the objectives and actions from the first workshop (RZSS and ASG 2014) and agree to concrete actions to reduce the extinction risk of the dama gazelle both in-situ and ex-situ. The principal elements of the workshop consisted of:

1) updating the current status;
2) review of progress since 2014;
3) opportunities and risks of each course of action;
4) application of this framework to individual sites and practical situations, and
5) recommended objectives and actions.



Confirmed extant populations

1. Aïr and Ténéré National Nature Reserve
2. Termit and Tin-Toumma National Nature Reserve
3. Manga
4. Ouadi Rimé-Ouadi Achim Faunal Reserve (including Wadi Hawach)

Unconfirmed extant populations

1. Tamesna
2. Alifa (Ati)

Captive and semi-captive populations

1. Guembeul Special Faunal Reserve
2. Ferlo Nord Faunal Reserve
3. Safia Acclimitization and Breeding Centre
4. Souss-Massa National Park
5. R'Mila Royal Reserve
6. Rabat Zoo
7. M'Cissi Acclimitization and Breeding Centre
8. Bou Hedma National Park

Potential reintroduction sites

1. Awleigatt National Park
2. Boujdour National Park
3. Assa Biosphere Reserve
4. Errachidia
5. Ahaggar Cultural Park
6. Gadabedji Biosphere Reserve
7. Ennedi Natural and Cultural Reserve

Rock art outwith Durant et al (2014)

1. Taghit
2. Wadi Sora ('Cave of Beasts')
3. Jebel Uweinat

Former range

Protected areas within former range

Subspecies boundaries

Sahara

Sahel

Figure 2. Key sites for dama gazelle (after Durant et al 2014). Source of mhorr stock covers two sites, El Hagounia and Tichla-Bir Ganduz (Abáigar 2018).

2. Current Status

2.1. Summary

As in 2014 there are, at most, six fragmented wild populations of dama gazelle: three in Chad, two in Niger, and one in Mali (which was last observed in November 2005). In addition, there is a small population released into an enclosure within the distribution range in Senegal (Figure 2). The former range of the species extended across the Sahel from the Atlantic to the Nile and was estimated to cover 3,616,260 km^2 (Durant et al. 2014). The remaining fragments represent about 0.65% of this area (Figure 2).

Captive and semi-captive groups are maintained in the region, the Arabian Peninsula, Europe and North America, numbering about 2500 in total, managed broadly as two separate populations, 'mhorr' *(N. d. mhorr)* and 'addra' (*N. d. ruficollis*).

Dama gazelles occur across the full spectrum of conditions from free-living to fully captive. Redford et al. (2011) proposed a 5-point scale to characterize populations (Table 1). This scale is utilized by the IUCN Red List of Threatened Species to define whether a population is 'wild' and thus eligible for assessment (IUCN Standards and Petitions Subcommittee 2017).

Table 2 lists the wild sites and the estimated population size where available. Table 3 lists captive and semi-captive populations in North Africa, their numbers and status. Table 4 summarises the number of dama gazelles in all situations.

2.2. Populations in Africa

2.2.1. Morocco

There are 43 georeferenced records of dama gazelle in the Saharan region, south of a line from Foum Zguid–Tata–Guelmim (approximately latitude 30^{o}N). The latest data were collected between 1950 and 1980 and the last observation was in the Drâa valley in 1993 (Morales Agacino 1950; Valverde 1957; Cano 1984, Cuzin 2003, and references therein).

A captive breeding group is maintained at R'Mila Royal Reserve (RR). Dama gazelles have been transferred from there by the Haut Commissariat des Eaux et Forêts et la Lutte Contre la Desertification (HCEFLCD) to Acclimatization and Breeding Centres (ABC) at M'Cissi and Safia in the east and south of the country, respectively. In December 2018, there were 64 dama gazelles at R'Mila, 22 at M'Cissi, and 15 at Safia. In addition, there are breeding groups at Rabat Zoo (7) and the privately-owned Al Maha Farm near Rabat (c.40).

Table 1. States of conservation as defined by Redford et al. (2011). Note: The first three states (shaded orange) are considered 'wild' by the IUCN Red List.

State	Characteristics of the population
Self-sustaining	Survive with little or no human help.
Conservation dependent	Need for significant conservation action directed at extrinsic factors, necessitating changes in human behaviour, e.g. anti-poaching, protected areas.
Lightly managed	Rely on limited human intervention and unable to maintain self-sustaining populations without long-term management to sustain the habitat or resources on which they depend.
Intensively managed	Reliant on direct human intervention at individual and population levels through extensive, directed habitat manipulation, provision of supplementary resources or augmentation from captive populations, reintroduction of captive-reared individuals.
Captive bred	Maintained in captivity, with management that provides food, care, and breeding for individual animals. Completely dependent on humans.

Twenty-one dama gazelles from three German zoos were introduced to the Rokkein enclosure (2,000 ha) in Souss-Massa National Park (NP) in 1994 and 1998, but later died out, unlike addax *Addax nasomaculatus* and dorcas gazelles *Gazella dorcas* that were released in the same enclosure.

Morocco has a long-term vision for the conservation and restoration of seven species of wild ungulates (Cuzin et al. 2003). The original objectives for dama gazelle were to:

1) maintain the three breeding populations in R'Mila, Safia, and M'Cissi, and
2) establish wild populations in the east (around Errachidia) and the south (Essmara, Boujdour, Safia).

A group of 24 dama gazelles were released into the wild from the Safia centre on 22 May 2015. Seven were soon killed by feral dogs so 11 gazelles that could be recaptured were returned to the enclosure, while six dispersed. Meanwhile, 39 feral dogs were removed, and the recaptured gazelles were re-released on 27 July 2015, when they dispersed to the north and southeast (Abáigar et al. 2019). Some animals were possibly poached, and the last sighting was in October 2017 (L. Sikli, pers. comm). No further releases in this area are planned at present due to concerns over the persistence of poaching and stray dogs (Abáigar et al. 2019) as well as habitat quality and the presence of land mines which limits monitoring (HCEFLCD 2019). A new enclosure (400 ha) to house and breed dama gazelles for future release is planned at Labouirat in the Drâa Valley, inside the proposed Assa Biosphere Reserve (BR) (HCEFLCD 2019). Measures taken and planned in support of the programme include:

- increasing the size of semi-captive populations in acclimatization stations;
- improving knowledge of the genetics of the species to gain a clear long-term vision for its conservation;
- improving conservation programs with technical and financial partners;
- reinforcing surveillance and scientific monitoring;
- developing human, technical and financial resources for the conservation of dama gazelle in semi-captivity;
- eliminating the causes of disappearance, such as poaching and human disturbance, and
- setting up structured reintroduction programmes with local and international partners.

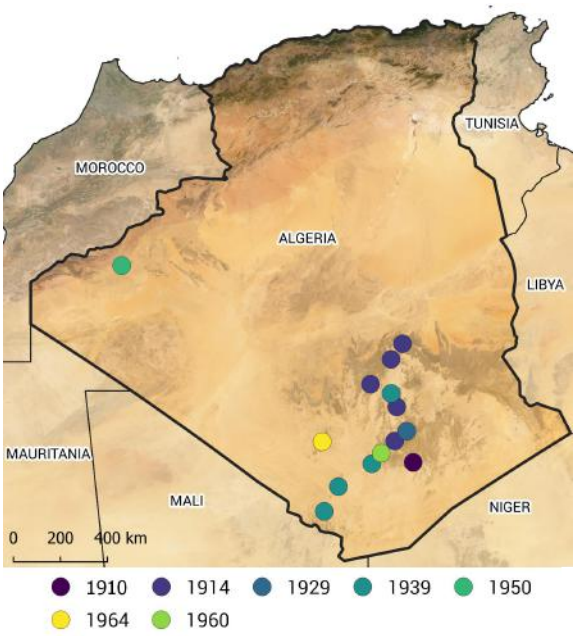


Figure 3. Former records of dama gazelle in Algeria and date of last occurrence (based on Rzebik-Kowalska 1991)

2.2.2. Algeria

Dama gazelles occurred on the Tindouf du Drâa in the southwest in the 1940s and 1950s and until the end of the 1970s-1980s in Ahaggar Cultural Park (CP) and Tassili N'Ajjer in the south (Kowalski and Rzebik-Kowalska 1991) (Figures 3-4). The species also features in many rock paintings in Ahaggar, Tassili N'Ajjer and sites such as Taghit in the Saharan Atlas (Figure 4) and was therefore evidently widely distributed at one time. There are some local reports from the south (including Tassili de Tin Gherghor) but no confirmed recent records. No dama gazelles are kept in captivity in the country. The dama gazelle is protected by law (Ordonnance 06-05 du 15 juillet 2006). A national report on Sahelo-Saharan antelopes was proposed in 2003 (Fellous and Maziz 2003) and development of a national strategy for antelopes is being planned.

Figure 4. Above: Dama gazelles shot in Algeria: (l) north of Tindouf (Monteil 1951), (r) Ahaggar in 1931 (Augerias 1931). Below: Dama gazelle rock art in Algeria (l) Tassili N'Ajjer (dama gazelle ahead of scimitar-horned oryx) © K. de Smet, (r) Taghit, western Algeria © A. Fellous-Djardini.

2.2.3. Tunisia

Five dama gazelles were transferred from zoos in Germany to the Bou Hedma NP (16,898 ha) followed later by three more, and 14 in 1994. The population failed to establish and only one male now remains. Poaching and predation by African wolves (*Canis lupaster*) are believed to have contributed to the decline (Jebali and Zahzah 2013). There are also three male dama gazelles in Haddej NP. Establishment of a breeding group at this site is being considered.

2.2.4. Libya

The former status of dama gazelle in the country is unclear. There are a few reports from the far south, but no specimens. In 2014 captive dama gazelles were photographed in Libya (RZSS and ASG 2014), perhaps brought from Niger or Chad. There has been no subsequent news since then, despite attempts to follow this up.

2.2.5. Senegal

Described by Sournia and Dupuy (1990) as 'observed occasionally in the northern Sahel zone where it was probably a seasonal visitor, but now extinct in the wild'. The Guembeul Special Wildlife Reserve (SWR) (Reserve Spécial de Faune de Guembeul; RSFG) was established in 1983 for captive breeding and acclimatization of Sahelo-Saharan antelopes. It covers 720 ha, about half of which is occupied by a lake. In 1984 seven dama gazelles (2.5) from the Estación Experimental de Zonas Áridas (EEZA) at Almeria in Spain were released. Numbers reached a maximum of 32 in 2002 but then decreased. The main causes of the reduction in numbers are:

- transfer of individuals to the Katane enclosure and the Bandia and Fathala Wildlife Reserves (Senegal) and a private centre in Mauritania;
- mortality during these capture operations, and attacks by dogs which killed five gazelles in 2008 (Abáigar et al. 2019), and
- Moreno et al. (2012) cited changes in vegetation structure as a likely cause of the decline.

In 2016 only seven dama gazelles remained.

In 2003 five (2.3) dama gazelles were

Figure 5. Dama gazelle in Ferlo Nord Wildlife Reserve, Senegal © S. Fall.

transferred from Guembeul to the Katane enclosure (1200 ha) in Ferlo Nord WR (Réserve de Faune de Ferlo Nord) (Figure 5) in the Sahelo-Sudanian zone of northern Senegal. The reserve has an area of 487,000 ha, with a core area of 84,734 ha. Population growth was slow at first, reaching 20 in 2012 and then declining. In 2018 a population of 15 was estimated but the size and vegetation cover in Katane make a precise estimate difficult. The animals exist on natural vegetation, and a certain amount of water is provided, especially during the dry season. Measures needed to increase the population size in Katane include:

- rigorous monitoring to understand population growth in relation to reproduction, mortality, health status and numbers;
- increased genetic variability through new founders, and
- determine the impact of predation by African wolf (*Canis lupaster*) [formerly golden jackal Canis aureus] and possibly spotted hyena (*Crocuta crocuta*) and of interspecific competition (exponential growth of the released population of scimitar-horned oryx *Oryx dammah*).

Future plans are to expand the enclosure to 5000 ha, evaluate carrying capacity, install watch towers, organise a gazelle day and awareness for local communities and develop a research programme including disease monitoring in the reserve and surrounding villages. The dama gazelles (number unknown) that were transferred to Bandia and Fathala Wildlife Reserves have not survived.

2.2.6. Mauritania

Dama gazelles formerly occurred across the Sahel zone but were reported to be extinct by Sournia and Verschuren (1990) and there have been no reports since then. There is a plan to reintroduce dama gazelles and other Sahelo-Saharan species into Awleigatt NP (16 km^2), situated about 60 km south-east of the capital, Nouakchott (T. Abáigar, pers. comm.). A small number were sent to a private centre from Senegal.

2.2.7 Mali

Dama gazelle formerly occurred across the Sahel zone and southern fringe of the Sahara in Mali but was already reduced to small scattered populations by the end of the 1980s (Heringa 1990). It occurred in the Gourma area

and around Menaka in the early 1970s, the Gourma and Ansongo areas in 1979, and south-east of Arouane and on the Mauritania border in 1980 (Heringa 1990 and references therein). Since that time, the only reports are from the Tamesna plains in eastern Mali which lie south-east of the Adrar des Ifoghas massif and extend south to Ansongo and Menaka and eastwards to the border and into the west of Niger.

Three surveys of Tamesna were conducted in 2002-2005 to establish the status of dama gazelle. A ground survey was conducted in February 2002. No dama gazelles were seen but local reports indicated their presence in three areas (Lamarque and Stahl 2002). A second ground mission was carried out in February 2005. Two blocks identified on the basis of the local reports and covering 1775 km^2 were surveyed systematically. Seven dama gazelles were seen and field signs of 18 more found, in the western block, indicating a density of 0.047/km^2 (Lamarque et al. 2007a). An aerial survey in November 2005 surveyed the same two blocks as in February and a third block identified from local reports. Three gazelles were observed in the western block in the same place as a concentration of tracks in February, the Tassamaka dunes west of Amasaouas (Lamarque et al. 2007b). No dama gazelles were seen in the eastern zone on the border with Niger. In February, numbers were estimated at 170; 130 in the east and 38 in the western zone but too few were seen in November to make a population estimate (Lamarque et al. 2007a, 2007b). The last confirmed record of dama gazelle in Mali was therefore in November 2005, though some local reports from western Niger were received in 2010 and may have referred to animals from the Tamesna population. The security situation prevents field missions at the present time.

The habitat in Tamesna was described as uneven due to tussocks of grass and difficult to drive in, thus forming a speculative refuge from hunting from vehicles. Genetic analysis of droppings collected on the February mission confirmed their presence (Lamarque et al. 2007a). The gazelles observed resembled those from Termit and Tin-Toumma National Nature Reserve (TTNNR) in Niger, falling within the proposed range of *N. d. dama*, except for the first two animals seen in February 2005 which were pale-coloured like *N. d. ruficollis* (Lamarque and Stahl 2002).

2.2.8. Niger

Dama gazelles are currently present at two sites: Aïr and Ténéré National Nature Reserve (ATNNR) (77,360 km^2) and Termit and Tin-Toumma National Nature Reserve (TTNNR) (97,000 km^2). In both sites they are confined to rocky areas, Mont Takoulkouzatt in ATNNR and the Termit massif in TTNNR, which likely represent refuge habitat. So, although the two reserves are contiguous, the two dama gazelle populations are isolated from each other (Figure 6). There were unconfirmed reports of dama gazelles in 2010 in the west of Niger (T. Rabeil, pers. comm.), which may have been part of the population on the Tamesna plains. Gadabedji Biosphere Reserve (7500 km^2) which lies at the southern edge of the former range has been identified as a potential reintroduction site. The population in ATNNR may number c. 30 and in TTNNR, 50-70, based on observations and field signs since 2012, though 30-50 individuals may be more realistic. Both populations appear to be stable.

