2023 Annual Report

Chad Oryx Reintroduction Project

A joint initiative of the Government of Chad and the Environment Agency Abu Dhabi, implemented in Chad by Sahara Conservation

Edited by Sahara Conservation

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Executive summary

This report provides an overview of activities and results through 2023 of the Scimitar-horned Oryx Reintroduction Project taking place in the Réserve de Faune de Ouadi Rimé-Ouadi Achim, Chad. A joint initiative of the Environment Agency Abu Dhabi (EAD) and the Government of Chad, Sahara Conservation implements this unique and highly ambitious program in-country with assistance from the Direction de la Faune et des Aires Protégées (DFAP).
The report integrates data, information, and observations collected by the project team, including valuable data on the behavior, social structure, calving performance, and survival of the oryx reintroduced. It uses data inputs from all project partners, including EAD, the Direction de la Faune et des Aires Protégées, Sahara Conservation, the Smithsonian's National Zoo & Conservation Biology Institute (NZCBI), and the Zoological Society of London (ZSL).

Cover photo: Reintroduced scimitar-horned oryx in Chad - © Sean Viljoen

Acknowledgements

This project would never have happened without the vision, the leadership, the resources, the skills and the animals of the Environment Agency - Abu Dhabi (EAD) and its leaders. The partnership between EAD, the Government of Chad, and Sahara Conservation has ensured the project's success in many ways. The initiative is not only one of the most ambitious wildlife reintroductions ever undertaken but also a glowing example of what can be done to save Africa's imperiled wildlife if we all pull together.

Abbreviations and acronyms

AP	African Parks
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (Center for International Cooperation in Agricultural Research for Development)
DFAP	Direction de la Faune et des Aires Protégées (Directorate of Wildlife and Protected Areas)
DSA	Division de la Santé Animale (Animal Health Division)
DSV	Direction des Services Vétérinaires (Veterinary Services Department)
EAD	Environment Agency - Abu Dhabi
FRWC	Fossil Rim Wildlife Center
GPS	Global Positioning System
IRED	Institut de Recherche en Élevage pour le Développement (Chad Livestock Research Institute for Development)
MEPDD	Ministère de l'Environnement, la Pêche et du Développement Durable (Ministry of the Environment, Fisheries and Sustainable Development)
NZCBI	Smithsonian's National Zoo & Conservation Biology Institute
OBC	Oryx Base Camp
Oryx	Scimitar-horned oryx (*Oryx dammah*)
Oryx Project	Chad Oryx Reintroduction Project (also "reintroduction project")
POROA	Ouadi Rimé-Ouadi Achim Project (project to support the development of the Réserve de Faune de Ouadi Rimé-Ouadi Achim)
RFOROA	Réserve de Faune de Ouadi Rimé-Ouadi Achim
RZSS	Royal Zoological Society of Scotland
SC	Sahara Conservation
VHF	Very High Frequency
UAE	United Arab Emirates
ZSL	Zoological Society of London

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INTRODUCTION

The Réserve de Faune de Ouadi Rimé-Ouadi Achim (RFOROA), located in Central Chad, was established by decree No. 135/PR/EFP/PNR of 10 May 1969 to protect Sahelo-Saharan antelopes, cheetahs, and ostriches. It covers a surface area of 7,795,000 hectares.
The reserve straddles five Provinces: Batha, Borkou, Bahr el Ghazal, Wadi Fira, and Ennedi-Ouest.
Unfortunately, the years of conflict and drought that the country experienced during the 1970s and 80s had negative consequences on Chad's wildlife. The scimitar-horned oryx (*Oryx dammah*) became extinct in the wild in the 1980s, but the reserve still supported populations of wild dorcas gazelles, bustards, and dama gazelles.
In September 2014, the Chadian Minister of Environment and the Environment Agency – Abu Dhabi (EAD) signed an agreement to reintroduce the scimitar-horned oryx into RFOROA. The NGO Sahara Conservation was entrusted to implement the activities on the ground in Chad. A new phase of the initiative was renewed in 2019, expanding the reintroduction efforts to include addax (*Addax nasomaculatus*) and dama gazelles (*Nanger dama*), as well as scimitar-horned oryx.

As the Oryx Project enters the final year of its second phase, 2023 has been a pivotal year in the ongoing efforts to restore and conserve the threatened populations of scimitar-horned oryx, addax, dama gazelles, and North African ostriches in the RFOROA.

A significant milestone was achieved this year with the formal downlisting from "Extinct in the Wild" to "Endangered" of the scimitar-horned oryx on the IUCN Red List of Threatened Species. This achievement reflects collaboration and long-term commitment, demonstrating how global interests align with local desire to see these animals back where they belong.

In 2023, another step was taken in dama gazelle conservation: for the first time in RFOROA's history, dama gazelles from a captive breeding group were successfully fitted with GPS tracking devices and released into the reserve, enabling us to monitor their movements and integration into the existing wild population of approximately 50 individuals.

Through rigorous monitoring and data collection, we have gained valuable insights into movement patterns, habitat preferences, and social dynamics of both reintroduced and wild-born scimitar-horned oryx. These findings will inform future conservation efforts and provide essential information on the ecological needs of oryx in their natural habitat.

As we continue to build on the successes of our conservation strategies, the Oryx Project remains committed to restoring not only oryx populations but also the ecosystems that support them. Through community engagement, scientific innovation, and rigorous monitoring, we are paving the way for a future where oryx thrive in their natural habitats alongside the people and vibrant biodiversity of the Sahelo-Saharan region.

Section I. *EX SITU* MANAGEMENT OF THE ENDANGERED SPECIES

Mohammed Manea Al Remeithi

Section Head - Animal Assessment and Conservation -
Terrestrial and Marine Biodiversity -
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1. Executive summary

This report provides a detailed overview of the continued efforts and achievements of the Scimitar-horned Oryx and other endangered species Reintroduction Project, led by the Environment Agency – Abu Dhabi, in collaboration with the Government of Chad and Sahara Conservation. Throughout 2023, we continued to strengthen our breeding programs and expand the reintroduction of endangered species, with significant progress made in translocating and establishing genetically diverse populations of scimitar-horned oryx, addax, and dama gazelles.

Key achievements in 2023 include exceeding the original target of 500 wild oryx in Chad, with the wild herd now numbering over 600, and further downlisting the species' conservation status of the scimitar-horned oryx on the IUCN Red List from 'Extinct in the Wild' to 'Endangered.' This represents a major milestone for the Project and highlights the effectiveness of our conservation efforts. The Project also expanded its focus on addax and dama gazelles, ensuring these species continue to thrive in their natural habitats.

2. *Ex situ* management of the endangered species

The Environment Agency – Abu Dhabi (EAD) has been at the forefront of wildlife conservation through its leadership in the Scimitar-horned Oryx Reintroduction Project. This initiative, launched in collaboration with the Government of Chad and Sahara Conservation, aims to reintroduce species that had been extinct in the wild, specifically in Chad's Réserve de Faune de Ouadi Rimé-Ouadi Achim (RFOROA).

In 2023, EAD continued its leadership in the *ex situ* management of the scimitar-horned oryx, addax, and dama gazelle as part of the ongoing efforts to restore the species to their historical range in Chad. The breeding and management program at EAD's Deleika Wildlife Conservation Centre in Abu Dhabi remained central to maintaining a healthy, genetically diverse population of oryx for reintroduction.

3. Breeding and genetic diversity

The primary objective of the *ex situ* management program is to ensure the genetic diversity and health of the scimitar-horned oryx, addax, and dama gazelle populations. In 2023, the breeding program saw continued success, with efforts focused on enhancing genetic diversity. This included the integration of genetic material from oryx populations sourced from Europe and the United States, ensuring that the gene pool remains robust and resilient.

Genetic analyses, conducted in collaboration with the Royal Zoological Society of Scotland (RZSS), played a key role in selecting animals for breeding and reintroduction. The results of this analysis indicated a continued increase in mitochondrial diversity within the reintroduced population, reflecting the positive impact of the program's genetic management strategies.

4. Animal preparation for translocation

In 2023, a total of 20 scimitar-horned oryx and 30 addax were selected and prepared for translocation to Chad. Each animal underwent a comprehensive health and fitness evaluation, including vaccinations and tests for common pathogens. This screening process ensures that only the healthiest animals are chosen for reintroduction, minimizing risks to both the animals and the wild populations they will join.

The physical preparation of the oryx and addax included conditioning the animals in pre-shipment pens at the Deleika Centre. The preparation phase is critical in acclimating the animals to the conditions they will face in the wild, such as varying temperatures and terrains. Each animal was tagged with an ear tag and fitted with an intradermal microchip for tracking and monitoring purposes once in the wild.

Fig. 1. Oryx health screening process at the Deleika Wildlife Conservation Center

5. Translocation logistics

The translocation of oryx from Abu Dhabi to Chad is a highly coordinated operation. In 2023, the animals were transported during the cooler months to ensure their comfort and survival. The translocation logistics were meticulously planned, with redesigned transport crates used to enhance animal safety during the journey.

The oryx were flown from Abu Dhabi to Abéché, Chad, and then transported by truck to the pre-release enclosures at the RFOROA. The timing of the release was aligned with seasonal conditions in Chad, ensuring the best chances for survival as the animals adapted to their new environment.

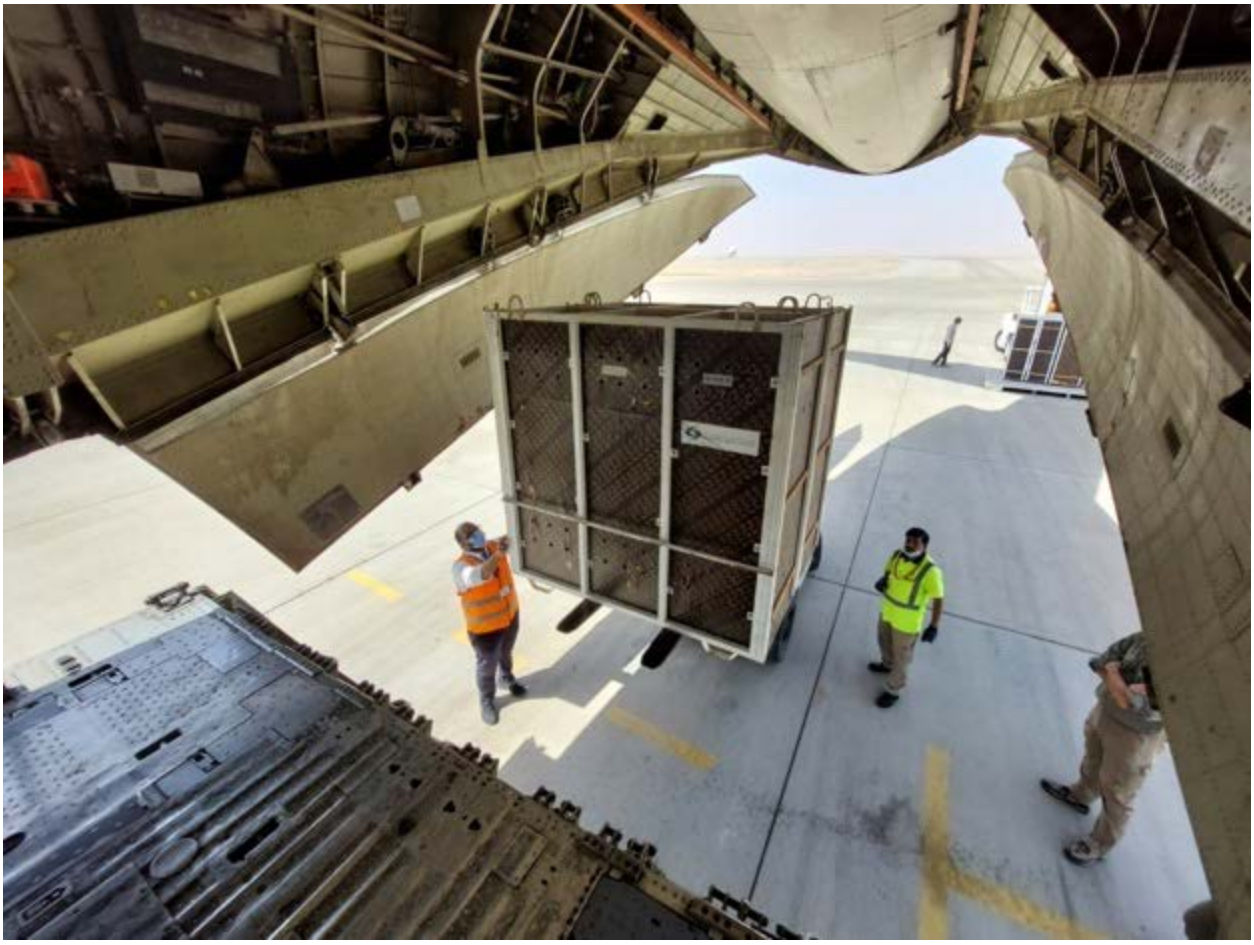

Fig. 2. Oryx in crates being loaded on the plane in Abu Dhabi

Fig. 3. Plane transporting oryx from Abu Dhabi landing in Abéché, Chad

6. Achievements

By the end of 2023, the *ex situ* management program had successfully maintained a healthy, genetically diverse population of scimitar-horned oryx. The oryx released this year contributed to the growing wild population in Chad, which now exceeds 600 individuals. This milestone is a major achievement, marking significant progress in the species' recovery from extinction in the wild.