In ATNNR 13 camera traps have been deployed since January 2017 to monitor the dama gazelles and a guide employed to work with the reserve management team; the data are collected every 6 months. No cases of poaching have been reported in TTNNR in recent years. Regular monitoring has been undertaken by the government agency and other partners, including the Sahara Conservation Fund. Management of TTNNR was devolved to a French NGO, Noé Conservation, in 2018, funded by a grant from the EU.

In July 2019 the Government of Niger issued a decree declassifying large parts of Termit and Tin-Toumma NNR in order to allow oil exploration. Full details are not yet available, but it seems that the important zones for dama gazelle as well as addax have been declassified.

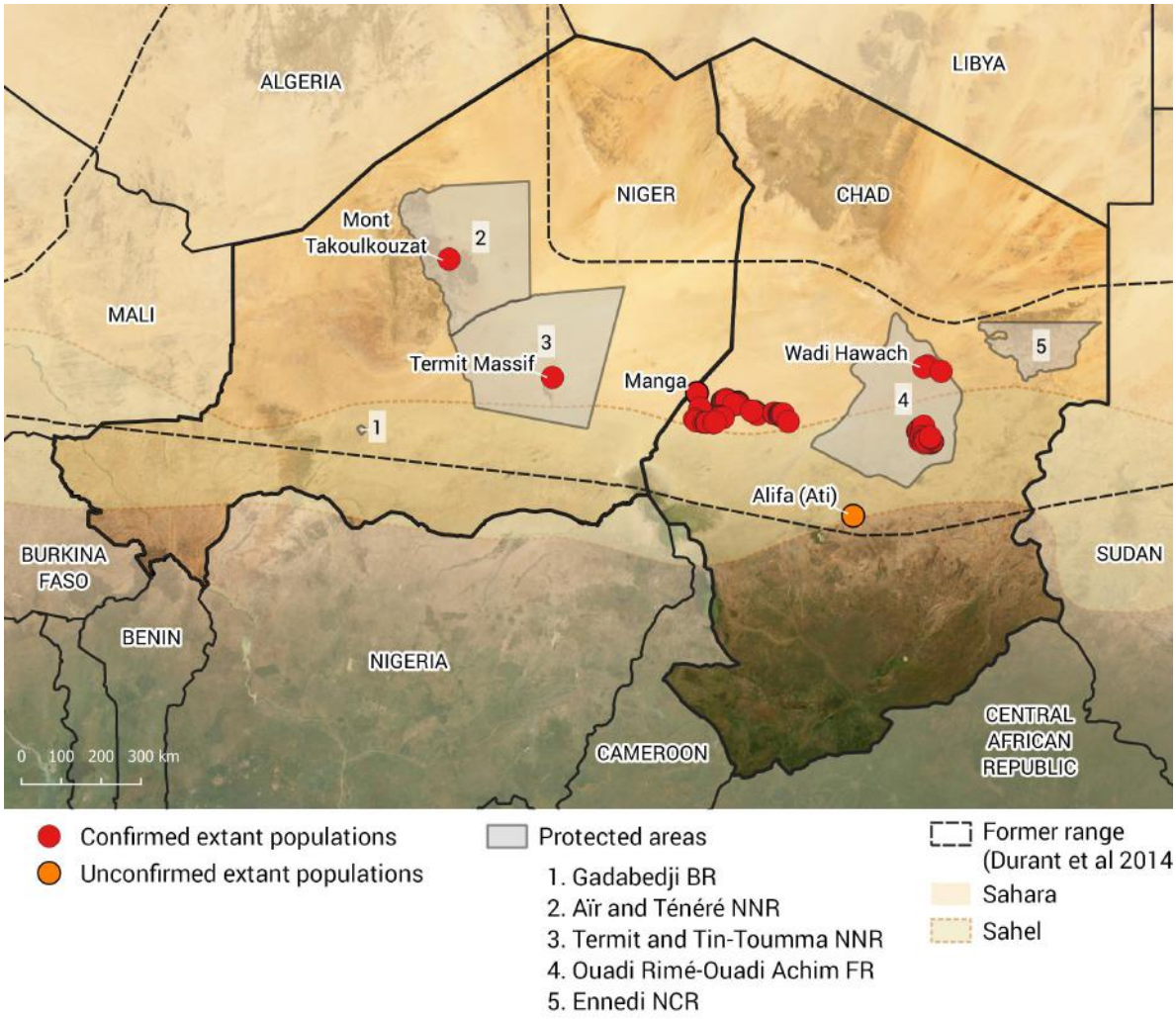


Figure 6. Dama gazelle areas of interest in Niger (after A.L. Abagana) and Chad (after A. Hatcha and T. Wacher). Points in Chad represent all dama gazelle sightings 2010 to 2017.

2.2.9. Chad

The main population of dama gazelles is in the Ouadi Rimé-Ouadi Achim Faunal Reserve (OROA; 77,950 km^2). The main group occupies an area in the south-east, with a smaller group in the north of the reserve near Ouadi Haouache (Wadi Hawach) (Figure 6) where tracks of four gazelles were seen in 2014 and one animal seen in September 2018. Dama gazelles also occur in the Manga region of western Chad. This is an area of vegetated dunes covering 6000-7000 km^2 situated north of Lake Chad (Wacher and Newby 2010). The most recent sightings were made during a ground and air survey in February 2015; there were too few sightings to allow a population estimate but dama gazelles are described as 'rare' (Wacher et al. 2015). The species was formerly reported at Alifa, south of Ati, where one poached animal was reported in 2014. This population has been genetically sampled, but its present status is unknown. Figure 6 shows the location of sightings 2001-2017.

In OROA, a 350 km line transect has been surveyed 8 times by vehicle (2800 km^2 in total). On the transects, 13 dama groups were seen, consisting of 25 gazelles in all (with groups numbering 0-9 individuals). The survey zone is estimated at 3500 km^2, resulting in an observed density of c0.011/km^2 and an implied population of 39 individuals. Outside the transects, 92 groups were observed in 2013–2018, 50% of which consisted of single individuals, and groups of 16–17 seen on only 2 occasions. The estimated population in the reserve is 30-50 individuals. Dama gazelles in OROA are variable in appearance and avoid

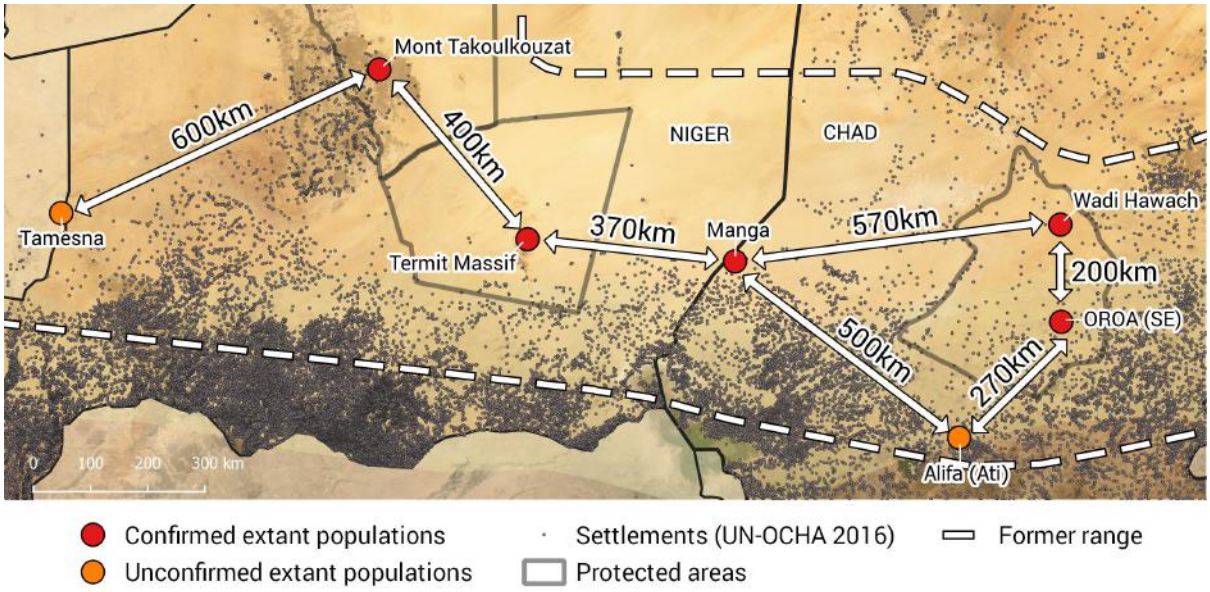


Figure 7. Distance between confirmed and unconfirmed extant dama gazelle populations and locations of human settlements in Niger and Chad. Settlement data after United Nations Office for the Coordination of Humanitarian Affairs (2016).

livestock. They show long flight distances compared to dorcas gazelles (T. Wacher, pers. comm.).

2.2.10. Sudan

Dama gazelles occurred across the Sahel zone of the country in Darfur and Kordofan provinces, east to the river Nile (Hillman and Fryxell 1988). Aerial surveys in 1975-1977 found that 'gazelles' were widely distributed across Northern and Southern Darfur and Northern and Southern Kordofan Provinces and estimated c.25,000 gazelles of all species (possibly including some dama gazelles) in arid areas west of the Nile (Hillman and Fryxell 1988). There were still a few dama gazelles in North Darfur according to Wilson (1980) and local reports from North Darfur and North Kordofan in the 1990s (East 1999) but there is no confirmed evidence of dama gazelle presence for about 30 years. A protected area was proposed around Wadi Howar in western Darfur within dama gazelle range, but it was never gazetted. No field research on the status of antelopes in Sudan has been carried out since the endangered species survey in 1990 (I.M. Hashim *in litt*. 2016).

2.2.11. Connectivity

The remaining wild populations of dama gazelle are situated a long way apart from one another. The distance between the Mali-Niger border and the edge of the Aïr massif is about 600 km; from the centre of Aïr to Termit massif is 400 km (c. 280 km from the edges); Termit to Manga is about 370 km and Manga to OROA 570 km (see Figure 7). More importantly, these zones are subject to varying levels of livestock grazing and development and they lack effective protection from disturbance or poaching. The possibility of regular movement of dama gazelles between them is considered to be extremely low or non-existent.

2.3. Populations outside Africa

2.3.1. Summary

Dama gazelles are maintained in captive and semi-captive conditions in public and private facilities in North America, Europe and the Arabian Peninsula. There are none in Australasia. Ex-situ dama gazelles are mainly managed as two populations: mhorr (*N. d. mhorr,* the western type) and addra (*N. d. ruficollis,* the eastern type). There are no *N. d. dama* in captivity. Europe has only mhorr, except for 11 addra in three zoos (Gilbert and Pajares 2018); North America has mainly addra. There are both mhorr and addra in the

Arabian Peninsula plus a few mixed animals in a breeding experiment at Al Ain Zoo in the UAE (see section 2.8). In total, the captive population consists of 2650 (addra, mhorr, and mixed).

Genetics/genomics and metapopulation management planning are needed to help with determining relatedness in the unmanaged captive populations. Research to support this is taking place led by both Royal Zoological Society Scotland (RZSS) (worldwide) and the Smithsonian Conservation Biology Institute (SCBI) (USA) via the Conservation Centers for Species Survival (C2S2) and Source Population Alliance (SPA) programmes.

2.3.2. Europe

The European Association of Zoos and Aquariums (EAZA) has 377 mhorr (148.229) in 19 EU and 7 non-EU facilities. The population trend is increasing. These are managed in a European Endangered Species Programme (EEP), currently coordinated by the Estación Experimental de Zonas Áridas (EEZA), Almeria, Spain. A studbook and husbandry guidelines are available at http://www.eeza.csic.es/documentos/STBDA_18.txt.

2.3.3. North America

The Association of Zoos and Aquariums (AZA) manages a population of addra gazelles through a Species Survival Plan (SSP) currently coordinated by San Diego Zoo Global Safari Park. There are 183 (83.100) animals in 21 institutions (18 AZA, 3 non-AZA). There were only 13 founders, but the gene diversity is 84.8%. Among the challenges that adversely affect the program are a lack of space, especially for males, a need to identify unrelated animals and encouraging institutions to work with this high priority species.

The Zoological Association of America (ZAA) also houses dama gazelle, but their Animal Management Plans (AMP, basically the equivalent of the SSP for AZA) are still in their formative stages. Three of the ZAA facilities' dama gazelles are included in the AZA SSP numbers. An additional five of these are included in the SPA numbers (see below). Three additional facilities contain 33 (11.22) dama gazelles. For a history of the species in North American zoos see Ayres (2018).

The Exotic Wildlife Association (EWA), based in Texas but also operating in other states, brings together private owners working mainly with ungulates and collaborates closely with the Second Ark Foundation (SAF). Their last survey (January 2015) showed 1,510 dama mainly on Texas ranches (Mungall 2018b).

The Source Population Alliance (SPA) was formed in 2014 to collaborate among the private and public sectors under the umbrella of the Conservation Centers for Species Survival (C2S2). There are 214 dama gazelles (60.124.30), in 14 facilities, including some overlap since five of those 14 facilities are also in AZA. Between 2014 and 2018 there has been an increase of 82% in participants (17 to 31) and 140% in animals (475 to 1196; all species).

2.3.4. Arabian Peninsula

There are about 285 dama gazelles in the Arabian Peninsula. There are 188 (60.106.22) registered in 10 facilities: 99 addra (28.56.15), 65 mhorr (24.41.0) and 24 mixed (8.9.7). Al Ain Zoo holds all of the mhorr as well as the mixed animals as part of the addra x mhorr breeding experiment (see section 2.8). In addition, there were 47 dama gazelles in Al Wabra Wildlife Preservation that are now believed to be in other private collections in Qatar, and about 50 in another private collection in the UAE.

2.4. Establishing new populations

Many observers have noted that dama gazelles, whether wild or semi-captive, are shyer and more prone to flee than other Sahelo-Saharan antelopes and that the species is also easily injured when handled and appears generally less resilient than other species. Although dama gazelles breed successfully in some collections, such as Al Ain Zoo, EEZA, and White Oak Conservation Center (USA), it has proved more difficult to establish new captive or semi-captive populations of dama gazelle than other

Table 2. Summary of wild dama gazelle populations.

Country	Site	Size (km²)	PA	Fence	No. 2018	Prote-ction	Security	Status[1]	Notes
MLI	Tamesna	3,000	X	X	?	X	Low	FL	Last seen November 2006 (reports from W Niger in 2010)
NGR	Aïr and Ténéré NNR	77,000 (600)[2]	✓	X	20-30	✓	Medium	CD	Management increasing
NGR	Termit and Tim-Toumma NNR[3]	98,000 (900)[2]	✓	X	30-50	✓	High	CD	Management devolved to Noé Conservation in 2018
TCD	OROA FR Central + Wadi Hawach	77,000 (1100+)[2]	✓	X	30-50	✓	High	CD	Source location for all the known captive addra gazelles
TCD	Manga	6,000-7,000	X	X	?	X	Medium	FL	
TCD	Alifa (Ati)	?	X	X	?	X	Low	FL	No recent information

[1]Management intensity (Redford et al. 2011): FL = free living; CD = conservation dependent; LM = lightly managed; IM = intensively managed; CB = captive breeding. [2]Area within PA mainly occupied by dama gazelles. [3]Information before the recent declassification.