The success of the *ex situ* management efforts at the Deleika Wildlife Conservation Centre continues to play a critical role in the long-term conservation of the scimitar-horned oryx and other endangered species, serving as a model for conservation programs worldwide.

Section II. *IN SITU* MANAGEMENT

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Project Director – Sahara Conservation

Mahamat Hassan Hatcha
Ouadi Rimé–Ouadi Achim Faunal Reserve Coordinator - Direction de la Faune et des Aires Protégées, Ministère de l'Environnement, la Pêche et du Développement Durable

1. Human resources

1.1 Staff

As the second phase of the Oryx Project comes to an end (2019-2024), twenty-two people are currently employed full-time on the project: 16 at the reintroduction site and six in the Chadian capital, N'Djamena, providing administrative and logistical support to the Project, in addition to the Sahara Conservation team based in France.

Situation December 2023	
Name	**Position**
Marc Dethier	Project Director
Honoré Todjibaye Midjigue	Cook
Dieudonné Kephas Doldiguim	Cook
Evariste Djibkibeng Malbe	Mechanic
François Madjitigal	Tractor driver/Driver
Yacoub Hassaballah Hagry	Driver
Mahamat Abdourassoul	Tractor driver
Djiddi Aklabach Ali	Tractor driver
Oumar Annadif	Head animal keeper and ecological monitoring officer
Kher Issakha	Animal keeper and ecological monitoring officer
Loutfallah Ali	Animal keeper
Habib Ali Hamit	Ecological monitoring officer
Taboye Abdelkarim	Ecological monitoring Team leader
Hissein Gadeye	DFAP permanent escort guard
Ahmat Anour	Driver
Daniel Nahodjingar	Administrative and financial manager
Nathan Djegolbe Watade	Administrative and financial assistant
Delphine Gossumta	N'Djamena office housekeeper
Dana Mahamat	N'Djamena office security
Debi Ali	N'Djamena office security
Takadji Nanga Yanga	N'Djamena office security

1.2 Staff activities

Marc Dethier, Project Director, returned to work for the Oryx Project in August 2023. He oversees and supports all field activities at the Oryx Base Camp (OBC), with assistance from the administrative and logistical team in N'Djamena.

Culinary team

Honoré Todjibaye Midjigue and Dieudonné Kephas Doldiguim are the cooks at the Oryx Base Camp. They manage the food supply by organizing the purchase of provisions from nearby towns. Having two cooks

allows the ecological monitoring team to stay in the field for several days without needing to return frequently to OBC.

Maintenance and transport

Evariste Djibkibeng Malbe and François Madjitigal are responsible for the maintenance and repair of vehicles. Yacoub Hassaballah Hagry and Abdoulrassoul Mahamat drive light vehicles, while Djiddi Aklabach Ali exclusively operates tractors. Ahmat Anour is a driver in N'Djamena.

Animal care and monitoring

Oumar Mahamat Annadif and Kher Issakha monitor the diets of animals in the enclosures and participate in field monitoring activities. Loutfallah Ali and Djiddi Akhabach Ali provide daily food and water for the animals.

The animal keepers start their day around 5 a.m., closing the drinking troughs in the enclosures to prevent attracting birds and jackals during the day. They prepare appropriate food for various species, including scimitar-horned oryx, addax, dama gazelles, and North African ostriches. At 3 p.m., they reopen the water troughs while remaining on-site to deter birds, especially crows, ravens and vultures that pollute the water, and distribute food. They also assist with maintenance at OBC.

Ecological monitoring

Taboye Abdelkerim, Habib Ali Hamit, and Ali Mahamat (since 2024) conduct ecological monitoring of animals in the wild. They are in constant contact with the teams from the Zoological Society of London (ZSL) and the Smithsonian's National Zoo & Conservation Biology Institute (NZCBI) and go into the field every day to observe the behavior of the oryx and addax. They carry out two field outings each day, one in the morning to observe distant groups and another in the afternoon closer to the camp.

Administrative support

In N'Djamena, Nathan Watadé serves as the administrative support officer under the supervision of Daniel Nahodjingar, Sahara Conservation's finances and administration manager. Four staff members handle security and maintenance at the Sahara Conservation office: Ali Debi, Takadji Nanga Yanga, and Dana Mahamat as security, and Delphine Gossumta as a housekeeper.

All staff members are employed by Sahara Conservation and registered with the National Social Security Fund. At the Oryx Base Camp, they have meals and accommodation, along with access to electricity, running water, internet, and television.

Additional activities

When needed, all staff members participate in special activities, including:

- Extinguishing bush fires
- Coordinating the logistics of transferring oryx and addax between Abéché and the reintroduction site

1.3 The rest period system

Given the staff's distance from their homes, a system has been set up to allow them to reunite with their families during their time off. In accordance with labor regulations, each Sunday worked counts as a day gained for leave purposes.

Following consultation in 2022, staff were granted 20 working days of rest after a two-month (60 days) stay at OBC.

1.4 The Directorate of Wildlife and Protected Areas escort guard

For all journeys between N'Djamena and OBC, the ranger Hissein Abderahim Gadaye, assigned to the project by the Ministry of the Environment, Fisheries and Sustainable Development (MEPDD) (Memorandum No. 004/PR/PM/MEP/SG/DPELCB/2017), escorts the vehicles.

1.5 Temporary staff

From September to October 2023, ten people from the area were hired to help create firebreaks.
They also carried out various jobs around OBC and the enclosures. Six of them stayed on in early November to assist with the arrival of oryx and addax.

At the beginning of November, a group of ten women from Arada came to OBC for five days to build a small "nomad camp", comprising five traditional huts, to house a delegation from the Ministry of the Environment, Fisheries and Sustainable Development, who visited OBC on November 14 and 15, 2023. The camp now serves as housing for visitors.

Fig. 1. Construction of the traditional huts

1.6 Interns

During the 2023-2024 period, the Project supervised four trainees, including three university students:

- Mahamat Ali (a graduate of the Garoua Wildlife School, Cameroon) placed camera traps in the 28 km^2 circular exclusion zone around OBC,
- Amné Abderahim (Degree 2 in Biology of Plant Organisms at the University of Abéché),
- Reine Balamon Mandeba (Master 2 in Plant Biology, University of N'Djamena),
- Rachida Nassingar (4th year of Veterinary Medicine at Alexandria University, N'Djamena). All three conducted research on woody vegetation in the same 28 km^2 area around OBC.

1.7 Oryx Project staff training

First aid

From November 16 to 20, 2023, an instructor from Mellivora Systems gave an introductory course in first aid to six staff members at OBC. Hissein Gadaye, the project's escort ranger, also completed the medic refresher course, enabling him to acquire the essential skills for responding to emergencies.

Drone training

From January 4 to 7, 2024, project staff (Oumar Annadif, Evariste Malbe, Rachida Nassingar, and Ali Mahamat) were trained in the use of small drones.

Fig. 2. Drone training

IMET

From February 11 to 15, 2024, several team members took part in an Integrated Management Effectiveness Tool (IMET) workshop to assess the effectiveness of conservation activities in the reserve.

Hypodermic rifle

From February 16 to 29, 2024, Taboye Abdelkerim attended a workshop to "train trainers" from the Ministry of the Environment, Fisheries and Sustainable Development on techniques for capturing wild animals with hypodermic rifles.

Vulture ecology

From February 26 to March 5, 2024, expert André Botha, co-chair of the IUCN Vulture Specialist Group, came to OBC to train staff in vulture ecology. He also demonstrated the proper way to attach a GPS transmitter to a vulture's back.

Fig. 3. Vulture tagging

2. Infrastructure management and maintenance

2.1 Base camp management

Work to extend OBC was completed in October 2023. The wire fencing encircling OBC was replaced with wire of a tighter mesh to prevent jackals from approaching and piercing holes in the water bladders. Chicken-wire was also placed around the bladders to prevent squirrels from puncturing them.

To enhance the comfort of the rangers protecting OBC, an electric cable was laid between the base and their camp, which now has permanent electricity and access to the OBC's internet connection.

Fig. 4. Construction of OBC extension

Fig. 5. Upgraded OBC facilities.

2.1.1 Water management

Two water bladders, totaling 500 m³, have been installed at OBC to meet the needs of both humans and the animals held in the enclosures.

From October 3 to November 20, a 24 m³ truck-mounted water bowser supplied water to OBC on two occasions, completing 21 journeys (150 km round trip) between Arada and OBC. Due to rising fuel prices, the cost per trip was 250,000 CFA francs in 2023, and has increased to 300,000 in May 2024. Water has to be trucked in because ground water is not accessible due to impermeable bedrock.
Monitoring water consumption reveals that one person consumes an average of 70 liters of water per day to meet their needs.

2.1.2 Electricity management

Since the construction of OBC in 2016, one of the primary goals has been to utilize green energy for electricity needs (solar, wind). However, an 18 kVA generator was purchased as an emergency backup system.

In 2022, a reassessment led to the installation of 93 450-watt solar panels, providing a total output of 41,850 watts—six times larger than the previous setup (6,750 watts).
During the night, a 3,000W wind turbine charges the batteries to meet constant needs such as refrigeration, internet, computer operation, lighting, and cooling fans for equipment.

2.1.3 Internet connection management

Reliable internet connectivity is crucial for the Project's operations. It enables the monitoring of animals fitted with GPS collars (oryx, addax) and serves as the only reliable means of communication with the outside world.

For tasks such as sending reports, photos, and other large files, we have opted for a dedicated bandwidth of 3072/1024 kbps (3/1 mega) for 1,500,000 CFA francs per month.

2.1.4 Vehicle management

Small vehicles

The Oryx Project operates:

- 4 Toyota twin-cab pick-ups,
- 2 Toyota single-cab pick-ups,
- 1 Toyota V8 station wagon.

All the vehicles are in good working order and properly insured.

Fig. 6. Oryx Project motor vehicle fleet

The Toyota twin-cab 18C4107TT is currently assigned to the ecological monitoring team and has an average annual mileage of 31,000 km, primarily for observing oryx and addax.

The single-cab pickup 18C4213TT is utilized for logistics at OBC, transporting personnel to and from the enclosures, and has been extensively used for bush fire control, averaging 18,000 km/year.
The twin-cab 18C4328TT has an average of 30,500 km/year.

The Toyota Land Cruiser V8, 18C4484TT (donated by EAD in July 2017), facilitates trips between N'Djamena and OBC (1,200 km) but is primarily stationed in N'Djamena. In May 2024, it recorded 101,009 km, supporting EAD personnel on missions in Chad.

VEHICLES	PURCHASE DATE	MAIN USE	MILEAGE IN KM December 2022	MILEAGE IN KM May 2024
Land Cruiser twin-cab 18C4107TT	August 2015	Addax/ oryx/ ostrich ecological monitoring	257,004	276,812
Land Cruiser single-cab 18C4213TT	January 2016	Enclosed animal monitoring	153,155	162,514
Land Cruiser twin-cab 18C4328TT	August 2016	Oryx/ addax/ ostrich ecological monitoring	263,077	273,712
Land Cruiser V8 18C4484TT	July 2017	Liaison OBC / Biltine/ Arada/ N'Djamena/ Ati/ Abéché		101,009
Land Cruiser twin-cab 18C5206TT	May 2021	Liaison OBC / N'Djamena/ Abéché/ Ati/ Biltine/ Arada	85,690	139,799
Land Cruiser twin-cab 18C5207TT	May 2021	Oryx/ addax/ ostrich ecological monitoring	58,699	97,240
Land Cruiser single-cab 18C5208TT	May 2021	Logistics / infrastructures maintenance		77,128

As our activities expanded, we acquired three new vehicles: one "single-cab" and two "twin-cabs" from CFAO in N'Djamena. The single-cab 18C5208TT and one twin-cab 18C5206TT are used for logistical support, while the second twin-cab 18C5207TT is dedicated to the monitoring team.

Sahara Conservation's Toyota twin-cab, based in N'Djamena, regularly supports these vehicles. Each vehicle is equipped with a GPS/InReach system, ensuring real-time movement tracking, driver safety, and text communication, including the transmission of the coordinates of collared animals to field teams.

Tractors

At the moment, four tractors and plows are used for making firebreaks and bush fire control. All the related operating costs are covered by the Oryx Project (fuel, maintenance, repairs, etc.).

- John Deere 6100D
- John Deere 5503
- John Deere 5500 (dysfunctional)
- Erdvark G40B motor graders (2)

In August 2023, we used the tractor-drawn graders for the first time. The blade width of these G40 graders is 3.1 meters, which is more efficient than the disc plows. They are ideal for creating and maintaining firebreaks.

Fig. 7. Oryx Project tractors

Fig. 8. Grader

2.1.5 Food management

We mainly buy food in the neighboring towns of Biltine and Abéché, and from time to time in N'Djamena, and fresh produce and meat from the weekly markets in Arada and Biltine or from nearby herders. Food is stored in the refrigerators and freezer installed in the kitchen.

On average, at least 12 people are constantly present at the OBC, with major increases when hosting various missions, such as the oryx and addax arrivals.

2.1.6 Enclosure management

Oryx enclosure

The wide mesh of the fence of the oryx enclosure does not prevent jackals from entering, as they can slip in by jumping through the highest and widest mesh.

In September 2023, 1,300 meters of large-mesh wire fence in the oryx enclosure (20 ha) were replaced by small-mesh fencing. The work was carried out over 15 days by a group of six people.

Addax/dama enclosure

In October 2023, a capture zone was set up in the "Moussa" group dama enclosure to facilitate capture and fitting of GPS collars on the animals.

A capture area with wire mesh modules was set up in the "Firmin" group dama enclosure to transfer the eight females present in this enclosure to the "Andrea" male's enclosure. Evariste, the mechanic, built a door that was placed along the outside fence on the east side to allow the team to enter this capture area.

Fig. 9. Fence work in the dama gazelles enclosure

2.2 Firebreak network

To protect the Project's facilities, along with the reintroduced animals and their grazing, we have opened a network of firebreaks, which also benefits local herders and their livestock.

A team of 10 laborers from the Wadi Fira and Batha regions spent 21 days building firebreaks using a plow-and-burn technique. They opened up 196 kilometers of firebreaks in the RFOROA, including 135 kilometers that utilized a 60-meter-wide plow-and-burn approach. This preventive fire technique involves burning a wide strip of grass between two plowed strips of land. When executed effectively, it can create wide firebreaks, measuring up to 50 meters.

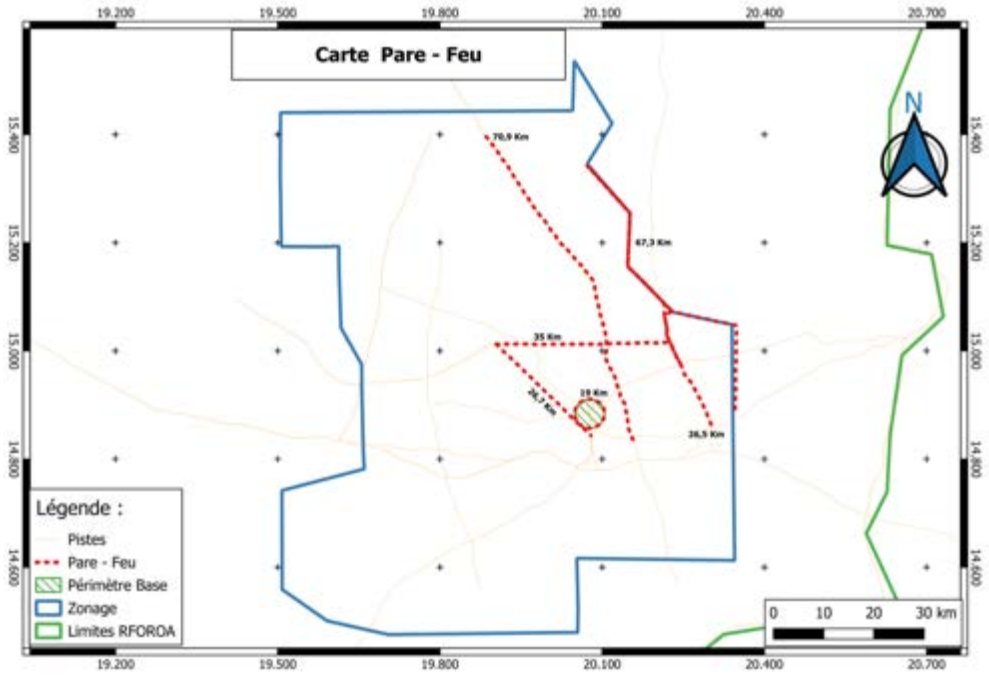

Fig. 10. 2023 firebreak network mapping

Fig. 11. Bush fires

Fig. 12. Creating firebreaks

2.3 Aerial support

2.3.1 Creation and maintenance of the landing strip

A compacted earth landing strip has been created in RFOROA, located 8 km south of OBC. Maintaining the strip involves grading the surface twice a season to remove vegetation and to level the hoofprints left by domestic livestock during the wet season. Because of temporary flooding, the strip cannot be used during the rainy season unless there are at least two days between consecutive rain showers, allowing sufficient time for the surface to dry.

The strip is 1,200 meters long. Aircraft such as Cessna 172 (Wings for Conservation), Cessna 182 (African Parks, MAF), and Cessna Caravan (MAF, AVMAX) land there. The strip is marked out and equipped with a regulatory windsock.

In November 2023, the Minister's delegation came to OBC aboard an AVMAX Caravan aircraft.

2.3.2 Cooperation with Wings for Conservation

A 6-month contract was signed with Wings For Conservation (WFC) for 20 flight hours/month with the Cessna 172 piloted by Jaime Dias. WFC is involved in the tracking of oryx and addax, the census of dama gazelles, and in the collaring of wild animals.
Unfortunately, Jaime Dias left Chad in January 2024.

2.4 Other offices

The project rents a villa in N'Djamena, divided into several offices.
A house in nearby Arada is also rented.

3. The different species in the enclosures

3.1 Scimitar-horned oryx

On November 7, 2023, a twelfth group of 15 oryx, fitted with GPS collars, arrived in Abéché from Abu Dhabi and was transferred to the pre-release, quarantine enclosure. After spending 61 days in the enclosure, the oryx were successfully released on January 17, 2024.

As a reminder:

Date	Number of founders	Release date
16 March 2016	25	14 August 2016
14 November 2016	25	21 January 2017 (14 released)
18 January 2017	25	3 August 2017 (42 released)
11 February 2018	25	6 August 2018
15 February 2018	25	6 August 2018
18 February 2018	25	6 August 2018
25 February 2019	25	17 September 2019
11 November 2019	25	17 December 2019
3 March 2020	25	22 September 2020
8 November 2021	25	5 December 2021
14 March 2022	20	17 August 2022
7 November 2023	15	17 January 2024
TOTAL	**285 individuals**	

In June 2024, there were no oryx in captivity.

Fig. 13. Oryx released from their crates.

Fig. 14. Oryx soft release into the reserve

3.2 Addax

Twenty-five addax arrived on November 14, 2023, and were released after spending 56 days in their quarantine enclosure, on January 16, 2024.

As a reminder:

Date of arrival in Abéché	Number of founders	Release date
13 November 2019	15	January 2020
6 March 2020	25	7 September 2020
15 November 2021	25	12 December 2021
7 March 2022	25	August 2022
14 November 2023	25	16 January 2024
TOTAL	**115 individuals**	

In June 2024, there were no addax in captivity.

Fig. 15. Addax released from their crates.

3.3 Dama gazelles

On November 11, 2023, a large team (EAD, MEPDD, SC, NZCBI, ZSL) involved in reinforcing the dama gazelle population placed three GPS transmitters on one female and two male dama from the "Moussa" group. On January 22, 2024, all six gazelles in this group were released from their enclosure. This group of dama, all from the RFOROA region, includes three males (two of which are wearing GPS tags) and three females (one of which is wearing a GPS collar).

Fig. 16. First dama gazelle release to the reserve

To promote genetic diversification, the dama females that were with the "Firmin" male were transferred to the "Andrea" male's enclosure. The eight females (four adults from Abu Dhabi and four juveniles born in the enclosure) passively changed enclosure on December 26, 2023.

There are currently (September 2024) 31 dama gazelles in the enclosure:

- Kalle group: 15 animals
- Andrea group: 15 animals
- Firmin group: 1 animal (1 male)

3.4 North African ostriches

At the beginning of 2023, one male and three females were in the enclosure. Two of the females laid eggs.

First nest

On February 21, 2023, for the first time in 50 years in the reserve, ten ostriches hatched (out of 20 eggs laid). They were released into the reserve 11 months later, in January 2024. They stayed next to the enclosure for about a month before moving further east into the RFOROA. These ostriches are not fitted with GPS tags.

Second nest

On December 24, 2023, a nest with two eggs was observed in the enclosure. A total of 12 eggs were counted before incubation began on January 15, 2024. The first hatch occurred on February 28, 2024, and by March 16, the ostriches had stopped incubating. Five ostriches were born, while the remaining 16 eggs were returned to OBC.

Fig. 17. North African ostriches and nest

On March 29, we observed that one chick could no longer stand on its feet. Two days later, a second ostrich showed the same symptoms: difficulty, if not impossibility in standing upright, loss of appetite, trembling wings, and crooked neck. We took them back to OBC to monitor their condition and prevent the condition from spreading.

We contacted veterinary surgeon Dr. Willem Burger, who advised us to inject an antibiotic (Limoxin 1 ml) and give Coca-Cola (5 ml, five times/day). Unfortunately, the condition worsened, and eventually, both ostriches died.

There are currently four ostriches in the enclosure (one male and three females) and another three 4-month-old ostrich.

4. Event management or participation

August 2023

- Meeting with Bertrand Dayot, head of mission for the PREPAS livestock program, to discuss the work carried out by the Oryx Project, especially regarding the fight against bush fires (village vigilance committees).
- August 30: an MEPDD team visited the OBC on a mission to monitor and evaluate the activities of RFOROA eco-rangers. The team included Hamat Hissein Mahamat Itno (Deputy General Director of Forestry, Wildlife and Fisheries), Kemba Kya Dambil (Legal Affairs and Litigation Department), and Director Abderaman Chaibo (DFAP).

September 2023

- We hosted Jean-Didier Apkon, Moussa Sougui, and Benjamin Saunders from African Parks for three days, to discuss the logistics of the arrival of addax in the Ennedi Nature and Cultural Reserve (RNCE). We later assisted the RNCE team by lending 67 wire mesh mobile units and 85 t-bars to construct the addax pre-release enclosure in Terkey. The Oryx Project director, along with Yacouba Hassaballah and ranger Hissein Gadeye, traveled to Terkey (RNCE) to assist the on-site team with the assembly of these fencing modules.

Fig. 18. Enclosure construction in Ennedi Natural and Cultural Reserve

October 2023

- Habib Ali Hamid participated as an onboard observer in the overflight mission with Wings for Conservation in the Koundjourou area.
- October 30 and 31: the Albia project mid-term evaluation team stayed at OBC, leading to several fruitful exchanges.

November 2023

- November 7 and 8: we provided logistical support to the RNCE for the arrival and release of 10 addax into the Terkey quarantine enclosure.
- November 14, 25 addax were translocated to the RFOROA. On this occasion, we welcomed:
    - The Minister of the Environment, Fisheries and Sustainable Development and a delegation from the Ministry,
    - A delegation from the Governorate of Wadi Fira and the canton chiefs linked to RFOROA,
    - Two representatives from the Delegation of the European Commission,
    - A team of nine people from the Support program for concerted management of protected areas and fragile ecosystems in Chad (APEF).

Fig. 19. The Chadian environment Minister about to release addax (second from the left)

- November 15 to 19: a three-person team from the African Parks (AP) Incubator Program (Marketa Antoninova, Jean-Marc Froment and Pierre-Armand Roulet) stayed at OBC.

- November 20 to 27: as part of an APEF-funded mission, the Project director flew to Salal to support Wings For Conservation's search for dama gazelles. Eight flights were made, but no individuals were found.
- November 28: telephone interview with Valentin Boulay, France TV Afrique, based in Dakar, on the importance of bush fires and their control in RFOROA.

December 2023

- December 8: Zoom participation in the presentation "The Great Green Wall, restoring Sahelian Ecosystems: Technical and Human Aspects" given by Dr. Y. Ouedraogo, Mr R. Panaditigri, and Prof. C. Vermeulen given in Dubai during COP 28.
- Afterward, we discussed this approach with Prof. C. Vermeulen, which should be implemented in the reserve, particularly in Ouadi Kharma and Ouadi Achim.

January 2024

- January 13: contact herpetologist Olivier S. G. Pauwels, Curator at the Royal Belgian Institute of Natural Sciences, for advice on the 24 young spur-thighed tortoises received from a resident of Bongor.
- January 16 and 17: a team from the RNCE, composed of Maxine Piron, responsible for addax monitoring, and Eudes Idjigberou, head of the RNCE's community department, visited to learn about the monitoring system for tracking the reintroduced animals. Their primary focus, however, was understanding the steps necessary to develop a management plan (PAG). They met with the Coordinator Mahamat Hatcha, and Abdelkarim Youssouf, a former POROA employee, who participated in the workshops for creating RFOROA's PAG.
- January 24: participation via Zoom in a side event titled "Rencontre entre le Sahel et le nord de l'Afrique équatoriale : les défis des questions liées à la transhumance transfrontalière, la survie des aires protégées, les ressources naturelles et les vies humaines, le développement, la sécurité et la paix" organized by the Congo Basin Forest Partnership. This was followed by discussions with Florence Palla (RIOFAC) on the availability of geoservices highlighted during the talk.

February 2024

- February 15: discussions with Violeta Barrios, SC Program Manager, and Florence Palla, RIOFAC Project Coordinator, on the possibilities of benefiting from the Comifac observatory geoservice.
- February 22: Maxine Piron and Nanta Benellem, from RNCE's Conservation Biology department, met the ecological monitoring team, in particular ZSL's Dr. Tim Wacher.