Table 3. Summary of current captive and semi-captive sites in Africa.

Country	Site	Range	Area (km²)	PA	Fence	Founders	Date[1]	No 2018[2]	Status[3]
TUN	Bou Hedma NP	Out	24	✓	✓	18 (5.13)	1990-94	1 male	LM
MAR	Souss–Massa NP	Edge	10	✓	✓	21 (13.8)	1994-98	0	LM
MAR	Safia ABC	In	5.59	✓	✓	16 (7.9)	2008	15 (5.9.1)	IM
MAR	M'Cissi ABC	Edge	40	✓	✓	?	2015?	22	IM
MAR	R'Mila RR	Out	4.65	✓	✓	6 (3.3)	1992	64	CB
MAR	Assa BR	In	4	✓	✓	0	2019	0	CB
MAR	Al Maha	Out	?	-	✓	?	?	40	IM
MAR	Rabat Zoo	Out	?	-	✓	?	?	7	CB
SEN	Guembeul SWR	Out	7.24	✓	✓	7 (2.5)	1984	7 (D)	LM
SEN	Katane (Ferlo Nord WR)	In	12	✓	✓	5 (2.3)	2003	15 (D)	LM

[1]Date founders released. [2]D = declining, I = increasing. [3]Management intensity (Redford et al. 2011): FL= free living; CD = Conservation Dependent; LM = lightly managed, IM = intensively managed, CB = captive breeding.

Table 4. Dama gazelle numbers in all situations (data from the Al Ain workshop, December 2018).

State	Country	Site/Group	Number	Total
Wild	Mali	Tamesna plains	?	**90-140**
	Chad	Ouadi Rimé-Ouadi Achim Faunal Reserve	30-50	
		Manga	?	
		Alifa (Ati)	?	
	Niger	Aïr and Ténéré National Nature Reserve	30-50	
		Termit and Tin-Toumma National Nature Reserve	30-40	
Semi-captive and captive in Africa	Morocco	R'MIla Royal Reserve	60-70	**173**
		M'Cissi Acclimatization and Breeding Centre	22	
		Safia Acclimatization and Breeding Centre	15	
		Rabat Zoo	7	
		Al Maha Farm	c.40	
	Tunisia	Bou Hedma National Park / Haddej National Park	3	
	Senegal	Guembeul Special Wildlife Reserve	7	
		Ferlo Nord Wildlife Reserve (Katane)	15	
Outside Africa	US	American Zoo Association	183	**2602**
	US	Zoological Association of America	33	
	US	Source Population Alliance	214*	
	US	Exotic Wildlife Association	1510**	
	Europe	European Association of Zoos and Aquaria	377	
	Arabian Peninsula	Public and private institutions	285	
Total				**2865-2915**

*Some also included in AZA total; ** = 2015 figure.

Sahelo-Saharan antelopes, such as addax, scimitar-horned oryx and dorcas gazelle, whether in North Africa or on Texas ranches. There may also be different susceptibility to predation, e.g. in Texas, dama gazelles – especially when young – are prone to predation by coyotes *Canis latrans* whereas this is rare for the larger and more aggressive scimitar-horned oryx.

At three sites within the region, released dama gazelles (mhorr) have initially increased then declined. In the Rokkein enclosure (1500 ha) in Souss-Massa, none have survived, and in Bou Hedma only one male remains. In the Katane enclosure in Ferlo Nord, the released population also increased but is now slowly decreasing. The real causes of the declines and/or disappearance have not been clearly identified.

At the R'mila Royal Reserve in Morocco, the dama gazelle population was founded with six (3.3) individuals, it increased to 120, then declined. The current population is stable at 60-70 but only 3-4 births are now registered each year. At Safia, the 16 (7.9) founders increased to 41 by 2015 (in 5 years) but the

population is now stable. The reasons for this repeated pattern are unclear, although some mortality due to enterotoxaemia is known in R'Mila and predation elsewhere. Above all there is a lack of adequate information to establish the reasons and data on reproduction and fertility are needed to explain the low growth rate.

In Souss-Massa, Bou Hedma and Katane, released scimitar-horned oryx have thrived while the dama gazelle has stagnated or declined (RZSS and ASG 2014). Although these factors may be unrelated, the fact that this has occurred three times indicates that scimitar-horned oryx may outcompete dama gazelles in more confined areas or that certain habitat characteristics are suited to scimitar-horned oryx but not dama gazelle. Further research is required and other factors, for example predation, stress, or inbreeding depression (given the narrow founder base of mhorr), should also be considered. The release of dama gazelle and scimitar-horned oryx into the same site, especially enclosed captive or semi-captive sites, should therefore be considered extremely carefully. In addition to interspecific competition, lack of critical mass, inbreeding, predation, density dependence, unsuitable habitat and/or forage have been advanced as possible causative factors to explain the lack of population growth.

2.5. Population summary

Numbers in the three wild populations (Aïr and Ténéré, Termit and Tin-Toumma and Ouadi Rimé-Ouadi Achim total 90-140. This does not include Alifa, Manga or Tamesna for which no estimates are available, so the total in the wild may be a little higher. There are 164 in release enclosures and breeding centres in Africa and about 2602 in the USA, Europe and the Arabian Peninsula. This figure is approximate because there is some overlap between five facilities that are members of both AZA and SPA and because precise figures for two collections are unavailable. Thus, the global population of dama gazelles (in-situ and ex-situ) is around 2865-2915 (Table 4).

2.6. Genetics

Genetic analysis of dama gazelles has assessed the diversity and relatedness of populations both in the wild and in captivity. The first study by Senn et al. (2014) analysed 124 samples, including wild samples from Niger (Termit and Tin-Toumma) and Chad (Manga and OROA), and samples from captive populations (*N. d. mhorr* from Al Ain Zoo, the EEP, Senegal and Safia; *N. d. ruficollis* from Al Ain Zoo and Marwell Zoo – see Table 5 for details). A subsequent study by Senn et al. (2016) added an additional 103 samples, including additional populations from the Aïr Mountains of Niger and the US captive population. Finally, an additional 25 samples (Aïr – 3, USA – 22) have been analysed by RZSS subsequently and are included here for the first time.

To date, genetic analysis of the captive population has relied on mtDNA, as standard nuclear microsatellite panels have proven ineffective due to poor sample quality, and lack power to distinguish recent inbreeding from ancient substructure. Further investigation of genetic structure with nuclear markers would be useful to clarify the taxonomic status of mhorr. This work is currently underway (see section 2.6.1). The challenge with providing nuclear evidence is that:

1) many thousands of markers are required in order to escape the extreme bottleneck effect generated by captive history, and
2) the most informative samples, those from the wild, are also low quality.

Therefore, this necessitates a costly approach such as hybrid capture in order to generate data of sufficient resolution. This work is currently scheduled for 2020 following analysis of the whole genome/ddRAD results (see 2.6.1).

This combined dataset includes 252 dama gazelle samples genotyped at the mitochondrial control region (d-loop) and Cytochrome B gene (methods as described in Senn et al. 2014, 2016). In total, 37 control region haplotypes (538 bp) have been discovered, 29 in the wild population and eight in the global captive population (Figure 8). Thirteen cytochrome B haplotypes have been

Table 5. Dama gazelle sample sites for the 252 samples used here.

Population	Details	Putative sub-species	Total number of samples (number in Senn et al 2016)
WILD			
Chad (OROA)	Wild Population in Ouadi Rimé-Ouadi Achim Faunal Reserve in Central Chad (~N14.9027, E19.8318).	*N. d. ruficollis*	18 (18)
Chad (Ati)	Ati locality.	*N. d. ruficollis*	1 (1)
Chad (Manga)	Wild Population in Manga region of Western Chad (~N15.33087, E15.1277).	*N. d. ruficollis*	32 (32)
Niger (Termit and Tin-Toumma NNR)	Wild population(s) in the Central (~N16.1047, E11.4171) & Northern (~N16.3706, E11.4581) massif of the Termit mountains.	*N. d. dama*	22 (22)
Niger (Aïr and Ténéré NNR)	Wild population in Aïr mountains (~N 18.642, E 9.80924).	*N. d. dama*	11 (8)
ZOO/CAPTIVE			
Al Ain Zoo *N. d. mhorr*	Origin unrecorded, highly likely to be descended from animals in the EEP (originally from EEZA).	*N. d. mhorr*	42 (42)
Al Ain Zoo *N. d. ruficollis*	Origin unrecorded, likely to stem from the North American Regional Studbook for addra (*N. d. ruficollis*) gazelle as it records the transfer of two females and a male to Al Ain Zoo in 1982.	*N. d. ruficollis*	20 (20)
Dama gazelle European Endangered Species Programme (EEP)	Animals sampled from City of Belfast Zoo, EEZA and Montpellier all ultimately originating from EEZA.	*N. d. mhorr*	12 (12)
Marwell Zoo *N. d. ruficollis*	Origin is the North American Regional Studbook for addra (*N. d. ruficollis*) gazelle.	*N. d. ruficollis*	5 (5)
Katane, Ferlo North WR, Senegal	Ultimately originating from EEZA via Guembeul Special Wildlife Reserve.	*N. d. mhorr*	3 (3)
Safia ABC, Morocco	Ultimately originating from EEZA via R´Mila Royal Reserve, Morocco.	*N. d. mhorr*	6 (6)
USA captive	Samples from 10 US institutions and previously published data from San Diego Zoo (Hassanin et al. 2012), all reportedly descended from animals from OROA.	*N. d. ruficollis*	75 (53)

identified (note that the longer 896 bp fragment of Senn et al. 2016 supersedes the shorter 421 bp fragment of Senn et al. 2014). Each control region haplotype was found to be associated with a single haplotype of the more slowly evolving Cytochrome B gene, and the genes were concatenated into a single fragment during analysis.

The genetic structure present within the dataset does not match any underlying geographical pattern. That is, closely related haplotypes are distributed among geographically separated populations and do not cluster by locality (Figure 9). A particularly striking finding is that two haplotypes (lM and lF) found within captive mhorr (Al Ain Zoo, EEP, Senegal and Safia) each group with

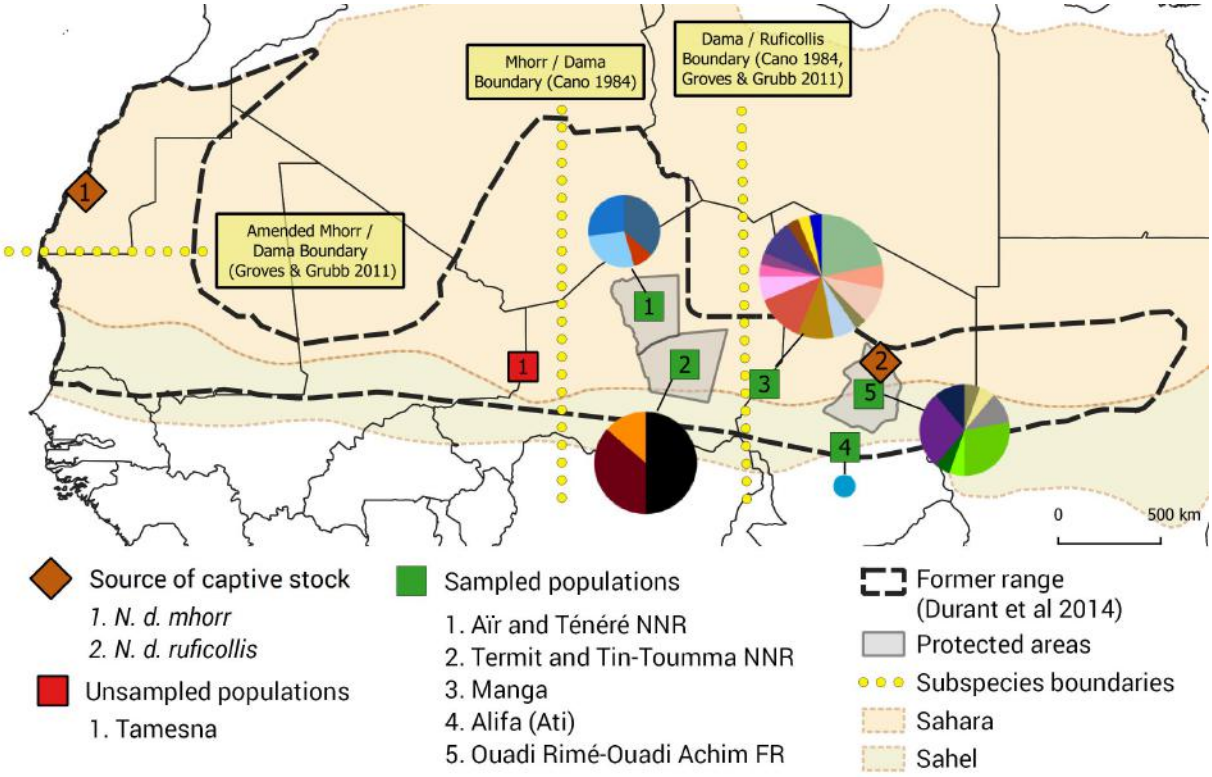


Figure 8. Genetic sampling locations of wild dama gazelle. Control region haplotypes are represented in circles, where the size of the circle represents the number of samples and the colour of each section represents the haplotypes identified.

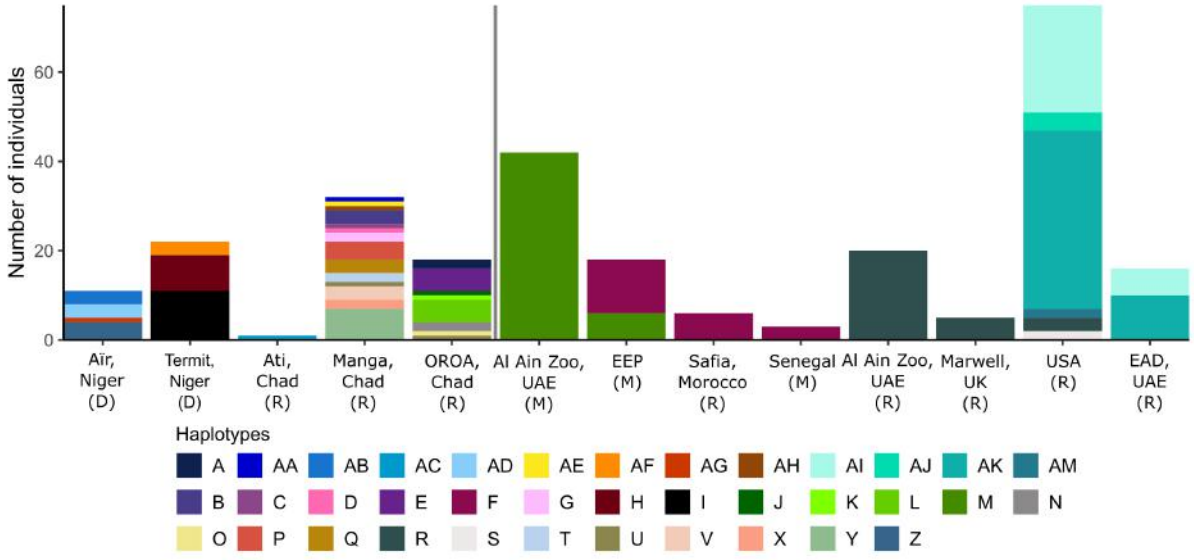


Figure 9. Control region haplotypes identified in wild (n=84) and captive (n=163) populations of dama gazelle (RZSS/ WildGenes).

haplotypes from wild and captive populations that represent the traditional dama and ruficollis forms (IM – Manga (R), Termit (D) and Aïr (D); IF – Manga (R) and USA (R)). These groupings have high statistical support and share common 'roots' in the more slowly evolving Cytochrome B (haplotypes i and l). Therefore, application of the traditional subspecies divisions would result in a polyphyletic phylogenetic arrangement in the mtDNA data, suggesting that these divisions are not valid. These analyses therefore revealed no genetic support at mitochondrial gene regions for the historical classification of subspecies.