March 2024

- March 2 to 4: the tourist agency EYTE' Voyages stayed at OBC with seven tourists.
- March 12: A Zoom meeting was organized to discuss with Éducation et Santé sans Frontière (Esafro) a health assistance program for the populations of the RFOROA. A first field mission will take place in September 2024.
- March 14: courtesy meeting in Arada with the prefect of the Al-Biher department.
- March 21 to 26: the tour operator SVS stayed at OBC with two tourists on a tour of Africa by car (Sophie and Fabien Pekus).

April 2024

- April 1: at the request of his parents, we assisted in the medical evacuation of a young nomad whose camp was located 10 km from OBC. Unfortunately, despite all efforts, the medical team at Arada hospital was unable to save him.
- April 11 and 12: Erick Mararv (Regional Director), Jean Didier Apkon (RNCE Operations Director), Jonas (Odzala Kokoua National Park Manager), and Manon Zeghdoudi (Odzala Kokoua National Park Tourism and Business Development Manager) from African Parks visited OBC's facilities, took part in an ecological monitoring field mission and watched a young addax being fitted with an ear tag.
- April 18 and 19: following their visit, Kingsley Holgate, a Fellow of the Royal Geographical Society and considered "Africa's most colorful modern explorer", and his Foundation team spent a night at OBC. They went out with the monitoring team in the morning.

5. Project management

5.1 Administrative documents

The Ministry of Environment, Fisheries and Sustainable Development, through the Directorate of Wildlife and Protected Areas (DFAP), plays the following roles:

- Ensure the protection of scimitar-horned oryx, addax, and their habitat by implementing appropriate management of the reserve and maintaining strong cooperation between the various local players;
- Provide all the permits required for the arrival of the animals and the Project's activities (CITES, veterinary, aircraft overflight and landing permits, planning permissions, etc.);
- Provide and help obtain any official permits for staff and operators working on the Oryx Project (invitation letters to obtain visas, residence permits, travel permits, etc.);
- Issue export permits for samples taken from reintroduced animals;
- Facilitate authorizations for documentary filming in the reserve;
- Guarantee and protect the pre-release site chosen by the project team.

5.2 Project staff security

To ensure the safety of the Project's staff, the guards' responsibilities include:

- escorting project vehicles during travels between towns and OBC,
- escorting the ecological monitoring team on field missions,
- guarding aircraft involved in project activities,
- maintaining control over the three-kilometer firebreak around OBC to prevent domestic animals from straying into the area or unauthorized campsites from being set up.

5.3 Law enforcement

Monitoring the reserve and enforcing the law is the responsibility of the government.
Sixty guards are assigned to the northern and southern sectors of the reserve. Forty of them are funded by the ALBIA project.

Patrol efforts primarily focus on areas where reintroduced animals are found, particularly around the Kharma, Mielé, Achim, and Haddad wadis. Due to limited resources, patrols are concentrated in these key areas rather than across the entire reserve. Patrols are conducted by vehicle, with teams of six to seven guards operating in the field on ten-day rotations.

While no incidents of poaching involving reintroduced species occurred in 2023, twelve cases of dorcas gazelle poaching were reported. Six poachers were apprehended, handed over to local authorities, and transferred to the courts.

Fig. 20 Réserve de Faune de Ouadi Rimé-Ouadi Achim rangers

5.4 Fight against bush fires

At the end of each rainy season, bush fires usually occur, often triggered by human activities, such as vehicle exhaust or herding activities.

In 2023, only four cases of bush fires were reported and quickly contained. The limited number of incidents was largely due to the reduced biomass caused by low rainfall that year, as well as the early departure of transhumant herders. To mitigate future risks, the Project's teams constructed several firebreaks in the core areas of the reserve.

5.5 Raising awareness amongst the pastoralist community

The reserve is a livestock area, home to two distinct categories of herders:

- transhumant herders who come up from the South at the start of the rainy season and leave once the seasonal pools dry up,
- local herders who reside in the reserve year-round.

During patrols, the rangers engage with both groups, raising awareness about the reintroduced species, the dangers of bush fires, the illegal poaching of wildlife, and the unchecked spread of portable water bladders and boreholes that are leading to overgrazing.

5.6 Difficulties

Given the size of the reserve, the resources allocated for surveillance under the Project - both human and logistical - are inadequate.

Patrols are faced with a lack of means of communication and personal equipment, and there is a shortage of accommodation and amenities for the rangers.
The project steering committees for monitoring and planning activities has not been held recently.

5.7 Recommendations

- Organize more regular steering committee meetings in accordance with the Project's needs;
- Recruit a local veterinarian for the medical monitoring of released animals, in cooperation with veterinarians in Abu Dhabi and Europe;
- Provide sufficient vehicles and fuel to enhance surveillance of the reserve;
- Provide the necessary means of communication (including Iridium) and personal equipment for the rangers;
- Build adequate housing and amenities at the rangers' camp.

Section III. FIELD-BASED POST-RELEASE MONITORING

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Introduction

Routine post-release monitoring of reintroduced oryx and addax populations was carried out in the field by the monitoring team throughout 2023 and early 2024. External support to the team on data management, particularly supervision of breeding records and coordination of monthly report editing, was remotely provided by the Zoological Society of London (ZSL) through regular email contact. ZSL staff made four visits to Chad to join the monitoring team in the field:

- 22 February 2023 to 12 April 2023,
- 25 August 2023 to 25 September 2023,
- 03 November 2023 to 05 December 2023,
- 21 February 2024 to 25 March 2024.

Fig. 1. Oryx project ecological monitoring team

1. Oryx and addax monitoring

- The CyberTracker sequence was regularly updated to reflect changes in the status and number of tagged individuals. The update extended identity codes in anticipation of future wild-caught tagging events for oryx and addax. Minor corrections were made, such as fixing errors in sex attribution for wild-tagged calves, and a new capacity was added to track individual satellite and ear-tagged dama gazelles, using methods consistent with those for oryx and addax.
- Every month, data verification was conducted on the identification records of tagged oryx and addax, alongside maintaining monthly resighting histories for each individual. By December 2023, this process involved reviewing CyberTracker field records for 170 surviving founder oryx, 148 tagged wild-born oryx, 80 surviving founder addax, and 60 tagged wild-born addax.
- A comprehensive monthly matrix was created, documenting the presence or absence of a functioning satellite collar for each oryx and addax from 2016 through 2023.
- Monitoring team members received refresher training in the field on how to use the CyberTracker sequence. This included reviews of data management methods and reinforcement of daily monitoring routines. In collaboration with NZCBI, a more efficient system was developed for identifying priority individuals to locate each day, based on their distance and direction from OBC.
- Opportunistic maintenance of a Dropbox photographic library for all founder oryx and tagged calves, organized by release group, was carried out. These images were made accessible to colleagues at DFAP, EAD, SC, and NZCBI, with a particular focus on providing imagery of the original founders from the earliest release groups—some of which no longer have collars or tags—as verifiable evidence of their survival and identification.
- Planning and execution of three-line transect surveys were carried out in collaboration with the DFAP Coordinator of the reserve, Mahamat Hatcha. A training presentation was developed and delivered to participants, covering key methods and responsibilities for surveys, results from previous surveys, and photographic guides to help distinguish commonly confused species such as foxes, cats, bustards, and vultures. Training also included proper GPS settings and navigation for transect surveys.

Fig. 2. Terrestrial line transect team

- Three internal supplementary reports were prepared and shared with partners, containing full analysis and results of the four-day line transect surveys conducted in March, September, and November 2023. These surveys estimated the mean oryx population at over 600 individuals in all three surveys. Additionally, formal density estimates were provided for dorcas gazelles and three species of large bustards, alongside data on livestock encounter rates and distribution.
- Participation in the capture and collaring/recollaring of released and wild-born oryx was carried out in collaboration with EAD, NZCBI, and SC colleagues.
- In collaboration with ZSL colleague Raj Amin, a 7-year analysis (Aug 2016-Aug 2023) using the resighting history matrix, including known deaths for all tagged oryx, was conducted to provide post-release annual survivorship/mortality and detectability estimates, accounting for the presence of functioning satellite collars. Age-specific survivorship comparisons between founder and wild-born males and females, as well as survivorship by season and release group, and survivorship by season of birth, have all been examined. Key outputs have been worked into a manuscript also covering translocation management and performance (>97% survival from capture at EAD to the moment of release 2 to 6 months later, among 263 oryx moved from EAD Deleika to RFOROA). The in-preparation version of the manuscript was circulated to SC and NZCBI before submission of a 'first draft' to EAD.
- The actual founder population and supplementary annual releases, with actual sex ratios over the period 2016-2023 were entered into Vortex 10, along with litters/year, based on the observed median calving interval (313 days) and known proportion of calving founder females (95%) in Chad. The observed sex ratio among 148 wild births (53% male) was also used, with estimated mortality rates and the confidence intervals for oryx males and females under and over one year of age, derived from the resighting matrix. The preliminary Vortex outputs based on these 'real' field values predicted a population between 500-700 oryx by 2023, with means close to 600.
- The general concordance between three independent approaches to estimating oryx population size (Vortex modelling predicting c. 600, three-line transect sample surveys all estimating between 620-640 oryx (though with very large confidence intervals), and a total aerial count over two days in September 2023 reporting 551 different oryx seen) provided the project's evidence for downlisting of the scimitar-horned oryx by the IUCN Red List status from 'Extinct in the wild' to 'Endangered'. It should also be noted that none of the transect sample surveys nor the aerial count covered all areas known to be in use by oryx at the time they were conducted.
- These analyses do not include events that unfolded during the particularly harsh dry season of 2024. Between May and July 2024, the monitoring team recorded the deaths of at least 65 oryx, 31 addax, seven dama gazelles, and found 88 carcasses of dorcas gazelles. Livestock using the area were similarly affected with high mortality rates, and these problems were not specific to the reintroduction program, being widely linked to drought, in this case reflecting a widespread loss of pasture combined with exceptionally high temperatures.
- In response, ZSL participated with SC and NZCBI in planning a coordinated aerial and ground transect survey to collect a wider overview of the situation. A full profile of the age, sex, and origins of the deceased oryx and addax was prepared and reported, along with an analysis of monthly temperature data from the OBC weather station.
- Results of these responses showed that detected losses occurred predominantly among younger age classes and the most recent releases (though collars on the latter provide a biased

measure); the survey information is still to be analyzed, but the weather station confirmed that March-May were the hottest three months recorded at the release site since the project began.

- It is noted that the population modelling approach used for the analyses conducted in 2023 allowed for two catastrophe events (loss of 10% of the population each time) every ten years (putatively one due to disease and one due to drought). The Oryx Project experienced a disease-related event in 2018, and now this drought has provided a second episode of rapidly elevated mortality six years later. Future monitoring must continue to determine if the modelling results are borne out by the future progress of the reintroduced oryx and addax.

2. Dama gazelles monitoring

- A database summarizing daily numbers, pen management organization, births, deaths, and origin of all captive dama gazelles held at OBC was maintained in collaboration with the monitoring team throughout the period. Initial results for age at first calving for males and females were obtained, along with a preliminary frequency distribution of calving intervals.
- Adherence to the dama management plan was promoted by prompting intervention to move the four female dama from EAD and their calves from pen 5 to pen 2, which changed the accompanying male from Firmin to Andrea. Improved shade and protection for pen-born calves on pens 5 and 6 were initiated, although further enhancement is still required.
- A ground plan for the manual capture of captive dama, aimed at enabling collaring and tagging in line with management plan recommendations ("Moussa's" group of six RFOROA animals, pen 6), was prepared and circulated to EAD and SC colleagues. It was subsequently built by the OBC team. Using this system, the five older members of the group were successfully caught and tagged in November, though the adult female suffered a broken horn.

Fig. 3. Placing a GPS device on a dama gazelle horn

- A Dropbox photographic library was created and maintained, accessible to DFAP, EAD, SC, and NZCBI colleagues, with folders containing chronologically sorted images of each captive individual dama.
- A sub-library was created to organize photographic records of collared and tagged dama gazelles after their release.

- A photographic reference guide was created, grouping images of dama individuals by age categories: 0-3 months, 3-6 months, 6-12 months, 1-2 years, and over two years. A preliminary copy was sent to the SC Niger field team.
- Routine monthly collaboration with Jaime Dias (Wings for Conservation) was maintained to review aerial photographs of all dama groups found during aerial 'total counts'. Direct comparison with the known-age photographic guide was used to obtain a full breakdown of age and sex, describe social group structures, and estimate annual recruitment in the wild dama population reported in each monthly survey. This information is planned to be combined with reproductive performance data collected in the captive group to model the growth prospects of the wild population.
- The release of the six-captive dama, originally planned for December 2023, was delayed until January 22, 2024. Monitoring of these gazelles via the three satellite-tagged individuals was established from the start, with twice-weekly visits. Data were recorded in CyberTracker, following a similar format to the oryx and addax monitoring.
- All the released dama have remained largely within a 10 km (or less) radius of OBC. The adult female and her 3-month-old calf quickly joined nine other wild dama, forming part of a remarkably habituated group that has begun to gather around OBC since the establishment of the captive group. The adult male dama Moussa, likely disadvantaged by blindness in one eye and broken horns, occasionally joined wild dama, usually other males, while the three younger tagged dama mostly remained together.

Fig. 4. Collared dama gazelle joining a bigger group of wild dama.

- Initially, prospects looked positive, but the entire release group was severely affected by harsh drought conditions. The satellite-collared adult female and the horn-mounted satellite-tagged sub-adult male both died in May, at a time when the monitoring team also found five recent wild dama carcasses. The satellite-collared adult male Moussa appears unlikely to survive, but as of the end of June, the other three remain alive with reasonable prospects of survival, being in no worse condition than the fully wild dama. Monitoring them will be challenging as they only carry small ear tags without satellite or VHF transmitters.
- Lessons learned include bringing forward the release dates for future dama reinforcement exercises to the end of the rainy season (August-September) and reviewing approaches to collar and transmitter design for this species.

3. Vultures monitoring

- In March 2023, three days were spent working with Andre Botha (co-chair of the IUCN/SSC Vulture Specialist Group (VSG)), Violeta Barrios, and Cloe Pourchier (SC) to develop a vulture monitoring project for the RFOROA. A presentation summarizing current knowledge of vulture status in the reserve and field data collection initiated by ZSL since 2018 was prepared and delivered. This was followed by field visits to active lappet-faced and Ruppell's vulture nests, including newly discovered nests and those known over the past seven years, demonstrating the vulture nest identification and recording system introduced by ZSL at RFOROA.

Fig. 5. Monitoring of a vulture nest

- As part of the follow-up, Tim Wacher has joined the VSG and developed a dedicated CyberTracker sequence for multi-species vulture monitoring. This allows the recording of opportunistic encounters, feeding and drinking behaviors at identified carcasses and water sources, and the systematic identification of tree and cliff nests, along with associated nest activities. The aim is to harmonize data sets between SC's vulture projects in Niger and Chad. By the end of 2023, the sequence was being tested by a Chadian student and will be finalized in 2024.
- In March 2024, ZSL participated in a return visit by Andre Botha to train and capture three vultures within the OBC perimeter, working with combined SC teams from Chad and Niger.
- SC personnel from both countries jointly reviewed a vulture data monitoring sequence to ensure alignment with the requirements for Chad and Niger.
- Results comparing movements and behavior of the single lappet-faced vulture and two Ruppell's vultures fitted with Spoortrack harness-mounted transmitters in March have been incorporated into monthly reports. The lappet-faced vulture and one Ruppell's vulture have continued to focus their activities around the OBC area, while the second Ruppell's is based in the inselbergs near Biltine but has made excursions across the width of the country to Kanem and briefly into Sudan.

4. Other activities

- Materials were prepared for the identification of mammal fauna at RFOROA (plus a few prominent additional species from further south that were previously found in the reserve). These were used in two interactive sessions conducted with RFOROA guards from Arada and Ati respectively, in September 2023. The objective was to capture local knowledge and nomenclature used by the guards, as well as to clarify some uncertainties in species identification. The sessions were led by the Coordinator, with members of the Oryx Project monitoring team and Tim Wacher helping facilitate. A report compiling Arabic, Goran, French, English, and scientific names for all the medium to large mammal species at RFOROA was submitted to Sahara Conservation and DFAP. The next step to develop a printed guide to mammal species names and identification available for rangers and guards of the reserve is being taken forward by Cloe Pourchier at the SC office in Paris.
- In March 2023, time was spent showcasing the Oryx Project to two groups of specialist tourists. A significant donation from one of the group members enabled SC to bring four students to OBC later in the year.
- In November 2023, considerable time was spent developing programs for four students at OBC, conducting field projects in support of their studies. These projects were supported by a donation from tourists earlier in the year. Three key activities were identified.
    - Mahamat Ali Adoum (wildlife specialist, Ecole de Faune de Garoua, Camroon) led a systematic 27-camera trap study deploying one camera per km^2 within the 3 km perimeter of OBC to investigate mammal species diversity. Training was provided on camera setup, mounting techniques, and management of imagery software (ExifPro and CTAP), with significant progress made. While the cameras were deployed, a program to monitor known and new vulture nests in the local area and to the northwest of OBC was conducted in preparation for vulture studies scheduled for February 2024.
    - Balamon Mandeba Reine (vegetation studies University of N'Djamena) and Amne Abdelrahim Abou-Grene (biology studies, University of Abeche) received training in the use of GPS, rangefinders, and clinometer to lead a study on tree species and thicket density around camera trap sites and a corresponding set of random sites within the 3 km perimeter.
    - Nassingar Madjilem Rachida (veterinary medicine, University of Alexandrie, N'Djamena) led a study to record water consumption of oryx, addax, and dama gazelles in the pre-release pens.

      All four students were encouraged to contribute to the projects. Introductory training in Microsoft Excel was provided by Taboye Abdelkerim Ben, with additional informal guidance from Tim Wacher. An internal report outlining the methods and objectives of the student projects was prepared and submitted to Sahara Conservation.

Fig. 6. Mahamat Ali Adoum setting up a camera trap

Fig. 7. Amne Abdelrahim Abou-Grene, Balamon Mandeba Reine and Nassingar Madjilem Rachida

- During a five-day visit by African Parks' staff to discuss the AP Incubator program, contributions included a presentation summarizing the methods, techniques, and results used to monitor the scimitar-horned oryx, addax dama, and other prominent wildlife at RFOROA. Structured aerial and ground-based overviews of the conditions and habitats in the central reserve area were also provided.
- Data and information on the status of oryx, addax, and dama gazelles were routinely provided in response to inquiries from the Environment Agency of Abu Dhabi and Sahara Conservation staff.

Section IV. REMOTE MONITORING OF ORYX AND DAMA GAZELLES

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1. Summary

1.1 Key findings

- Analyses of seasonal movement behavior by reintroduced oryx revealed that oryx spent the most time (in fact, twice as much time) in a 'resting' state during the hot, dry season and the most time in a 'foraging' state during the rainy season.
- Oryx spent the most time in a 'traveling' state during the cool, dry season, potentially reflecting a cost/benefit tradeoff between energetically costly long-distance movements and the benefit of finding nutritious vegetation at a distant location.
- Throughout all seasons, oryx with more experience were more likely to 'travel' than their less experienced counterparts. However, the impact of experience was weakest during the hot, dry season, indicating that environmental conditions impose greater constraints than the benefits associated with long-distance movements in this season.

1.2 Management applications

- NZCBI personnel collaborated with Fossil Rim Wildlife Center to assess the potential impacts of lightweight GPS collars on dama gazelle, a species known to be sensitive to many physical and management factors. The selected tracking device did not cause any notable physical effects or significant impacts on behavior, indicating that this device is safe for long-term deployment on this species.
- NZCBI personnel shared maps and assessments comparing land surface temperatures and vegetation cover in 2024 to long-term means from 2003 to 2023, as measured by satellite-borne sensors. These products, along with tallies of mortalities across all four species managed in the RFOROA, contribute to a developing description and explanation of the severe 2024 dry season.

1.3 Products

- NZCBI personnel maintained an EarthRanger site to visualize real-time tracking data from reintroduced oryx, addax, dama gazelles, and ostrich on a secure online platform, along with FIRMS notifications to indicate potential bush fires.
- In October 2023, NZCBI personnel presented "Google Earth Engine as a Conservation Tool for Reintroduced Populations and Protected Areas" at Google's "Geo for Good" summit.
- In November 2023, EAD and NZCBI personnel fitted 35 addax and 15 oryx with GPS collars at Deleika Wildlife Center in Abu Dhabi. Most animals were released into the RFOROA, while ten addax were released into the Ennedi Natural and Cultural Reserve.
- Three dama gazelles from the captive breeding population in the RFOROA were fitted with tracking devices. One subadult male was fitted with a horn-mounted solar GPS/satellite tag, while two adults were fitted with lightweight (ca. 400 g) Lotek GPS/satellite collars. These animals were released into the RFOROA in January 2024.
- Seven free-roaming oryx were captured in the reserve and fitted with GPS collars in November 2023. These individuals included two previously captured animals with malfunctioning collars, enabling the recovery of previously lost movement data.
- In May 2024, NZCBI personnel collaborated with Sahara Conservation to submit a grant proposal to NASA. This project would investigate the impacts of fire breaks on bush fires in the RFOROA,

determine best practices for fire break location, type, and size, and support and inform future fire break construction.

- A manuscript on oryx movement seasonality was shared with Sahara Conservation, EAD, and other partners. Following opportunities for revision, this manuscript was submitted to the journal *Movement Ecology,* where it is currently under review.

2. Status of the reintroduced oryx population

Of the 278 founder oryx released into the RFOROA between August 2016 and January 2024, 155 founders were observed alive between January 1, 2023, and May 31, 2024 (current end date of available CyberTracker data). Any founder not directly observed within the previous year is considered a potential mortality. Using this "minimum number known alive" approach, oryx releases exhibit mean annual survival rates of 0.6 to 0.96 (see Table 1). Cohorts nearly always exhibit a lower annual survival rate during the first year after release (paired t-test; p = 0.1). Release 4, impacted by a Rift Valley Fever outbreak in 2018, and Releases 9-10, which faced a historically severe dry season within one year of release, exhibited the lowest founder survival rates.

Table 1. Founder survival for oryx releases 1-10

Release	Time since release (yrs)	Released founders (m.f)	Known living founders (m.f)	Proportion known living	Year 1 founder survival	>Year 1 annual founder survival
1	7.9	8.13	6.5	0.71	1	0.96
2	7.4	6.8	4.6	0.71	1	0.96
3	6.9	14.23	8.11	0.63	0.95	0.905
4	5.9	38.35	5.12	0.23	0.45	0.89
5	4.8	3.20	2.11	0.57	0.65	0.93
6	4.6	7.17	2.7	0.33	0.67	0.8
7	3.8	8.18	5.13	0.69	0.96	0.81
8	2.6	7.18	5.12	0.68	0.8	0.8
9	1.9	5.15	3.8	0.55	0.95	0.63
10	0.5	5.10	1.4	0.33	NA	NA

All founder oryx are marked before release, enabling identification for up to three years via GPS collar and many more years via ear tag (although some founder oryx have lost ear tags after release). Since 2019, the reintroduction project has also marked nearly 150 oryx calves born in Chad with ear tags. However, unmarked Chad-born calves are extremely difficult to identify after weaning from marked dams. Consequently, direct counts of living calves are likely underestimated. NZCBI personnel are actively collaborating with Dr. Tim Wacher and Dr. Raj Amin from ZSL, among others, to estimate survival rates by age class based on data from marked founder oryx and Chad-born calves.

In 2022, the project's ecological monitoring team, along with Dr. Wacher and NZCBI personnel, identified a group of "high priority" oryx across release groups, sexes, life history traits (e.g., reproductive output), and other characteristics. We revised the post-release monitoring program to observe these "high priority" individuals at least once a month. Marked, Chad-born calves comprise a large proportion of this group, increasing the available data to reliably estimate the survival of founder oryx after release and Chad-born oryx after weaning.

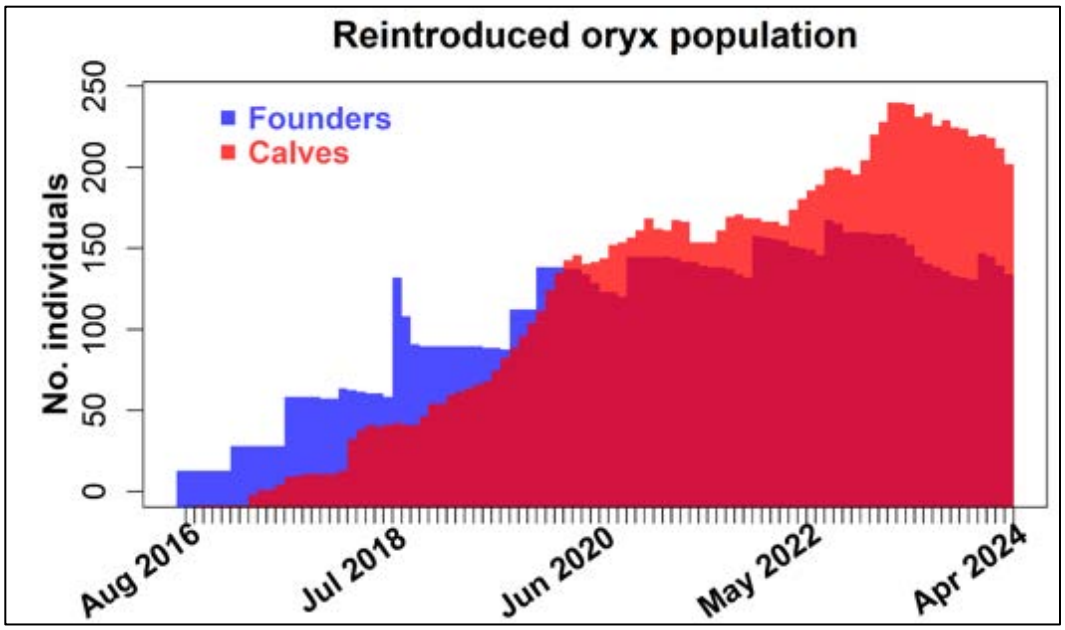

Fig. 1. Estimated number of founder and Chad-born oryx in the RFOROA from August 2016 to May 2024. These "minimum number known alive" population estimates are calculated monthly and consider any oryx not directly observed during the previous year as a possible mortality.