Table 6. Genetic statistics for the concatenated Control Region and Cytochrome B haplotypes.

	Aïr, Niger (D)	Termit, Niger (D)	Ati, Chad (R)	Manga, Chad (R)	OROA, Chad (R)	Al Ain Zoo, UAE (M)	EEP (M)	Safia, Morocco (R)	Senegal (M)	Al Ain Zoo, UAE (R)	Marwell, UK (R)	USA
N	11	22	1	32	18	42	18	6	3	20	5	75
No. haplotypes	4	3	1	14	8	1	2	1	1	1	1	6
Polymorphic sites	50	27	0	66	60	0	17	0	0	0	0	47
Gene diversity	0.782	0.628		0.921	0.856		0.471					0.616
(SD)	(0.075)	(0.060)		(0.027)	(0.055)		(0.082)					(0.041)
Nucleotide diversity	0.015	0.007		0.015	0.014		0.006					0.012
(SD)	(0.008)	(0.004)		(0.007)	(0.007)		(0.003)					(0.006)

Of a total of 84 fecal samples collected from the five wild sample sites, there are 29 globally unique haplotypes, compared to 8 globally unique haplotypes found within the 163 samples collected in the captive populations (Figure 9). No haplotypes are shared between the captive and wild samples. Only a single haplotype was identified in each of Al Ain Zoo (both M and R), Safia (M), Senegal (M) and Marwell (R), and only two haplotypes have been identified within the EEP (M). Mitochondrial diversity is greater within the USA (R), with six haplotypes identified. Gene diversity within the wild population in Termit (D) is similar to that of the USA (R) captive population (Table 6), although gene diversity was higher in all other wild populations (except Ati (R) which has only a single sample).

Of the wild populations, Manga (R) has the greatest gene diversity (Table 6), with 14 haplotypes identified. For the first time mitochondrial DNA from the Aïr Mountains (Niger) were analysed, though the sample size (n=11) is low, so it is difficult to say anything conclusive about genetic diversity. It should be noted that this small set of 11 samples contains four unique haplotypes not found elsewhere, which highlights the general trend in wild dama for high levels of mitochondrial DNA diversity.

The USA (R) population contains the greatest gene diversity of the captive populations (YY). The samples in this dataset originated from seven institutions (AZA and private holders) but represent only a small fraction of the North American captive populations. The current sample set recovered six control region haplotypes, although two pairs of haplotypes were very closely related (IR & IAM, IAI & IAJ; Figure 10) and are separated by only one base pair difference. These haplotypes could result from mutation after introduction to the USA. It seems likely that at least four female lineages are represented in the North American dataset.

Interestingly, the level of gene diversity uncovered in the US population is, so far, comparable to that found in the wild population in Termit (D), and the nucleotide diversity is higher than that in Termit (Table 6). This is a marginally positive sign for the US captive population which clearly shows higher genetic diversity than its counterparts in Europe and Arabia, but it may signal a more depressing situation for the Termit population. Despite the relatively high number of dama gazelle in Termit, it could be that the population has undergone a bottleneck, i.e. it is derived from a small number of founders. Today's population of 30-50 individuals is

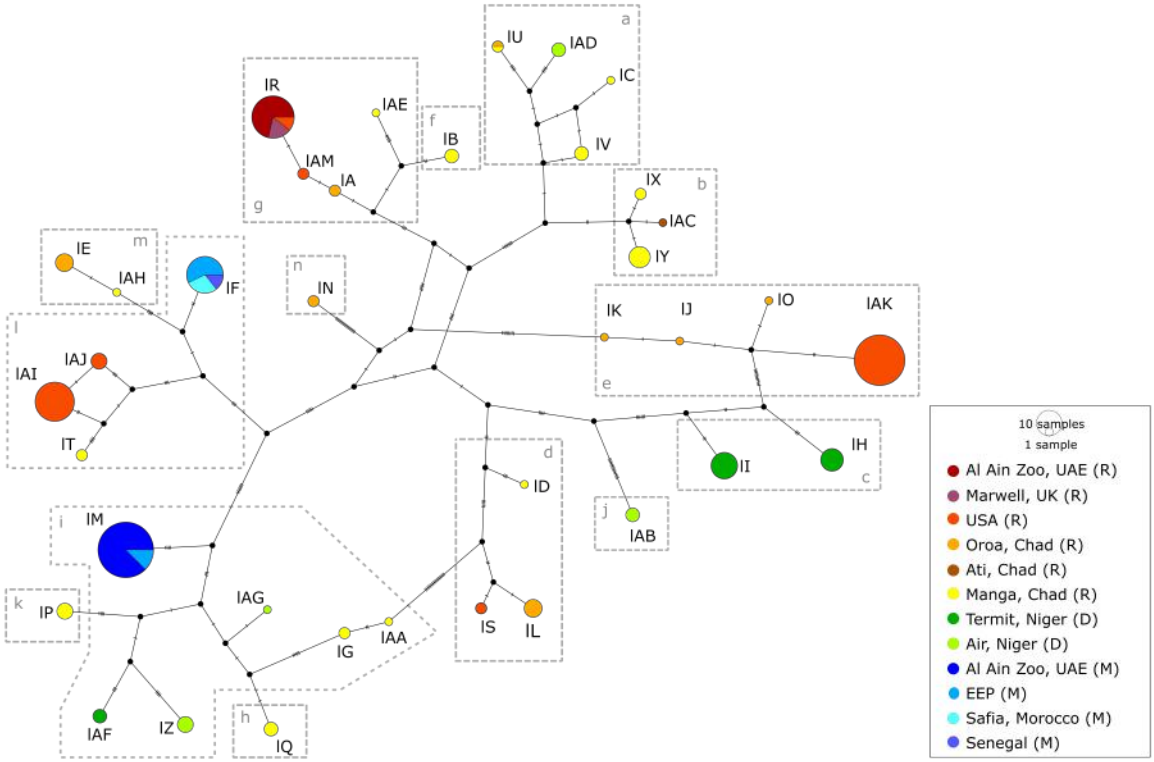


Figure 10. Control region haplotype network (circles) with associated Cytochrome B haplotypes represented by grey boxes. Each circle represents a haplotype and the hash marks represent the number of base-pair mutations. Circle size indicates number of samplers. Circle colours refer to the sample origin as in the caption, shown in the legend. Grey boxes illustrate the Cytochrome B haplotype associated with each control region haplotype. Letters refer to the haplotype identifier. RZSS/WildGenes.

located in a marginal habitat for the species and has managed to survive while the others distributed in the original habitat have been killed because of hunting or drought.

It is important to note that regardless of the captive sample size, the sample can only represent the number of founders within that captive population (Senn et al. 2014).

2.6.1. Genomics

Modern techniques and new technology have vastly increased the capacity of genetic analysis, allowing the whole genome (the entirety of the genetic information on an individual) to be sequenced, not just short lengths of DNA, as has been done previously. The results of genomic sequencing are potentially much more informative but produce a huge amount of information (billions of base pairs) that requires careful and sophisticated analysis.

So far, work at the Smithsonian Conservation Biology Institute (SCBI) has sequenced one reference genome (addra) and re-sequenced 4 individuals (2 addra, 2 mhorr) to examine genome-wide variation. All these samples were derived from captive animals in the USA (AZA for addra, SPA for mhorr). Based on these initial samples, genomic diversity (observed heterozygosity) in the mhorr was found to be significantly lower than addra, with more than one third of the genome occupied by homozygous-by-descent regions, reflecting the small number of founders originally used to establish the mhorr captive population and subsequent inbreeding (Dobrynin et al. *in prep*). In contrast, the two addra gazelle genomes showed high levels of heterozygosity across the genome and no evidence of inbreeding. Despite these differences, overall variation for the species was high, relative to other ungulate species. Genomics research is continuing at SCBI in collaboration with the Royal Zoological Society of Scotland and a variety of partners using wild and museum samples to produce tools for monitoring genetic diversity and inbreeding. For example,

RZSS genotyped ~130 captive dama gazelles at approximately 20,000 single nucleotide polymorphic sites across the genome; these data are now being analysed at SCBI and RZSS. In order to obtain nuclear genetic evidence to investigate the putative 'subspecies,' it is necessary to analyse a large number of markers in a substantial sample of wild animals. Evidence from captive animals alone is not sufficient, given the extreme bottleneck that some of the captive populations have undergone (Senn et al. 2014).

2.7. Intraspecific variation

Several dama gazelle subspecies have been described, mainly based on variations in pelage patterns observed in specimens obtained from different parts of the range. Specimens in the east have a larger amount of white on the hindquarters and only a reduced or no brown haunch stripe; the amount of chestnut-brown tends to increase towards the west and the stripe on the haunches becomes larger and more prominent. Cano (1984) proposed three subspecies *N. d. mhorr* (in the west, east to about 7^{0}E); *N. d. dama* (between about 7^0 and 14^{0}E) and *N. d. ruficollis* (east of 14^{0}E). Drüwa (1985) proposed two subspecies, *N. d. mhorr* and *N. d. dama* (including *N. d. ruficollis*). Groves and Grubb (2011) also proposed three subspecies but said that all specimens they examined from Senegal resembled *N. d. dama*, not *N. d. mhorr*, and they placed the boundary between these two forms approximately along the Senegal river. *N. d. mhorr* is extinct in the wild and all surviving animals are descended from not more than four founders, from the five animals captured in 1958 in what was then Spanish Sahara (Cano 1991, Abáigar 2018). As far as is known, all the eastern dama gazelles in captivity derive from 35 caught in OROA in 1967 (van den Brink 2018). *N. d. dama* from the central part of the distribution is not represented in captivity.

Analysis of mitochondrial DNA sequences revealed no genetic support for the traditional 3-subspecies arrangement (Senn et al. 2014, 2016; section 2.6. above). It is not known if the variation in colour has any adaptive variation or if it represents an east-west cline – there are extensive geographic gaps in sampling across the range. A lack of clear natural barriers to limit movements of individuals, and therefore gene flow between different parts of the range, and the very small number of mhorr founders, are among other factors to consider (Senn et al. 2014). Wild herds may show variation in appearance, especially in the centre of the range (e.g. photos of wild groups containing different phenotypes in RZSS and ASG 2014). Additionally, two animals showing *ruficollis* pattern were observed in Mali, to the west of 7^{0}E (Lamarque et al. 2007b) and some dama gazelles photographed or portrayed in rock art in southern and western Algeria are also relatively pale (section 2.2.2). A thorough review of historical descriptions, colour patterns, taxonomic arrangements, rock art and other evidence is provided by Kitchener (2018). Any taxonomic arrangement has implications for management of wild and captive populations. The variation in coat colour indicates some underlying genetic variation which may be adaptive (see discussion in Senn et al. 2014) but it cannot be assumed that this is the only important form of variation. Constraining breeding by coat colour alone may in fact eliminate other important variation.

2.8. Experimental breeding

Due to a lack of genetic differentiation found between the proposed dama gazelle subspecies, a diversity of phenotypes found in extant wild populations, and a likely lack of previous barriers to gene flow across the dama gazelle range, a recommendation was made at the 2013 workshop to conduct a cross-breeding experiment between mhorr and addra gazelles. The specific objectives of the experiment were to investigate:

1) whether the proposed subspecies were reproductively isolated;
2) the phenotypes of any mixed offspring, and
3) any implication of these on future management options.

Al Ain Zoo offered to carry out this experiment because it was one of the few zoos with large

Table 7. Structure of breeding groups and results to date.

Group	1		2	3	4	5	6
PHASE 1 (2014-2016)							
Structure**	1.2* MM ♂ AA ♀		1.2 MM ♂ AA ♀	1.2 AA ♂ AA ♀	1.2 AA ♂ MM ♀	1.2 AA ♂ MM ♀	1.2 MM ♂ MM ♀
Offspring combination	MA		MA	AA	AM	AM	MM
Births	-		5.1	2.4	4.2	4.3	2.0
Surviving	-		3.1	0.1	2.2	2.3	2.0
PHASE 2 (2016-2019)							
Structure**	1.3 MA ♂ AM ♀ MM ♀ AA ♀		1.1 MM ♂ AA ♀	1.3 AM ♂ AA ♀ MM ♀ AM♀	1.1 AA ♂ MM ♀	1.1 AA ♂ MM ♀	1.2 AM ♂ AM ♀ AM ♀
Offspring combination	MAAM	MAAA	MA	AMAA	AM	AM	AMAM
Births	2.1	0.3	0.0	0.1	1.0	0.1	1.2
Surviving	2.1	0.0	-	0.0	1.0	0.0	0.2
PHASE 3 (FROM FEBRUARY 2019)							
Structure**	1.4 AAAM ♂ AA ♀ AM ♀ MAAM ♀ MM ♀		1.3 MAAM ♂ AMAM ♀ AM ♀ MM ♀	Disbanded			1.4 AMMA ♂ AM ♀ AMAM ♀ MA ♀ AA ♀

*Animals lost following capture and relocation. Group not reestablished due to lack of available animals.
** MM = pure mhorr; AA = pure addra; MA = mhorr sire, addra dam; AM = addra sire, mhorr dam; in 4 letter combinations 1st and 2nd characters indicate parentage of sire, 3rd and 4th characters indicate parentage of dam: e.g. MAAM = sire (Mhorr ♂ x Addra ♀), dam (Addra ♂ x Mhorr ♀).

enough herds of both mhorr and addra, the subspecies had always been managed separately, and some baseline genetic research had already been carried out. The research has provoked some controversy, arising partly from a misunderstanding of the purpose of the experiment (Schreiber et al. 2018, and for a response see Senn et al. 2018). It should be underlined that the experimental animals are housed in completely separate holding facilities, and Al Ain Zoo is committed to maintaining them separately for as long is necessary. It is also continuing to breed other mhorr and addra groups. The experiment has been carried out with as minimal interference as possible due to the extreme sensitivity of the animals.

It should be noted that the results of this experiment will have limitations due to the small number of animals and experimental replicates that can be produced, however, the evidence will assist with building a bigger picture.

Phase 1 of the experiment began in 2014 soon after the workshop, with 6 groups of 1.2 animals forming two groups with mhorr males

Table 8. Causes and age of deaths of offspring in the dama gazelle breeding experiment.

Combination	Age of Death	Cause of Death
AMAA	0 days	Abortion
AM	0 days	Suspected septicemia
MAAA	1 day	Maternal neglect (female 1082)
AA	1 day	Pneumonia, Pasteurella
AM	1 day	Suspected septicemia
MAAA	2 days	Maternal neglect (female 1082)
AA	2 days	Maternal neglect (female 1082)
AA	2 days	Maternal neglect (female 1082)
MAAA	3 days	Septicemia, salmonella spp.
AMAM	3 days	Dam injured/maternal neglect
AA	5 days	Maternal neglect (female 1082)
AA	15 days	Undefined trauma, infection
MA	3 months	Trauma (translocation)
AM	3 months	Trauma (collision)
MA	9 months	Trauma (translocation)
AM	16 months	Trauma (collision)
AM	2 years	Trauma (conflict)

Table 9. Potential fitness characteristics of all offspring combinations produced (note that these results are based on a small amount of data and not all possible combinations were tested).

Breeding Combination	Births*	Deaths - Neonate	Minimum ICP	Average ICP	Birth Weight – Average (kg)**
MM	2.0	0.0	7	-	4.65
AA	2.4	2.3	7	8.75 (n=4)	4.5
MA	5.1	0.0	7	7.5 (n=4)	6.2
AM	9.6	2.0	7	8.4 (n=10)	5.0
MAAM	2.1	0.0	7	7.5 (n=2)	5.2
MAAA	0.3	0.3	9	9.5 (n=2)	3.5
AMAA	0.1	0.1	-	-	3.0
AMAM	1.1	1.0	9	9 (n=1)	4.4
AMMA	1.0	0.0	-	-	5.6
AMMA	1.0	0.0	-	-	5.6

* Not an indicator of fitness (matches not paired for equal lengths of time).
** Taken within 48 hours of birth. ICP = Intercalving period.

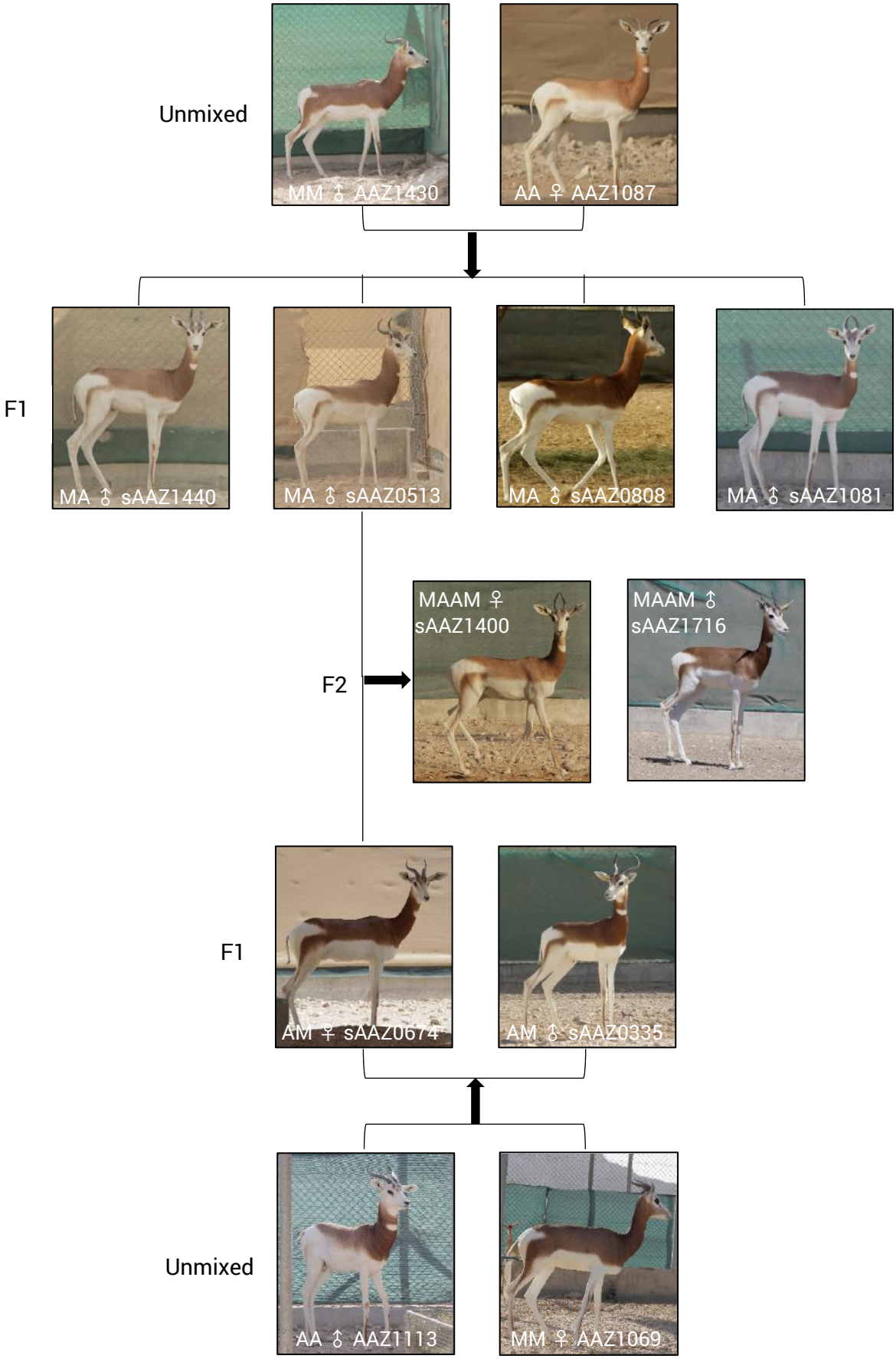


Figure 11. Phenotypes of unmixed parental groups and mixed offspring of the dama gazelle breeding experiment © Al Ain Zoo.

and addra females, two with addra males and mhorr females and two control groups with pure addra and mhorr. Following the birth of a manageable number of F1 animals, successive breeding groups were established to cover as many of the cross and back-cross combinations as possible (Table 7).

Phase 1 saw successful breeding in all F1 breeding combinations with a total of 17.10 births, of which 13.6 were in the experimental groups. Successive breeding during Phase 2 demonstrates that the offspring of F1 crosses are fertile, however, to date not all individual matches have led to breeding. Four back-crosses were born but died due to maternal neglect as neonates, infection and abortion (Table 8). Collectively, neonate mortality of the crossed animals (31%) was less than the neonatal mortality of the unmixed groups (41.5%) and does not exceed that of the general breeding population at Al Ain Zoo. Offspring that have survived the neonate stage have been healthy with no observed abnormalities or behavioural differences. Characteristics that may represent fitness are shown in Table 9.

Offspring have phenotypes intermediate between mhorr and addra, resembling the description of *N. d. dama* as shown in Figure 11.

It was agreed at the 2019 workshop that the breeding experiments was providing useful information. It was also recommended to extend the experiment to produce an F3 generation (Figure 12), hence Phase 3 breeding groups were established in February 2019.

Additionally, plans have been developed to carry out cytogenetic research and analysis of sperm characteristics. Follow-up molecular genetics research on all offspring will take place in 2019.

Figure 12. An F3 juvenile bred as part of the dama gazelle breeding experiment. Sire: mhorr x addra, dam (mhorr x addra) x (addra x mhorr) @ Al Ain Zoo.

3. Review of Progress 2014-2018

Progress made on actions and objectives in the five years 2014–2018 was reviewed. Each action in the planning logframe (Table 10 in the Edinburgh workshop report; RZSS and ASG 2014) was scored using a 'traffic-light' system (green = achieved; orange = partly achieved; red = not achieved). Actions were then categorized as: completed, ongoing, or omit (Table 10). The overall conclusion from this exercise was that, although a lot had been achieved, the 2014 version was over-ambitious given the scale of the resources available.

Table 10. Review of progress 2014–2018 (based on the Conservation Strategy logframe, Table 10 in the Conservation Review; RZSS and ASG 2014).

Vision
Sustainable and free-living populations of dama gazelle in indigenous range, supported by well-managed populations elsewhere.

Action	Responsible parties*	Prog-ress	Notes	Action 2018-2022	Responsible parties*
OBJECTIVE 1. SECURE AND EXPAND WILD POPULATIONS					
1.1. Support local NGO in monitoring in Aïr and Ténéré NNR and Field survey in March 2014 (funded by UNESCO, WHC)	SCF, UNESCO, DFCAP		Done by DFCAP and SCF	Continue	SCF, UNESCO, DFCAP
1.2. Continue monitoring in Termit and Tin-Toumma NNR			Done by DCFAP, SCF, Noé	Continue	Noé, DFCAP partners
1.3. Re-survey Manga area in dry season	SCF, ZSL		Done by SCF, ZSL, DCFAP	Continue: Q1 2019	SCF, ZSL, DFCAP
1.4. Investigate reports of dama gazelles near Ati	SCF, ZSL		Funding/security	Continue (low priority) if situation permits	SCF, ZSL, DFCAP
1.5 Investigate reports of dama gazelles on Tassili de Tin Gherghor (Algeria)			No reports received 2014-2018	Continue (low priority)	ANN, DGF
1.6. Follow up local reports from E. Niger	SCF, PCBR		Security issues. Error for west Niger (Tamesna)?	Continue for West Niger when possible	DFCAP, SCF
1.7. Identify sources of local information in Sudan			ASG member contacted; no recent information	Continue (low priority)	ASG
1.8. Enhance protection in OROA			Capacity and infrastructure increased	Continue	DCFAP with support from POROA
1.9. Carry out corridor assessments and feasibility			Completed at Al Ain workshop	Completed. None needed	N/A
1.10. Promote value of the Bahr al Ghazal corridor to the government				Omit – impractical	N/A

Action	Responsible parties*	Prog-ress	Notes	Action 2018-2022	Responsible parties*
OBJECTIVE 2. MAXIMIZE THE EFFECTIVENESS OF CAPTIVE POPULATION MANAGEMENT					
2.1. Develop a globally integrated population management plan	AZA, EAZA, EWA, C2S2, AZAA		Regional progress (AZA, SPA, EAZA, Arabian Peninsula)	Continue	AZA, EAZA, EWA, SPA
2.2. Develop best practice husbandry / management guidelines	C2S2, AZA TAG, EAZA TAG		EEZA (Almeria) have produced guidelines in the mhorr studbook	Continue Distribute guidelines	EEZA
2.3. Expand C2S2 consortium	C2S2, EWA		Expansion, numbers	Continue	SPA, EWA
2.4. Investigate reports of additional captive animals in the Middle East and North Africa			Followed up in Libya (no success) None in ME None in Niger/Chad	Continue (low priority)	
OBJECTIVE 3. ENHANCE THE ROLE AND POTENTIAL OF REINTRODUCTIONS AND REPATRIATIONS					
3.1. Review operations to date and ID reasons for success and failure	EEZA-DPN (Senegal)-HCEFLCD-TWCS		Partially achieved	Continue	EEZA
3.2. Identify and evaluate options for future releases	EEZA		Done at Al Ain workshop	Continue	All
3.3. Assist in developing management plans for each site (to include contingency plan to deal with carrying capacity issues)	EEZA		No progress	Replace with ensuring dama needs included in all site management plans	
3.4. Assess feasibility of establishing a captive breeding/repatriation site within the range (e.g. Bahr al Ghazal, OROA)			Done in part at Al Ain workshop	Continue	
3.5. Carry out Population Viability Analysis for all current populations in Table 3 above			No progress	Continue – high priority	Government agencies, main stakeholders
OBJECTIVE 4. RAISE THE PROFILE OF THE DAMA GAZELLE AND ITS PLIGHT					
4.1. Publish and distribute the conservation strategy	RZSS, ASG, all		Published 2014	Completed	N/A
4.2. Translate strategy into French	RZSS		Published 2014	Completed	N/A
4.3. Publish popular book on dama gazelle.	E.C. Mungall		Published 2017	Completed	N/A
4.4. Initiate an education and awareness programme on dama gazelle and ecosystem in range countries (schools, media, public).			Partly achieved	Continue	

Action	Responsible parties*	Prog-ress	Notes	Action 2018-2022	Responsible parties*
OBJECTIVE 5. CONDUCT RESEARCH CRITICAL FOR THE CONSERVATION OF DAMA GAZELLE					
5.1. Compile plan of in-situ and ex-situ research needs			Done at Al Ain workshop	Completed Monitor progress	All
5.2. Continue GPS radio-collaring and biological research in Texas	SAF, EWA		Analysis to be published	GPS radio-collaring analysis in progress	SAF, EWA
5.3. Assess the role of cryobanking as part of future conservation action(s) in relation to wild dama gazelle and compile research needs			Work begun; Progress report needed	Continue	SCBI, Edinburgh Univ, RZSS
OBJECTIVE 6. CONTINUE TO CLARIFY TAXONOMY AND SUBSPECIES STRUCTURE					
6.1. Record morphological data and take genetic samples from all museum specimens with locality data	NMS, RZSS		Some progress	Continue data collection; Analyze specimens	NMS, RZSS
6.2. Continue genome sequencing	RZSS, C2S2 SCBI		3-4 sequences produced	Continue	RZSS, C2S2, SCBI
6.3. Continue genetic research and morphological research into connectivity and subspecies structure	RZSS, SCF, AAZ, NMS		Some results published; nuclear data needed.	Continue More wild samples needed?	RZSS, SCF, AAZ, NMS
6.4. Experimental breeding of *N. d. mhorr* and *N. d. ruficollis* to assess reproductive isolation, phenotypic variation and future management options	AAZ		Breeding groups established, breeding successful.	Continue	AAZ, RZSS
OBJECTIVE 7. SECURE THE RESOURCES NECESSARY FOR DAMA GAZELLE CONSERVATION					
7.1. Develop budget for each action	All		No progress	Omit	N/A
7.2. Develop business plan	All		No progress	Omit	N/A
OBJECTIVE 8. ENSURE EFFECTIVE IMPLEMENTATION					
8.1. Undertake a systematic review to assess the feasibility and appropriateness of the options in Table 9, specifically: population viability analysis, long-term stability/prospects, financial implications, and cost/benefit analysis	All		Done at Al Ain workshop.	Continue work on details	

Action	Responsible parties*	Prog-ress	Notes	Action 2018-2022	Responsible parties*
OBJECTIVE 8. ENSURE EFFECTIVE IMPLEMENTATION					
8.2. Set up contact group of key stakeholders ('Dama team') to take the process forward	Workshop participants		Dama network established	Continue	RZSS
8.3. Set up 'Dama-library' of key reports and publications (Google Groups etc)	RZSS		Dama-library established	Continue to update	
8.4. Develop Monitoring & Evaluation Plan involving all stakeholders	All		Partial progress	Continue	

4. Assessment of Conservation Options

4.1. Context

As the information in section 2 above indicates, the dama gazelle is very close to extinction in the wild. The wild population numbers 90–140, split into 3–6 fragmented populations. The three core populations in protected areas are stable but show little sign of growth. The populations in Aïr and Ténéré and Termit and Tin-Toumma occupy rocky, hilly habitat which may be suboptimal. The habitat in OROA appears to be more suitable and it is unclear why the population is not increasing or why the dama gazelles do not extend their range beyond a relatively limited area of the reserve. One released population in Katane is small and declining. Two other releases were unsuccessful and the reintroduction into the wild at Safia in 2015 appears not to have resulted in an established population. The ex-situ population is much larger, but still limited in size and it contains a range of genetic diversity, from low to relatively high, depending on the population (addra or mhorr) and the facility. Wild dama gazelles are far more diverse though a large, but unknown amount of genetic variation must have been lost as local populations were extirpated and the range contracted. The ex-situ population is managed as two separate units, spread across many institutions. Furthermore, dama gazelles possess certain characteristics that make them less easy to manage and handle which complicates the establishment of new populations.