As of May 2024, the Chad reintroduction project has deployed 280 collars on reintroduced oryx. Each deployment lasts between 4 and 1,873 days, with a median of ca. 479 days (Figure 2). Since 2019, all collars fitted to reintroduced oryx have been set to record a GPS location every four hours and communicate positions every 16 to 24 hours. The data transmission frequency is adjusted to maximize collar lifespan and account for previous battery expenditure (e.g., if a collar was previously activated, fitted to an animal, and then removed without full deployment, as occurred in November 2022 and March 2023).

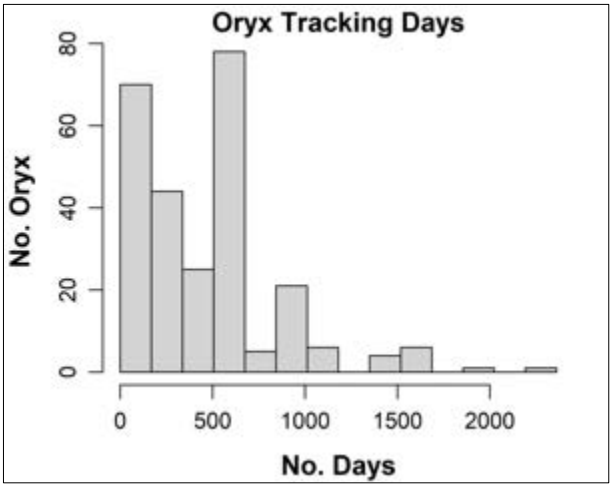

Fig. 2. Tracking durations for founder oryx fitted with GPS / satellite collars. From 2016 to present, reintroduced oryx with completed deployments were tracked for a median of 479 days (range 4 – 1873 days).

Oryx reintroduced into the RFOROA since August 2016 regularly move across an area of 17,370 km^2, roughly centered on the release site (Figure 3). The vast majority of oryx movements occur within the RFOROA, although at least nine animals have been recorded outside the reserve's boundary. In most cases, these individuals spent very little time outside the reserve, and the boundary crossings were part of very long-

distance (>100 km) movements. In response to several long-distance movements by addax in May 2024, we added "geofence" and "locality" alerts to the project's EarthRanger platform to notify the ecological monitoring team and other partners when a collared individual crosses the reserve boundary or approaches within 1 km of known villages or towns.

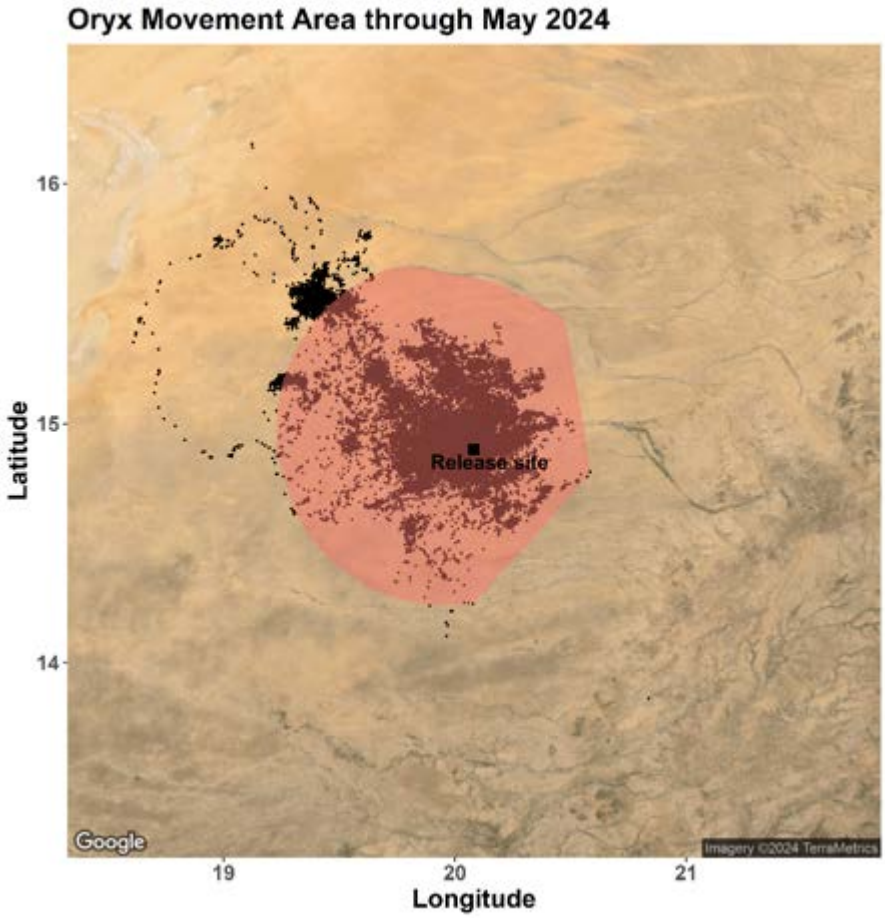

Fig. 3. Oryx movement area, as measured by a 97.5% minimum convex polygon of all locations reported by oryx GPS / satellite collars and direct field observations from August 2016 through May 2024. Black circles indicate locations reported by oryx collars from January 2023 through May 2024.

3. Capture, sampling, and collaring activities in 2023

In 2019, the project adopted a revised monitoring strategy focused on long-term monitoring of a representative sample within the reintroduced population. The target number of 50 was based on a power analysis indicating that at least 50 individuals were required to achieve 80% power to detect the actual difference in survival rates among release groups 1-4 (with α=0.1). This sample size is also a reasonable number of animals for a monitoring team of two to four to regularly observe, based on experiences during Phase I. Data produced through the long-term monitoring of these oryx are used to estimate demographic and population parameters, as well as to evaluate and refine management protocols.

Fig. 4. EAD and NZCBI personnel fitting an addax with a GPS collar at the Deleika Wildlife Center in Abu Dhabi. Oryx and addax collared in November 2023 were released into the reserve in January 2024.

Fig. 5. EAD and NZCBI personnel fitting a dama gazelle with a GPS collar at the oryx release site in the RFOROA. Dama fitted with tracking devices were released into the reserve in January 2024.

Fig. 6. EAD and NZCBI personnel fitting a free-roaming oryx captured in the RFOROA with a GPS / satellite collar. All individuals captured in the field in November 2023 were released within 40 minutes.

From November 11 to 13, 2023, a joint team of personnel from EAD, SC, ZSL, NZCBI and IRED (Chad Livestock Research Institute for Development) captured, sampled, and collared seven free-roaming oryx.

The Project's ecological monitoring team located groups of oryx in the field, and NZCBI and ZSL personnel ranked individuals in each group based on release, collar function, birth type (founder or Chad-born), calving history, sociality (to maximize the potential for monitoring other oryx), and other factors. Once priority oryx were selected, EAD personnel maneuvered a vehicle typically used for field monitoring (such that most reintroduced oryx are acclimated to its presence), allowing Dr. Jon Llona Minguez of EAD to dart the selected individual. Once an oryx was sedated, EAD personnel approached on foot and restrained the animal using horn covers and applying pressure to various body sections. Once the animal was immobilized, additional team members approached to conduct a brief health check and collect biological samples. The following samples were collected from each oryx:

- 2-3 x 9 mL tubes of serum
- 2-3 x 9 mL tubes of whole blood preserved in EDTA
- 2 x nasal swabs preserved in RNALater
- 2 x oral swabs preserved in RNALater
- 2 x ocular swabs preserved in RNALater
- 1 x fecal sample collected per rectum
- Attached parasites (e.g., ticks) preserved in RNALater

Each recaptured oryx was then fitted with a GPS/VHF/satellite collar programmed to record a GPS location every four hours, broadcast a VHF signal for ca. 12 hours daily, and operate for at least three years. The immobilized oryx was then reversed, manually steadied as it regained mobility, released, and monitored for 15 to 60 minutes, depending on the animal's condition. Captured oryx were visited several times over the following days, and no animals showed negative impacts from capture and handling.

Table 2. Oryx immobilized, sampled, and collared in the field 11-13 November 2023**.**

Date	Birth type	DOB	Sex	Age at capture (y)	Time since release (y)	Old collar	New collar	New ear tag	Notes
11/11/2023	1	8/1/2018	F	5.28	3.13	R75	V76	Y1042	Released in 2020 w/o collar; captured on 11/18/2021 & fitted w/R75
11/11/2023	98	4/23/2018	F	5.56	5.27	20_NOR	R77	NA	Captured on 11/17/2021 & fitted w/N20
11/12/2023	1	12/6/2018	F	4.94	3.14	NA	V86	NA	Released in 2020 w/o collar
11/12/2023	1	5/13/2018	F	5.5	3.14	NA	V63	O386	Released in 2020 w/o collar
11/12/2023	99	8/7/2020	M	3.27	NA	NA	V78	O348	5th calf of R02B23F
11/13/2023	99	1/31/2020	F	3.79	NA	NA	V46	O359	4th calf of B20F
11/13/2023	NA	NA	M	NA	NA	NA	V99	--	Adult male MNI; took blood sample to identify animal via genetics

4. Seasonal activity budgets of reintroduced oryx

We investigated how oryx spend their time after being released into the RFOROA – particularly how their behavior budgets change across the distinct seasons characteristic of the Sahel, and with greater post-release experience. We divided movement data collected from over 270 oryx reintroduced since August 2016 into three seasons – rainy, cool/dry, and hot/dry – identified in a previous analysis (currently under review in the journal *Movement Ecology*). We then selected collared animals with at least two years of available tracking data, separated these relatively continuous movement paths by season, and analyzed seasons separately. Each seasonal data set contained between 99,000 and 215,000 locations from at least 41 individuals, representing 9,000 to 21,000 unique animal-days of tracking data. We calculated the distance (or "step length") and turning angle between all consecutive pairs of locations from each animal-year in the seasonal data set. Initial explorations revealed interesting differences (Figure 7): oryx showed greater directional persistence during the rainy season, and took longer steps during the cool, dry season. We considered step lengths and turning angles as observations of an animal's latent behavioral state and used hidden Markov models (HMMs) to infer these states.

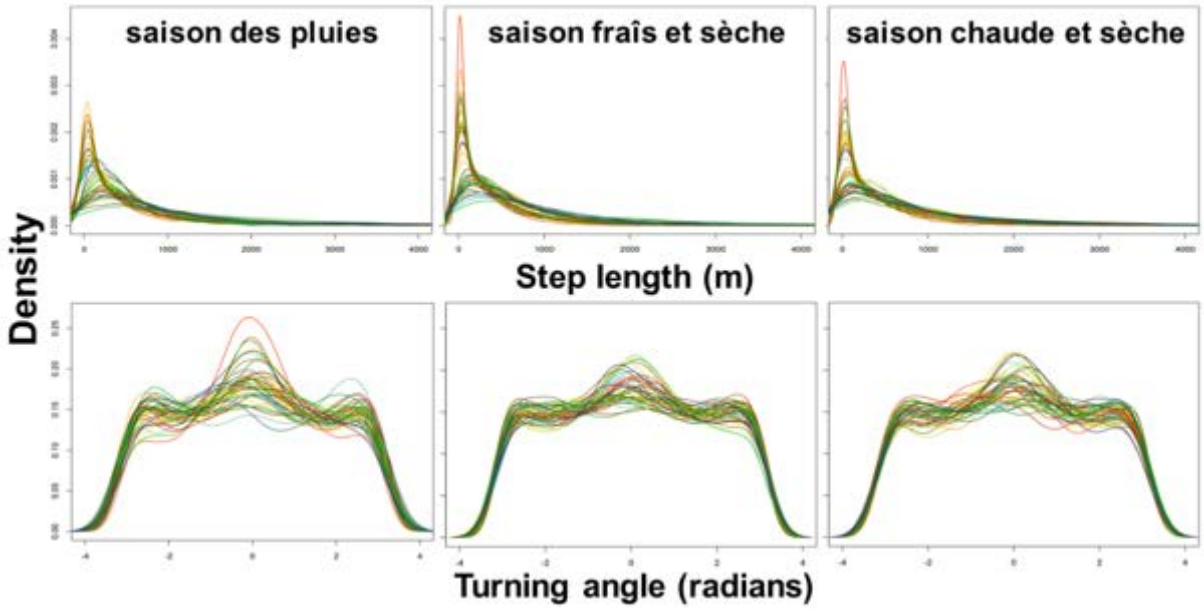

Fig. 7. Density distributions of step length and turning angle indicate seasonal differences. Each color indicates a different individual-year combination from the seasonal data set.