In such an extreme situation, without objective consideration of all available options and a willingness to make difficult decisions, there is little hope of improving the current status. There are no simple choices, and all involve risks, but not taking any action carries an even higher risk of seeing the species slowly become extinct in the wild.

Five key options for dama gazelle conservation were assessed:

1) addressing issues of intraspecific variation;
2) enhancing wild populations;
3) reinforcing existing populations;
4) establishing new populations, and
5) maximizing genetic diversity / enhancing captive populations

The associated opportunities and risks of each option, including the consequences of taking no action, were reviewed (sections 4.2-4.6 below and summarized in Table 14 at the end).

4.2. Addressing issues of intraspecific variation

Four key points that may influence practical decisions on conservation of dama gazelle

were discussed. The following recommendations were made:

1. The breeding experiment:

- The experiment has been useful, and the results so far are encouraging, but any hybrid vigour may be lost in future generations.
- The experiment should be continued to produce more offspring and into the F3 generation.
- Genetic testing, semen analysis and cytogenetics should be carried out.
- The potential conservation role of the offspring should be evaluated (e.g. for eventual release or merger with other captive populations).

2. The lack of *N. d. dama* in captivity:

- Recommended that addra/*N. d. ruficollis* animals would be the most appropriate source for future reintroductions or reinforcement operations in the central parts of the range. This conforms to the principle of 'next-nearest available source' in the IUCN Guidelines on Conservation Translocations (IUCN/SSC 2013). The mixed phenotypes observed in some sites further support this decision.
- Mixed mhorr x addra animals could also be considered in these cases.

3. Reconnecting populations:

- Restoring landscape connectivity is desirable in theory, to ensure dispersal and genetic exchange, but is impractical in the near- and medium-term due to the long distances between remaining populations, the transformation of habitats, and extreme difficulty in protecting animals from poaching over extensive distances.

4. Release sites with mhorr gazelles:

- Use of mhorr to reinforce these sites was considered most appropriate, see principle of 'next-nearest available source' in the IUCN Guidelines on Conservation Translocations (IUCN/SSC 2013).
- However, the possibility of utilizing mixed source animals (which contain mhorr genes) is not excluded due to the potential genetic diversity benefits this might bring.

4.3. Enhancing wild populations

This is the least invasive intervention, but success depends on a good understanding of the factors preventing growth of the current populations, the carrying capacity of sites and other issues.

The remnant populations in Alifa and Manga are small and unprotected (and no gazelles may be left in Alifa) and their future is in doubt, so investing time and effort in these sites is questionable. The status of the Tamesna dama gazelles is unknown (last seen in November 2005) and the security situation precludes any field work or conservation intervention at the present time and for an unknown period in the future. The three other populations (Aïr, Termit, OROA) are all in protected areas and are subject to varying levels of management. Poaching does not appear to have a significant impact and indications are that numbers are stable. The reasons why they are not growing or expanding are not understood. In both Aïr and Termit, the dama gazelles occupy rocky massifs which may represent suboptimal refuge habitat where the terrain protects them from vehicle hunting. OROA provides more favourable habitat but the dama gazelles restrict themselves to a small part of the reserve (c.1100 km^2) and numbers appear to be stable. All remaining sites are isolated and the chances of dispersal between sites are very low. A table listing the advantages and disadvantages of implementing conservation actions in these sites is in Table 11.

4.4. Reinforcing existing populations

The aim of supplementing existing populations with new animals, either captive-bred or caught from the wild, is to increase numbers, and in the case of wild animals, widen genetic diversity. Associated risks include disruption to existing social and reproductive systems, introduction of disease,

and genetic disruption (outbreeding depression).

Captive bred animals may in general be genetically depauperate (e.g. mhorr gazelles), and existing populations may be at carrying capacity in current conditions, so a careful analysis of whether introducing supplementary animals into a wild population would add any real genetic or demographic value is required. There is a high potential risk of disease transmission from captive-bred animals as well as disruption of existing social and behavioural systems. Situations vary, and after following strict quarantine regulations, exotic ungulates released onto Texas rangeland have been remarkably free of diseases and parasites and have not played any conspicuous role in spread of pathogens to other wildlife or to livestock (Mungall and Sheffield 1994). It is also necessary to evaluate the risk to released captive-bred animals of exposure to local diseases (transmitted from domestic or wild animals).

Releasing wild-caught animals potentially has a more positive genetic effect and may lower the risks of disease. However, the risk of losing valuable wild animals to injury during capture and transfer would be high.

Releasing captive-bred animals to supplement semi-captive populations is somewhat different because the animals on-site may be already genetically limited, so even a small amount of additional variation may be beneficial. The size of these populations is very small, so the demographic benefits are potentially higher, too.

All existing sites were reviewed against the above considerations and scored against several criteria (Table 11). Of the six wild populations, reinforcement of Manga, Alifa (Ati) and Tamesna received no support because they are unprotected and/or insecure and are already in a precarious state. Of the three other populations in protected areas, OROA was identified as the most suitable site for a supplementary release, in terms of natural habitat, access, and the infrastructure already in place for the release of scimitar-horned oryx. Interactions between scimitar-horned oryx and dama gazelles, both dama gazelles already on site and dama gazelles added, would need to be monitored.

However, in this and any other case, a detailed feasibility study is essential, including thorough veterinary screening protocols and identification of the most appropriate source animals. Research into why the existing population is not growing is also needed to ensure there is scope for population growth before any risks to the extant population are taken. Acclimatization and/or quarantine facilities to hold animals before release, and a training programme for husbandry and management would be required along with resources and capacity for long-term monitoring and any corrective actions that may be required.

The semi-captive population at Katane in Ferlo Nord WR in Senegal is in urgent need of supplementation because of the declining population and small number of founders. Preliminary work is needed before additional animals are released:

- repairs to the fence to prevent predators (including stray dogs) to enter, or gazelles leaving;
- a survey of current numbers and sex/age composition;
- a Population Viability Analysis (PVA) on carrying capacity of the proposed expanded area, and
- understanding external threats.

Guembeul SWR is an acclimatization and captive breeding site. It is small (7.5 km^2, half of which is occupied by a lake), there is a problem with encroachment by the invasive *Opuntia*. Additionally, it is situated outside the indigenous range so its role in dama gazelle conservation requires re-evaluation. In view of the small number of captive gazelles available, transferring new animals directly to Katane may be preferable to reinforcing the Guembeul population.

The Safia and M'Cissi acclimatization stations In Morocco are part of the existing HCEFLCD programme to re-establish populations of dama gazelles and other species and can be

Table 11. Characteristics of potential reinforcement sites for dama gazelle in range states.

Country	Site	Area (km²)	Fence	Current Number	Indigenous Range	Protected Area	Level of Management	Habitat Quality	Threat Level	Security	Logistics	SHO Present	Form	Notes
WILD														
MLI	Tamesna	3,000	N	?	I	N	L	M	H	L	L	N	Dama	
NGR	Aïr and Ténéré NNR	77,000 (600)*	N	30-40	I	Y	M	M	M	M	L	N	Dama	Management increasing
NGR	TTNNR Termit	97,000	N	30-40	I	Y	H	M	M	M	M	N	Dama	
NGR	TTNNR South		N	0	I	Y	M	M	M	M	L	N	Dama	
TCD	Manga	6-7,000	N	10-15	I	N	L	M	H	L	L	N	Dama	
TCD	Alifa/Ati	?	N	?	I	N	L	L	H	L	L	N	?	No recent information
TCD	OROA**	77,000 (1,100+)	N	40-50	I	Y	H	H	M	H	H	Y	Ruficollis	
SEMI-CAPTIVE AND CAPTIVE WITHIN THE REGION														
TUN	Bou Hedma NP	24	Y	1	O	Y	H	M	M	H	M-H	Y	?	Release not successful
MAR	Safia ABC	5.59	Y	15	I	Y	H	M	L	H	M-H	N	Mhorr	
MAR	M'Cissi ABC	40	Y	22	E	Y	H	M	L	H	H	Y	Mhorr	
MAR	Assa BR	16	Y	0	I	Y	M	M	M	H	M	N	?	Transfers planned
SEN	Katane (Ferlo Nord WR)	12	Y	15	I	Y	H/M-L	H	M	H	M - L	Y	?	Numbers declining
SEN	Guembeul SWR	7.24	Y	7	O	Y	H	L	M	H	H	Y	?	

*Dama area. **Including Wadi Hawach. Fence = area fenced or not; Indigenous Range = I,O,E = in, out, edge; Threat level= threats to dama; Security = security for operations; Logistics = logistics for acclimatisation and husbandry; SHO Present = scimitar-horned oryx present at the site; H,M,L = high, medium, low; Y,N = yes, no.

supplemented as needed from breeding groups in Morocco, EAZA or the Arabian Peninsula. The same applies to the new breeding facility in Assa.

On the other hand, some wild populations are under serious threat and extremely difficult to protect, so the risks of capture should be balanced carefully against the risk of losing the population altogether, along with its

Table 12. Potential reintroduction sites for dama gazelle.

Country	Site	Area (km²)	Indigenous Range	Habitat Quality	Protected Area	Level of Management	Threat Level	Security	Logistics	Notes
MAR	Errachidia	1,000	Edge/ out?	M	N	M	M	H	H	HCEFLCD plan to release
MAR	Boujdour-Essmara-Safia	5,000	In	M	N	M	H	H	M	
MAR	Assa BR	16	In	H	Y (prop-osed)	M	M	H	M	HCEFLCD plan to release
ALG	Ahaggar CP	450,000	In	M	Y	H	M	M	M	
MLI	Ansongo-Menaka FR	17,500	In	L	Y	N	H	L	L	Ineffective PA
NGR	Gadabedji BR	7,600	In	H	Y	H	L	H	M	Ostrich and giraffe already released.
TCD	Ennedi NCR	60,000	In	M	Part	L-incr	M - H	H	L-incr	African Parks taking on management
Threat Level = threats to dama; Security = security for operations; Logistics = logistics for acclimatisation and husbandry; H,M,L = high, medium, low; Y,N = yes, no; Incr = increasing.										

valuable genetic material.

4.5. Establishing new populations

Many successful reintroductions of antelopes and other ungulates have taken place worldwide and a considerable amount of expertise exists. This is the most expensive option requiring long-term planning, construction of acclimatization facilities, and long-term commitment. One of the main challenges for dama gazelle is identifying sites that are adequately protected and also contain an adequate extent of suitable habitat.

In Morocco there are long-term plans to release dama gazelles at Errachidia in the east, using animals from the M'cissi breeding centre and in the far south, from the Safia breeding centre, once security from poaching can be assured. In the shorter-term, it is planned to transfer animals to an acclimitization and breeding centre at Lagouirat for future release into the proposed Assa Biosphere Reserve. The source of all these gazelles is the R'Mila reserve.

There are very few protected areas in the rest of the former range. Gadabedji Biosphere Reserve in Niger was the highest-ranking site according to the criteria selected (Table 12). The site is unfenced and the core zone covers 7500 km². The reserve lies at the southern edge of the former range of dama gazelle and it was established to restore dama gazelle and scimitar-horned oryx (*Oryx dammah).* The habitat has been rehabilitated and ostrich and West African giraffe have been recently reintroduced. However, it is surrounded by agricultural and pastoral communities, and

large numbers of herders move through the reserve in summer/the rainy season: 19,066 in March 2010, 29,426 in August 2014, and 5,195 in January 2018 (T. Rabeil *in litt*.). A meeting with local communities took place in March 2019 to discuss the roles of the Core, Buffer, and Transition Zones. A further important consideration is that it may also be a future release site for scimitar-horned oryx, in which case, release of dama gazelles may not be advisable at this stage (as discussed above).

As with the options considered above, a full feasibility study would be required. It is likely that a concerted effort by the ex-situ community would be needed to produce enough animals to sustain a full reintroduction attempt (perhaps 25 animals a year for 5 years). Additional facilities for holding, breeding and acclimatizing animals may be needed in the range states.

Ansongo-Menaka Faunal Reserve in Mali lies close to the last known population in Tamesna but is overgrazed and lacks effective management. Furthermore, that part of eastern Mali is not secure.

4.6. Maximising genetic diversity

4.6.1. Summary

As set out in section 2.6, genetic diversity in some of the ex-situ population is very low, which may limit the usefulness of many animals for release into the wild. Much more diversity is found in the wild populations (though still likely only a small fraction of the original). Preserving as much of the wild variation as possible is extremely urgent, and all possible ways to obtain new genetic material should be explored.

Some captive breeding populations are even more limited genetically, due to serial founder events, but could be enhanced by improved management. A metapopulation management plan is required for the captive population, underpinned by Population Viability Analysis (PVA) modelling and where appropriate, nuclear genetic data, to understand the best options for future management. In the case of semi-captive populations in reserves, only regular release of new individuals will avoid the progressive loss of genetic diversity.

4.6.2. Acquiring privately held animals

Many private animal collections contain antelopes, some of which are acquired directly, not sourced from established breeding programmes. However, enquiries since 2014 have not located any dama gazelles in private collections in the Middle East or in zoos in North Africa that may be descended from new founders, unrepresented in the known captive breeding programs. The possibility of finding such animals now seems extremely low, yet it is still worth the effort of following up any possible sources, given the high genetic value of any new wild-caught founder.

It is a common practice in parts of the region for gazelles to be kept privately, in gardens or courtyards, usually after having been found as young animals. A photo of a privately held animal in Libya, considered to be most likely sourced from Niger or Chad, was shown in the Edinburgh report. In Niger and Chad, the species concerned are mainly red-fronted *Eudorcas rufifrons* and dorcas gazelles *Gazella dorcas*. Since 2014, government agencies in Chad and Niger have not found any dama gazelles in these circumstances, though vigilance should be maintained in major urban centres and settlements close to areas of dama distribution in Chad and Niger as well as in Libya. If any captive dama gazelles are located, all efforts should be made to bring them into a breeding facility and integrate them into breeding herds, with the permission of relevant government agencies.

4.6.3. Capturing young animals

New-born dama gazelles spend the post-natal phase hiding or lying-out. Catching them during this time is much less intrusive than capturing adults. However, all remaining populations occur at low density, individuals are widely dispersed, and births occur throughout the year, meaning there is no single season in which to concentrate a search. However, the Sahara Conservation Fund has

reported synchronized births in the wild from July to September following the beginning of the rainy season (Speeg et al. 2014). It is unlikely that the large effort needed would justify a systematic search and may even be unfeasible. This method may be more appropriate in protected areas where rangers are patrolling, and local herders are present. It should not be attempted unless a holding facility and staff trained in hand-rearing are available. For an account of hand-rearing dama gazelle in Texas see Mungall (2018c).

4.6.4. Capturing adults

Catching wild animals carries a high risk of causing injury or death, amplified in dama gazelle by the species' fragility and shyness. However, these risks must be balanced against the urgent need to preserve some of the wild diversity before it disappears altogether, especially as some populations are in a precarious state.

Any capture operation would need thorough planning, trained capture staff and vets, suitable transport, and a holding facility. Ultimately, construction of breeding centres in Niger and Chad may be required to house the captured animals with transfer to countries outside the range deemed to be a less favourable option.

After a detailed review, Manga was identified as the only feasible site for a capture attempt, because the population is small, genetically very diverse, but unprotected and under threat. The following measures were agreed:

1) carry out a scoping survey early in 2019 to locate the remaining gazelles;
2) identify an expert capture and veterinary team and select a preferred capture method;
3) trial the selected method on a property in Texas;
4) attempt live capture in Manga in late 2019, and
5) transfer any captured dama gazelles to a purpose-built enclosure at the existing holding facility (for scimitar-horned oryx) in OROA.

There are several ways in which any animals successfully captured can be utilized in the short-term:

1) early release into OROA or another site;
2) breed the wild-caught animals at the OROA facility to build up a larger population for future release, and
3) captive breeding with animals from the ex-situ population to spread the wild genetic material more rapidly among a larger number of individuals.

Any decisions will be influenced heavily by the number and sex of gazelles captured. Having only one sex, or a very small number (e.g. 1.1, 1.2, 2.1) will not allow establishment of a viable breeding population, limiting the choice of action to early release or mixing with captive-bred animals from the global population. Based on recent reports, it appears unlikely that several pairs could be successfully captured which again would limit the number of generations these animals could be bred (assuming they have several years of reproductive life left). The logic of bringing in dama gazelles (of the appropriate number and sex) seems inescapable, though strict protocols to minimize disease risks would be essential. Another option is to mix with animals captured in OROA but the risks of damage to the largest population are considerable. See the decision tree (Figure 13).

Given the much-depleted genetic diversity present in the global captive population, and its importance as an insurance population against complete extinction, all ways to integrate new founder material into the global captive population in the future should be explored.

The only recorded live capture of wild adult dama gazelles is the operation in Chad in 1967 undertaken by the noted animal collector Frans van den Brink, that established the addra breeding line. His team pursued wild animals in a vehicle (for a maximum of 3 minutes) and caught them using a rope noose on the end of a shark fishing pole (van den Brink 2018). The gazelles that founded the mhorr breeding line originated with animals

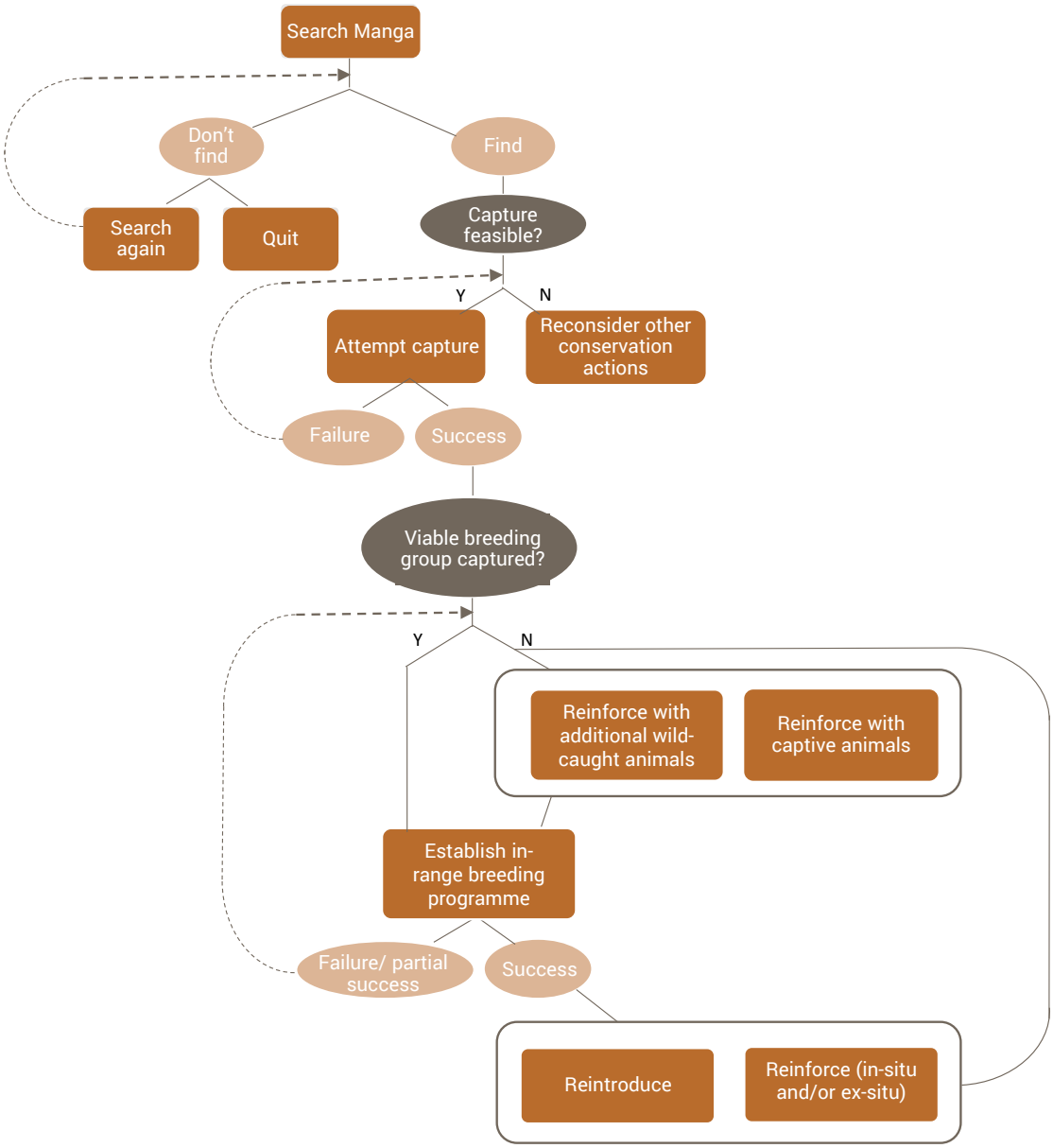


Figure 13. Decision tree related to the potential capture of any remaining dama gazelle from the Manga region.

kept by military personnel and the original capture method is unknown but may have involved neonates (Abáigar 2018). On Texas ranches and large collections, a range of different capture techniques are used. A range of techniques has been developed to capture antelopes including darting with anaesthetics, nets, etc. (Table 13).

4.6.5. Increasing diversity in captive populations

As described in section 6, the analyses carried out to date revealed only 8 maternal haplotypes in the captive population, 2 in mhorr and 6 in addra, with five of the eight populations sampled containing only a single haplotype (Figure 14). The mhorr population in the EAZA EEP contains two haplotypes, but the captive groups that originate from this population appear to contain a lower subset of this genetic diversity. For example, Al Ain Zoo contains only one of these, and the populations in Senegal and Safia in Morocco have only the other one. This illustrates clearly that the existence of these two haplotypes was unknown or not taken in account when selecting founder individuals for the EAD and Al Ain populations, as well as those

Table 13. Summary of methods for obtaining new founder dama gazelles.

Technique	Notes
ACQUIRE EXISTING CAPTIVE ANIMALS	
Middle East collections	Enquiries since 2014 failed to locate any dama
Private/pets in Niger and Chad	No dama gazelles located by government agencies
	Maintain vigilance
	Is there a legal basis for confiscation?
	Are funds available to purchase?
ACQUIRE FROM THE WILD - YOUNG	
Catch by hand in hiding phase	Less invasive
	Small, dispersed populations and extended birth season mean huge search effort
	Needs experience in hand-rearing
ACQUIRE FROM THE WILD - ADULTS	
Lasso from a moving vehicle	Used by Hans van den Brink in in Chad
	Maximum 3-minute chase may not be enough
	Difficult to use on uneven terrain
	Risk of injury
Net gun from a helicopter	High risk of injury when tangled in net
Dart from a helicopter	Possible to approach close enough?
	Done successfully in West Texas
Dart from the ground	Difficult to approach within range
Drive into nets using vehicles and/or helicopter	High risk of injury when tangled in net
Sweep net: extended between two vehicles	Used recently to capture Scimitar-horned oryx in OROA. But these were sick animals and approaching close enough to the dama makes it unlikely to be practical
	High risk of injury when tangled in net

reintroduced in Morocco and Senegal, and the need to consider this in future transfers.
In the case of addra, the six recorded haplotypes are all present in the USA population, but at different frequencies in the animals sampled and most likely in different facilities (note that sampling could be much more extensive). However, only one haplotype is found in the Arabian Peninsula and in Morocco. The potential for transfers between the captive populations should be explored. Transferring animals from the USA to Al Ain Zoo to address this issue was agreed in principle at the workshop.

Three haplotypes are thus unique to the USA and are present in only a few of the sampled animals. The more extensive sampling and data generated by the C2S2, RZSS and SCBI collaborative project will provide a basis for metapopulation management via C2S2. Figure 14 shows that there are potentially genetically beneficial transfers between breeding groups that would increase help to improve the viability of the overall population. This is the case for both *N. d. mhorr* and *N. d.*

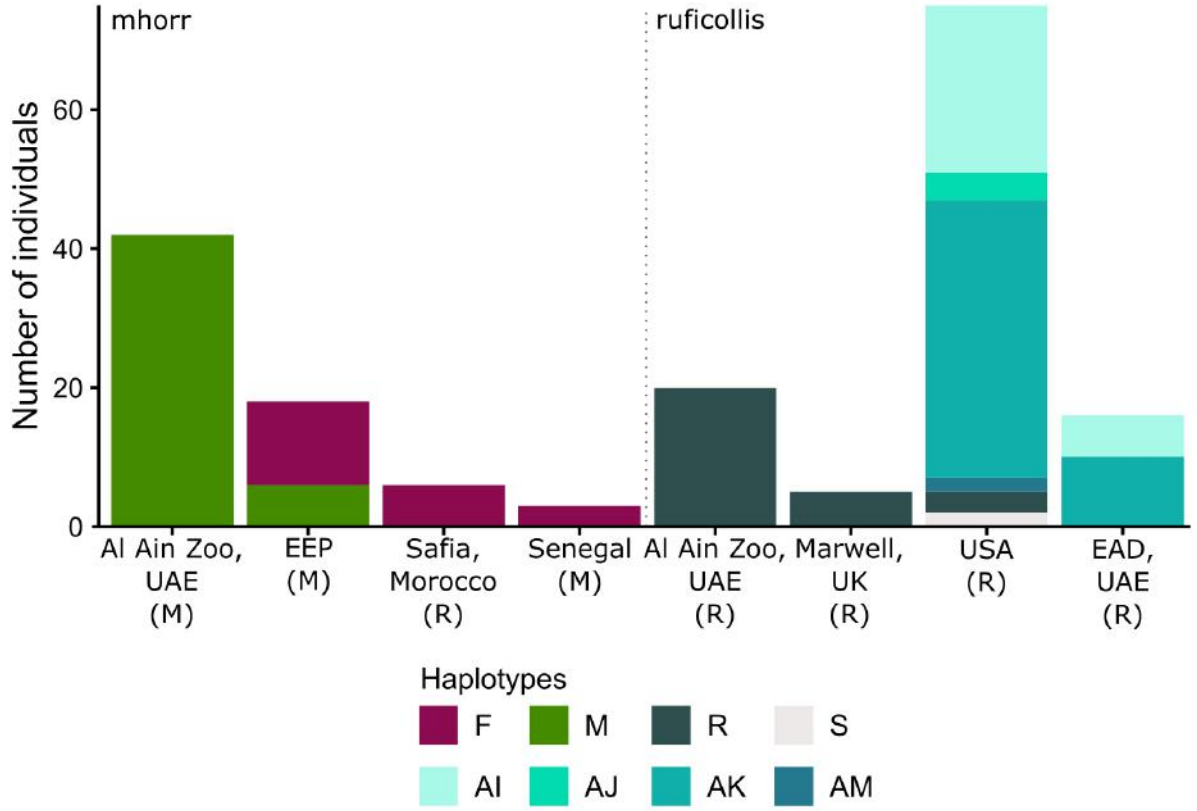


Figure 14. Haplotypes identified in captive populations of dama gazelle. Height of bars indicates the number of samples. AIN = Al Ain Zoo; EEP = EAZA; SAF = Safia (Morocco); MAR – Marwell Wildlife, SEN = Senegal; EAD = Environment Agency-Abu Dhabi. Source: RZSS-WildGenes.

ruficollis. Studbook keepers, conservation geneticists, and captive population representatives should collaborate to prioritise the most appropriate and feasible exchanges as part of an agreed metapopulation management plan.

The captive environment has some space limitations and there are many restrictions on international movement of animals due to veterinary regulations, e.g. it is currently impossible to import ungulates, or any tissue or reproductive material, from Africa into the USA and the European Union.

4.6.6. Cryobanking

Storage at very low temperatures to preserve gamete or cell lines may offer a means to conserve valuable genetic material for future use. Work on cryopreservation of semen has taken place both at the SCBI and EEZA. Banking of gametes/cell lines from the wild is a possibility that should be further explored, especially in any plans that involve wild capture.

4.7. Summary of Conservation Options, Opportunities and Risks

Table 14. Summary of the main conservation options for dama gazelle and associated opportunities and risks.

Option	Opportunities	Risks and constraints	Issues / Assumptions
WILD POPULATIONS			
Status quo (no additional action)	• Low cost	• Populations stagnate or become extinct • Threats are not controlled • Genetic diversity is lost	
Enhance conservation of existing sites	• Increased viability of populations reduces risk of extinction • Maintains species in natural environment • Once extirpated, difficult to re-establish • Lower costs than reintroduction • Benefits whole biodiversity of the area • Retains species in local memory	• Two populations are in suboptimal habitat • Factors limiting population growth are unknown • Security threats and inaccessibility at some sites	• Suitable habitat is available • Need to improve knowledge of population dynamics and interspecific competition / interactions
Connect existing sites	• Increased viability of populations reduces risk of extinction • Increased genetic diversity of populations • Moves from site to landscape level approach (change of scale)	• Existing sites are very far apart • No records of movement between sites for 20 years • Habitat between sites is suboptimal or subject to heavy pressure • Difficult to protect large distances between sites • Local community cooperation and support needed • Cross-government cooperation and support needed for some sites • Potential exposure of core populations to new threats	• Suitable habitat is available and threats can be reduced • Population will increase rather than disperse
Reinforce existing populations	• Genetic diversity of populations potentially increased • Increased viability of populations reduces risk of extinction	• Potential risk of outbreeding depression • Disruption to existing social and reproductive systems • Introduction of disease and parasites to existing population	• Suitable source animals are available • Full feasibility study needed • Current population is not at carrying capacity

Option	Opportunities	Risks and constraints	Issues / Assumptions
WILD POPULATIONS (cont.)			
Reinforce existing populations (cont.)		• Captive population is genetically depauperate and may introduce limited variation • Captive-bred animals may not survive in the wild • Mortality or injury during capture and transport • Reduced resilience of captive population	
Reintroduce to new sites	• Metapopulation viability increased • Fragmentation reduced • Risks are spread • Enhances local biodiversity	• Captive-bred animals may not survive in the wild • Captive population is genetically depauperate • Lack of protected sites in historic range • High cost • Injury or mortality during capture and transport • Risk of interspecific competition (e.g. SHO) • Impact on source population • Low level of expertise in reintroduction techniques	• Suitable sites exist or habitat restored • Full feasibility study needed • Community agreement secured • Suitable source animals are available
SEMI-CAPTIVE INSIDE RANGE			
Status quo (no additional action)	• Low cost [time & effort]	• Populations stagnate or go extinct	
Enhance site action (secure fences, manage habitat)			• Requires capacity building and training
Reinforce existing populations	• Genetic diversity of populations potentially increased • Demographic viability increased	• Potential outbreeding depression • Captive population is genetically depauperate and may introduce limited variation • Disruption of existing social and reproductive systems • Introduction of disease or parasites	• Feasibility studies needed • Site is large enough to increase population • Do new animals integrate? • Other forms available and acceptable • Release new founders only inside indigenous range