We explored histograms of step lengths and turning angles to identify plausible starting values. We then ran 50 HMMs with starting values randomly drawn from plausible ranges to select the parameters for our final HMMs, employing a gamma distribution for step lengths and a von Mises distribution for turning angles. State 1 in our final seasonal HMMs was characterized by very small step lengths (state-level mean < 10 m) and highly variable turning angles, indicating low directional persistence and thus reflected resting-ruminating behavior (Figure 8). State 2 was characterized by intermediate step lengths (near the overall population-level mean of 500 m) and high variation in turning angles, indicating small-scale movements and foraging behavior. State 3 contained longer step lengths (1-2 km) and turning angles centered around 0, indicating strong directional persistence and thus representing transiting behavior.

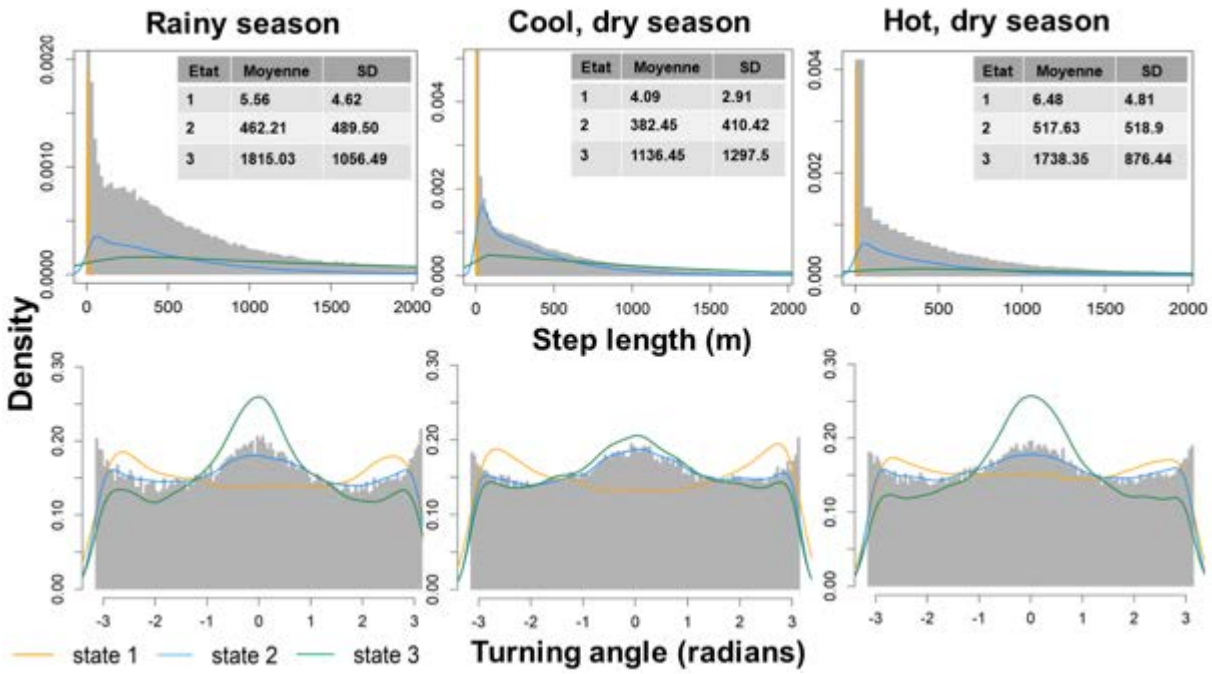

Fig. 8. Summary and density distributions of step length and turning angle parameters for final seasonal hidden Markov models.

We generated behavior budgets for each individual and season by grouping all steps within each season by the state identified by the final seasonal HMMs. As might be expected, reintroduced oryx spent roughly twice as much time in state 1 (resting or ruminating) during the hot, dry season and the most time in state 2 (foraging) during the rainy season, when nutritious forage is the most abundant (Figure 9). Interestingly, oryx spent the most time engaging in long-distance movements during the cool, dry season, which may represent a cost/benefit tradeoff between energetically costly long-distance movements and the benefits of finding nutritious vegetation at another site.

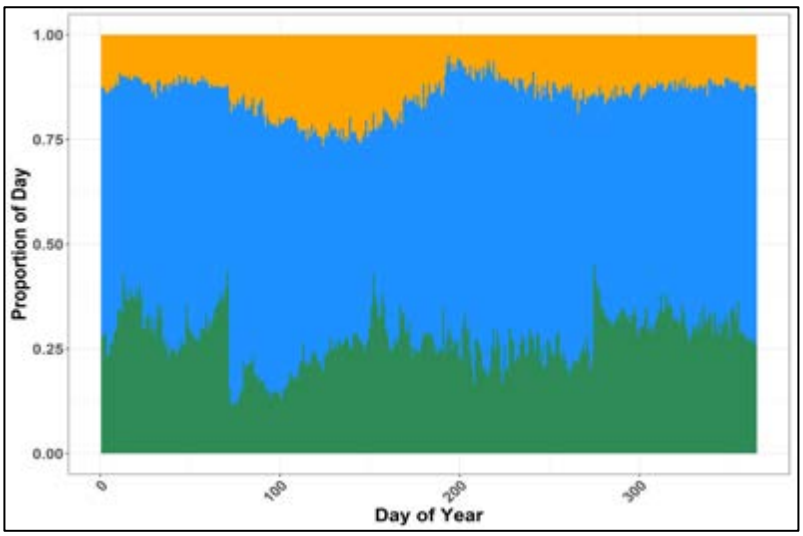

Fig. 9. Mean proportions spent in states 1-3 for each day of a generic calendar year, across all individual oryx and seasons.

The amount of post-release experience gained by a reintroduced oryx affected the probability that it engaged in different behavior states. Across all seasons, oryx with more experience were more likely to engage in long-distance movements (state 3) than their less experienced counterparts (Figure 10). This increased proportion of time spent in state 3 was offset by reduced time spent on resting behaviors (state 1), and somewhat less time spent engaging in foraging behaviors (state 2). These outcomes are intriguing because we might expect reintroduced oryx to become "more efficient" with greater experience. However, the effects of experience were weakest during the hot, dry season, indicating that extreme environmental conditions impose greater constraints than the potential benefits provided by seasonal movement strategies learned after release.

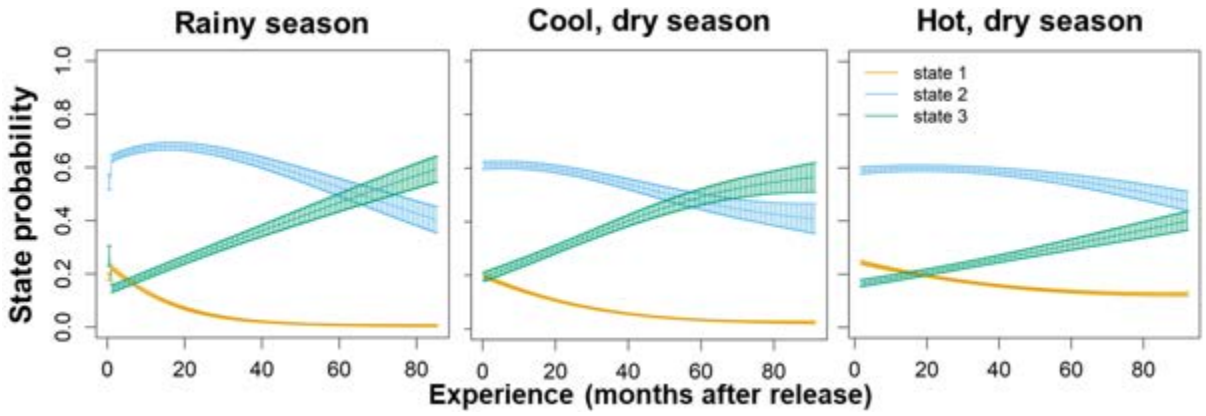

Fig. 10. Post-release experience affects the probability an oryx will engage in a particular behavioral state in each season.

5. Selecting appropriate tracking devices for dama gazelle

Dama gazelles were originally distributed across Sahelian savannas and grasslands, ranging from the Atlantic to the Nile. Today, the species is assessed as Critically Endangered, with only four small, fragmented populations of ca. 250 individuals spread across Mali, Niger, and Chad. An estimated 50 dama are estimated to occupy the RFOROA, and the 2020-2028 Dama Gazelle Conservation Strategy has identified the reserve as a highly suitable site for population reinforcement. However, despite the available habitat, small predator populations, and relative lack of poaching in the RFOROA, dama are distributed across a relatively small area (ca. 1,100 km^2), and young animals are rarely observed.

In 2020, Sahara Conservation led a dama rescue operation in the Manga region of Chad, resulting in the establishment of a captive breeding population in the RFOROA. While the goals of this program are under active development, a primary objective is to reinforce the wild dama population in the reserve. Tracking dama released as part of a population reinforcement initiative also offers a unique opportunity to monitor wild dama more closely and the potential to identify factors limiting population growth.

In 2023, we surveyed and reviewed lightweight tracking devices from six different manufacturers. In consultation with species experts, we identified the Lotek LiteTrack Iridium 360+ collar (Figure 11) as the most suitable tracking device for dama. Wilson et al. (2021) proposed to limit the mass of a tracking device so that any additional force it exerts on a tracked animal represents less than 3% of the gravitational force exerted on the animal for 95% of its activity. This paradigm accounts for an animal's "lifestyle": for example, a cheetah wearing a collar that constitutes 3% of its body mass would experience an additional force of ca. 16 kg during a high-speed chase, while a sloth wearing a collar equivalent to 3% of its body mass would experience negligible additional force due to its slow speed. Since wild dama are often observed running at high speeds, we limited the tracking device weight to between 1.6 to 2.98% of the average body mass of an adult dama. Other criteria included previous successful deployments on the species and the suitability of the device shape for dama morphology (oval, with adjustable foam padding on interior surfaces). To evaluate the potential impacts of the selected collar model on dama gazelles, we conducted a short-term trial on animals under human care at the Fossil Rim Wildlife Center.

Fig. 11. Lotek LiteTrack Iridium 360+ collars selected as the most suitable collar for dama gazelle. Total collar weight is ca. 400g (exact weight depends on collar circumference, which varies with animal size) and will not exceed 1.6-2.98% of the body mass of a typical adult dama gazelle.

FRWC animal care specialists and veterinarians selected two male and three female dama to be fitted with collars and one male and three females to serve as age- and sex-matched controls (Figure 12). A joint NZCBI-FRWC intern collected daily video observations of each focal and control animal for four weeks before collars were fitted to the focal animals, five weeks while collars were worn by the focal animals, and one week after the collars detached from focal animals (5 June to 4 August 2023). All observations were preceded by a 15-minute acclimation period, lasted for 10 minutes, and were distributed randomly across morning (8:00-12:00) and afternoon (17:00-19:00) periods, during which

dama were consistently active. Focal animals were fitted with collars on 27 and 28 June 2023, either using a drop-floor restraint device or through immobilization via a remote dart delivered intramuscularly. Collars were fitted near the vertical center of the neck, near the white "neck patch" common to dama pelage, with a "two-finger gap" between the collar and the neck. All collars were programmed to automatically detach after five weeks.

Fig. 12. Focal dama gazelle at Fossil Rim Wildlife Center fitted with Lotek LiteTrack Iridium 360+ collars during June-July 2023.

Ca. 60 hours of video observations (n=356) were recorded and annotated with specific behaviors, utilizing an ethogram developed during previous studies of oryx behavior, with minor modifications based on input from dama experts. Across all focal animals, the mean duration of maintenance and stress-related behaviors during each observation decreased from the pre-attachment period to the attachment period (Figure 13). Additionally, focal animals exhibited highly similar behavior budgets before and while collars were attached (Figure 14). Based on ancillary information from weather stations and observer notes, minor changes observed in stress behaviors may have been caused by biting insects, which dramatically decreased in abundance in late June.

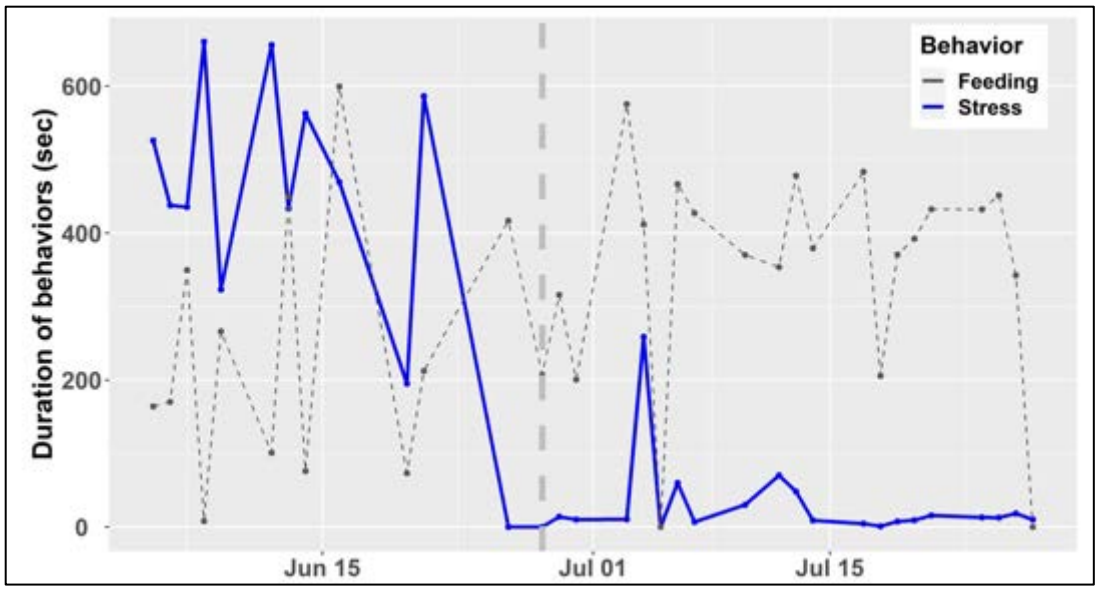

Fig. 13. Time series of feeding and stress behaviors by focal animal 854 Blue during pre-attachment and attachment periods. Date of collar attachment date shown by *vertical dashed gray line*.