Option	Opportunities	Risks and constraints	Issues / Assumptions
SEMI-CAPTIVE INSIDE RANGE (cont.)			
Reinforce existing populations (cont.)		• Released animals may not survive • No *N. d. dama* available for central part of range • Mortality during capture and transport	
Extend existing fenced areas	• Increased carrying capacity • Increased population size • Relatively achievable compared to other options	• Increased risk of fire and predation • Harder to manage, control and assess population • Funding for construction • Increased resources required for maintenance and management of area • Might exclude other wild species from a large area	• Size of site is the main limiting factor • Habitat in the extended area is suitable • Community and governmental agreement is secured
Establish new semi-captive populations	• Metapopulation viability increased/increased resilience of total population • Risks are spread • Animals reared in and adapted to native environment	• Few potential sites • Released animals may not survive • High cost and long timeframe. • Might exclude other wild species from a large area • Mortality during capture and transport • Support and cooperation from local communities and governments required • Known difficulty in establishing populations	• Captive population is genetically depauperate • Viable source animals are available • Community and governmental agreement secured • The species is especially difficult to move and handle
Transfer animals between sites	• Increased genetic diversity	• Mortality during capture and transport • Few potential sites • High cost • Feasibility study completed • Disruption of existing social and reproductive systems	• The species is especially difficult to move and handle
SEMI-CAPTIVE OUTSIDE RANGE			
Status quo (no additional action)	• Low cost [time & effort]	• Populations stagnate or go extinct • Increased inbreeding	

Option	Opportunities	Risks and constraints	Issues / Assumptions
SEMI-CAPTIVE OUTSIDE RANGE (cont.)			
Reinforce existing populations	• Genetic diversity of populations increased • Populations can be used as a model for understanding population dynamics in the wild	• Potential outbreeding depression • Disruption of existing social and reproductive systems • Additional resources required to maintain larger population • Introduction of disease or parasites • Released animals may not survive • Not in indigenous environment (risk to future released populations?)	• Captive population is genetically depauperate • Feasibility studies needed • Adequate knowledge of management • Need to identify partners which align with conservation objectives • Assumption that sites are adequate for increasing the numbers • Community support exists • Site is large enough
Expand existing sites	• Increased capacity	• Habitat is suitable or can be restored • Community support	
Establish new sites	• Metapopulation viability increased • Risks are spread	• Known difficulty in establishing populations • High cost • Availability of suitable sites	• Captive population is potentially genetically depauperate • Need to identify partners which align with conservation objectives • Study to identify the need
Transfers between sites	• Increased gene flow/ genetic diversity	• Injury/death during capture • High cost	
CAPTIVE			
Status quo (no additional action)	• Low cost [time & effort]	• Population increase is curtailed by limited space availability • Increased levels of inbreeding	• Political and financial support continues
Enhance existing breeding programs	• Improved management of genetic diversity	• Low founder base • Additional resources required to maintain larger populations	• Capacity is available
Introduce new founders (e.g. from wild)	• Higher numbers	• Veterinary restrictions on transfers into Europe, North America	
Introduce new founders (e.g. from wild) (cont.)	• Increases genetic diversity (new founders)	• Export restrictions from range countries • Risk to wild animals (death during capture?). Negative PR?	

Option	Opportunities	Risks and constraints	Issues / Assumptions
CAPTIVE			
Establish new populations	• Increased capacity and number of animals • Spreads the risk	• Resources • Injury/death during capture	• Suitable animals are available
Acquire privately held animals (in range countries	• Increases genetic diversity (new founders)	• Risk to wild animals (death during capture?). Negative PR?	• Legal basis exists • Funds available to purchase
Assisted reproduction	• Increase genetic diversity/ increase captive population without affecting source	• Ban on import of semen into EU/USA • Risk of injury or death • High cost (?)	• Techniques are established and reliable
Establish captive breeding facilities inside range using wild animals	• Animals acclimatise to indigenous conditions • Short transfer to release sites if using wild-caught animals • Possibility of semen collection	• High cost (capital, training, maintenance) • Long transfer if using captive animals from USA or UAE	

5. Research Needs

5.1. Wild populations

- Demography.
- Population dynamics.
- Space use and movement patterns
- Interactions with other livestock and wild species (competition and predation).
- Diet.
- Reproductive biology.

5.2. Captive and semi-captive populations

- Population dynamics.
- Space use and movement patterns (Senegal, Texas).
- Behaviour (in particular, stress).
- Predator control, avoidance and training.
- Population viability analysis / metapopulation management plan of the captive population.
- Breeding experiment: quality of sperm in offspring, genetic diversity, karyotyping, inbreeding effects.
- Analysis of reasons why dama gazelles do not survive at some sites while other antelope species thrive. (competition, specialist requirements, sensitivity to predation).
- Collate details of capture techniques and veterinary drug protocols used in captive populations.

Wild dama gazelles, Manga, Chad © T. Wacher

6. Objectives and Actions for Dama Gazelle Conservation 2019-2028

Revised sets of objectives and actions were developed, based on the discussions in working groups and plenary sessions, and aligned with the main themes of the workshop, then compiled into a standard logframe format (Table 15). The long-term Vision for dama gazelle conservation developed in 2013 was retained.

Table 15. Objectives and actions for dama gazelle conservation 2019-2028.

Vision

Sustainable and free-living populations of dama gazelle in indigenous range, supported by well-managed populations elsewhere.

Objective	Action	Timeline/ Urgency	Indicator	Responsibility
WILD				
1. Monitor wild populations effectively	1.1. OROA	Ongoing	Survey results	DCFAP, SCF
	1.2. Manga	2019-2020	Survey results	DCFAP, SCF
	1.3. Alifa/Ati	L	Survey results	DCFAP, SCF
	1.4. Aïr and Ténéré NNR	H	Survey results	DFCPR, SCF
	1.5. Termit and Tin-Toumma NNR	H	Survey results	Noé Conservation, DFCPR
	1.6. Tamesna Plains (Western Niger)	L-M	Contacts established	DFCPR
	1.6.1. Establish local contacts	L-M	Local reporting system	DFCPR
	1.7. Tamesna (Mali):	L	Contacts established	Government agency
	1.7.1. Establish local contacts	M	Local reporting system	Government agency
	1.8. Algeria: follow-up local reports	L-M	Results available	ANN, DGF
	1.9. Sudan: follow-up local reports and survey former range when feasible	L	Results available	SWS, ASG, Government agency
	1.10. Provide training in survey and monitoring methods for all range states	M	Training courses conducted	Government agencies, NGOs
	1.11. Produce ID card for local use	M	ID card produced and distributed	ASG
2. Secure and expand key wild populations	2.1. Aïr and Ténéré NNR: follow recommendations in Regional AP	H	Recommendations implemented	DFCPR

Objective	Action	Timeline/ Urgency	Indicator	Responsibility
WILD (Cont.)				
2. Secure and expand key wild populations (cont.)	2.2. Termit and Tin-Toumma NNR: follow recommendations in Regional AP	H	Recommendations implemented	Noé Conservation, DFCPR
	2.3. OROA: follow recommendations in Regional AP	H	Recommendations implemented	DCFAP, EAD, SCF
	2.4. Incorporate dama gazelle conservation in all site management plans	M	MPs produced	Government agencies
3. Reintroduce to new sites	3.1. Gadabedji BR: conduct feasibility study	M	Study produced	DFCPR, SCF
	3.2. Ennedi NCR: conduct feasibility study	M	Study produced	DCFAP, APN
	3.3. Errachida: conduct feasibility study	M	Study produced	HCEFLCD
	3.4. Boujdour-Safia ABC: conduct feasibility study	M	Study produced	HCEFLCD
4. Reinforce wild populations	4.1. OROA: conduct feasibility study	H	Study produced	DCFAP, EAD, SCF
SEMI-CAPTIVE				
5. Secure and expand semi-captive populations	5.1. Katane			
	5.1.1. Extend area to 5000 ha	H	Extension created and fenced	DPN
	5.1.2. Conduct drone survey	M	Survey report	ABZC, DPN
	5.1.3. Conduct training programme	H	Programme completed	ABZC, DPN
	5.1.4. Conduct feasibility study on obtaining new stock	H	Study produced	DPN
	5.1.5. Conduct Research on movement patterns population dynamics and diet	M	Results produced	DPN, partners
	5.2. Guembeul BR: Evaluate role in dama conservation and need for new stock	M	Study produced	DPN
	5.3. Safia & M'Cissi ABCs: Continue government programme	M	Breeding continues	HCEFLCD
	5.4. Assa BR: Continue government programme	M	Enclosure created	HCEFLCD
	5.5. R'Mila RR: Continue breeding programme	H	Breeding continues	HCEFLCD

Objective	Action	Timeline/ Urgency	Indicator	Responsibility
SEMI-CAPTIVE (Cont.)				
5. Secure and expand semi-captive populations (cont.)	5.6. Conduct feasibility study into possible reintroduction in Algeria	L-M	Study produced	ANN, DGF
	5.7. Conduct feasibility study on establishment of a breeding group at Haddej NP, Tunisia	M	Study produced	DGF, Marwell Wildlife
CAPTIVE AND SEMI-CAPTIVE OUTSIDE RANGE				
6. Maximise the effectiveness of captive populations	6.1. Maximise genetic diversity of captive populations	H	Populations have optimal diversity	SSP and EEP coordinators, SPA, EWA, others
	6.1.1. Exchange animals between AAZ and EAD	H	Exchanges completed	AAZ, EAD
	6.1.2. Exchange animals between AAZ and EAZA	H	Exchanges completed	AAZ, EAZA, Studbook keeper
	6.1.3. Exchange animals between Morocco and EAZA	H	Exchanges completed	HCEFLCD, EAZA
	6.1.4. Transfer addra from US to AAZ	H	Exchanges completed	AZA, SPA, SAF, AAZ
	6.1.5. Develop a metapopulation management plan for animals in the Arabian Peninsula	M	Plan developed	All regional holders
	6.1.6. Evaluate role of mixed animals in reintroduction and reinforcement operations	L-M	Evaluation conducted	AAZ, Key stakeholders
	6.1.7. Identify collections in Texas with rare haplotypes and implement appropriate animal transfers or exchanges	H	Animals identified Transfers arranged	RZSS, SCBI Studbook keepers
	6.2. Continue to develop the C2S2 consortium	Ongoing	Increased number of holders Increased number of animals	C2S2, SPA, EWA
	6.3. Continue the breeding experiment at Al Ain Zoo	M-H	Results available	AAZ
	6.4. Increase range state capacity for dama husbandry and management	M	Trained teams in each facility	Government agencies

Objective	Action	Timeline/ Urgency	Indicator	Responsibility
CAPTIVE AND SEMI-CAPTIVE OUTSIDE RANGE (cont.)				
6. Maximise the effectiveness of captive populations (cont.)	6.4.1. Establish a training programme	2019	Training courses provided	HCEFLCD, EAD, EEZA
	6.4.2. Circulate husbandry guidelines	M	Guidelines circulated	EEZA
	6.4.3. Translate guidelines into French	M	Translation available	EEZA, NGOs
	6.5. Carry out PVA and metapopulation management plan for all captive populations to evaluate different future strategies of management	L-M	PVA conducted	SPA, SAF, Studbook keepers, owners
	6.6. Produce a long-term plan for producing enough animals for release operations	Urgent	Plan developed	SPA, SAF, Studbook keepers
	6.7. Review development of wider metapopulation models	L	Review conducted	SPA, SAF, Studbook keepers
7. Obtain new founders	7.1. Obtain privately held animals			
	7.1.1. Monitor possible captive animals in Chad and Niger	L-M	Captive animals obtained	DCFAP, DFCPR
	7.1.2. Develop a protocol and holding facilities	L-M	Protocol developed	DCFAP, DFCPR, NGOs
	7.2. Capture wild animals from Manga	2019-2020	New founders obtained	DFCPR, SCF, others
	7.2.1. Conduct scoping survey	2019-2020	Survey results	DFCPR, SCF
	7.2.2. Feasibility study on capture methods	Done 2019	Study published	SPA, EAD, SCF
	7.2.3. Plan capture operation	Done 2019	Plan developed	DFCPR, SCF, others
	7.2.4. Ensure suitable holding facility available in OROA	Done 2019	Facility available	DFCPR, SCF, EAD
	7.3. Collate all capture and veterinary information in US	L-M	Summary available	SPA, AZA
	7.4. Train range state personnel in gazelle handling and management (see 6.4.1)	L-M	Training courses provided	HCEFLCD EAD, EEZA, AAZ

Objective	Action	Timeline/ Urgency	Indicator	Responsibility
OTHER				
8. Continue genetic research	8.1. Record morphological data and take genetic samples from all museum specimens with locality data	Ongoing	Data available	NMS, RZSS
	8.2. Continue genome sequencing, including SNP analysis, structural variant analysis and chromosomal-scale analyses of intraspecific variation	Ongoing	Results available	SCBI, RZSS, partners
	8.3. Assess the role of cryobanking	L	Study published	SCBI, RZSS
	8.4. Include option of gamete preservation in any wild capture operations	L-M	Protocol developed	SCBI, RZSS
	8.5. Obtain and analyse new samples	Ongoing	Samples analysed	RZSS
	8.6. Continue genetic and morphological research into intraspecific structure, using nuclear markers	Ongoing	Analyses published	RZSS
	8.7. Carry out genetic analysis on any untested captive populations (Morocco)	M	Analyses conducted	RZSS, HCEFLCD
	8.8. Continue breeding experiment and carry out genetic analysis, semen analysis, and karyotyping on offspring	Ongoing	Results available	AAZ, RZSS
9. Conduct research on biology and conservation of dama gazelle	9.1. Compile lists of in-situ and ex-situ research needs	L-M	Lists available	Done at Al Ain workshop
	9.2. Continue research in Texas on movements and population dynamics	Ongoing	Some results available, some in progress	SAF, EWA
	9.3. Analyse radio-collaring data from the Safia release	Ongoing	Analysis available	EEZA, HCEFLCD
	9.4. Conduct research into interspecific interactions and competition at OROA and other sites	L-M	Research results available	DCFPR, SCF
	9.5. Review release operations to date and reasons for success and failure	M	Review published	EEZA, Government agencies

Objective	Action	Timeline/ Urgency	Indicator	Responsibility
OTHER				
10. Implement the strategy effectively	10.1. Continue and expand Dama network*	Ongoing	Key stakeholders participate Regular updates produced	RZSS
	10.2. Maintain 'Dama-library' (Google Groups etc)	Ongoing	Library up-to-date	RZSS
	10.3. Hold a review meeting in Texas	2022	Meeting to be held	SAF, EWA
	10.4. Publish and distribute the 2019-2028 strategy	H	Strategy published in EN and FR	AAZ, ASG, RZSS
	10.5. Initiate an education and awareness programme on dama gazelle and ecosystem in range countries (schools, media, public)	L-M	Programmes established	Government agencies, NGOs
	10.6. Develop Monitoring & Evaluation Plan for the strategy	M	M&E Plan available	AAZ, ASG, RZSS
	10.7. Obtain adequate resources for each component	2019-2028	Resources obtained Actions implemented	All
H,M,L = high, medium, low.				

* Note that the Dama Network is open to all who are interested in receiving updates on dama conservation. To be added to the list please email hsenn@rzss.org.uk.

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