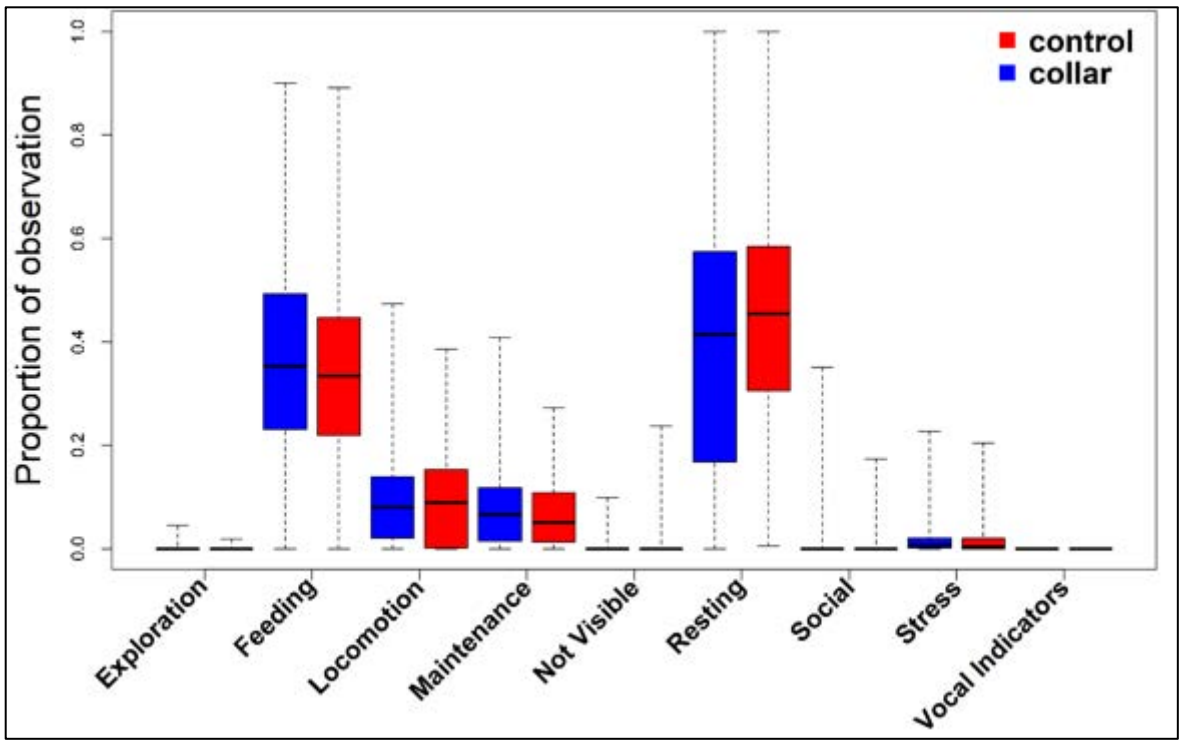

Fig. 14. Behavior budgets of collared and control animals during the period when collars were attached.

In October 2023, NZCBI personnel fitted a solar-powered GPS/satellite tracking device weighing ca. 80g to the horn of a dama gazelle under human care at Smithsonian Conservation Biology Institute (SCBI) in Front Royal, VA (Figure 15). Similar to previous trials of horn-mounted tags on captive oryx at SCBI in 2018-2019, daily observations by animal care specialists indicated no negative behavioral or health impacts following tag attachment. Based on these device tests, we selected Lotek LiteTrack Iridium 360+ collars for use on adults and 50-80g solar-powered GPS/satellite tracking devices fitted to horns for subadult, dama gazelle released as part of population reinforcement efforts in the RFOROA.

Fig. 15. Fitting a captive dama gazelle at SCBI in Front Royal, VA with a horn-mounted tracking device.

6. Movement and space use by released dama gazelle

On 22 January 2024, three dama fitted with tracking devices in November 2023 and three dama marked with ear tags were released from the captive breeding population managed at the reintroduction project's base camp into the RFOROA. Within one week of their release, all individuals had integrated with groups of wild dama (Figure 16). Before her mortality in June 2024, adult female NNN-Y12F remained with her recent calf, O16F, and was frequently observed in large groups with a maximum of 13 animals. Adult male OOO-Y19M is usually observed with one or two wild-born adult female dama. Before its mortality in June 2024, subadult male Y11M-balise largely remained with immature animals Y15F and Y16M from the same release. Both battery-powered collars fitted to the neck and solar-powered tags mounted to horns functioned well, a promising indicator for the tracking device selection process used in 2023 and for future dama releases and related tracking activities.

Fig. 16. Tracked dama NNN-Y12F, OOO-Y19M, and Y11M-balise integrated into groups of dama gazelle native to the RFOROA within two weeks of release

All tracked dama remained within 5 km of the release site until April, when NNN-Y12 abruptly made multiple east-west roundtrips of ca. 50 km each. In contrast, both OOO-Y19M and Y11M-balise remained near the release site. After their release, all three animals largely moved across an area ca. 200 km^2 in size (Figure 17).

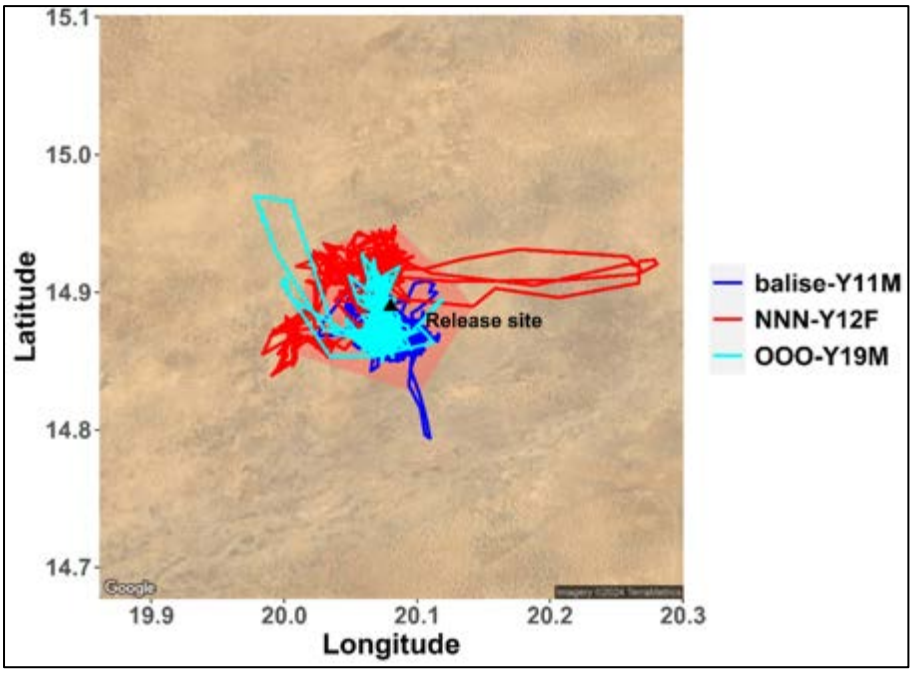

Fig. 17. Post-release movements (colored lines) and high-use area (red shading) for two adults (OOO-Y19M and NNN-Y12F) and one sub-adult (Y11M-balise) dama gazelle released into the reserve in January 2024.

7. RFOROA One Health Project

Following the massive mortality event that impacted reintroduced oryx in 2018, NZCBI initiated a collaboration with Sahara Conservation, the University of Edinburgh, IRED, DSV (Veterinary Services Department), DSA (Animal Health Division), and CIRAD (Center for International Cooperation in Agricultural Research for Development) to better understand the diseases circulating in both wildlife and livestock within the RFOROA. From September 23 to October 1, 2022, a joint team of personnel from IRED, DSV, DSA, SC, the University of Edinburgh, and NZCBI conducted field missions in Missimeme, Al Argané, and Abu Naga to collect samples from camels, cows, sheep, and goats grazing within the reserve. After two missions to Garoua, Cameroon, to obtain dry ice, the samples safely arrived at CIRAD under cold chain conditions in May 2024. From June to August 2024, collaborators at CIRAD will perform molecular and serological tests on these samples to detect 15 regionally important vector-borne diseases.

In addition, collaborator Dr. Stephanie Brien from the University of Edinburgh has analyzed samples collected from livestock in the RFOROA in 2022 and oryx captured in the reserve from 2021 to 2023 (Table 2, Figures 18-19). Approximately 50% of sampled oryx were infected with various hemoparasites, compared to ca. 80% of sampled livestock. These preliminary results indicate that antelopes reintroduced from a captive environment generally carry a genetically similar but reduced hemoparasite burden compared to livestock. Further analyses will compare hemoparasite loads among oryx with varying amounts of post-release experience to characterize timelines of disease exposure.

Risk factor	Total	Infected		Abundance			
	n	n	%	Range		Mean	Median
Total	395	277	70.1	0	166,893	22,453	3817
Livestock	294	237	**80.6**	0	166,893	28,985	23,828
Wildlife	101	40	**39.6**	0	123,839	3440	0
Chad	340	259	76.1	0	166,893	25,475	10,711
Livestock	294	237	**80.6**	0	166,893	28,985	23,828
Wildlife	46	22	**47.8**	0	60,040	3041	0
Wildlife	101	40	**39.6**	0	123,839	3440	0
Baseline	35	11	31.4	0	2670	143	0
Acclimatisation	27	8	29.6	0	60,040	2339	0
Semi-free-ranging	20	7	35.0	0	123,839	10,128	0
Free-ranging	19	14	**73.6**	0	40,499	4037	713

Fig. 18. Hemoparasite burden of wildlife and livestock species in the RFOROA and other study sites. (Source: Stephanie Brien, University of Edinburgh.)

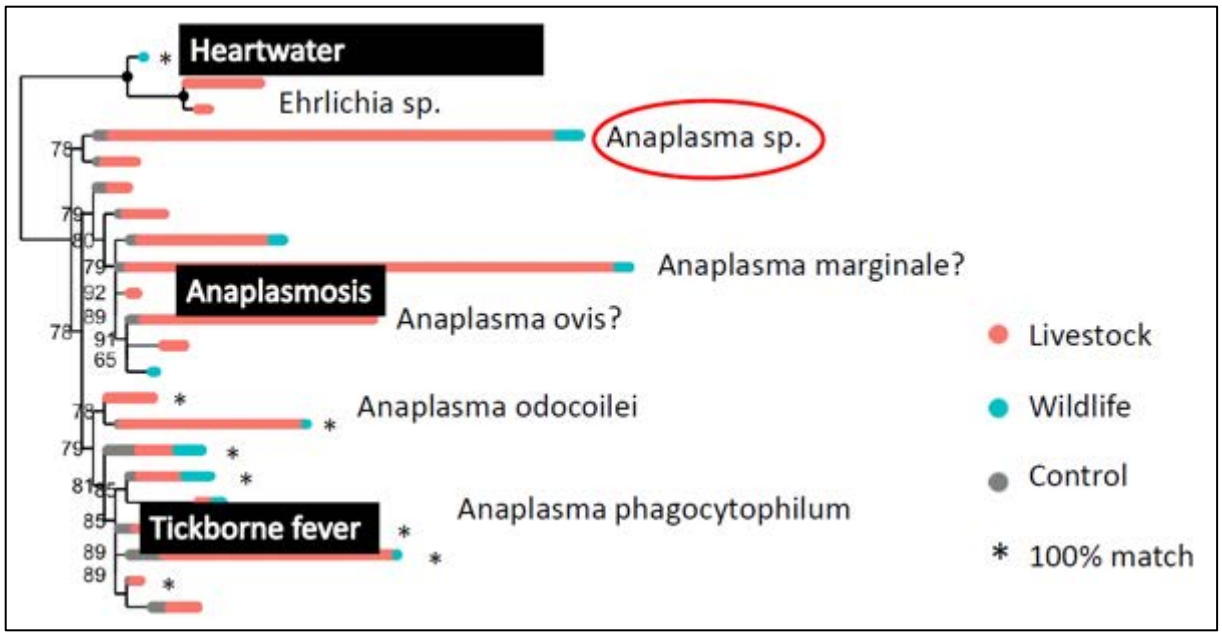

Fig. 19. Phylogenetic tree of hemoparasites detected in livestock and wildlife species roaming the RFOROA, Chad, and other study sites.

In addition, NZCBI personnel are collaborating with former EAD veterinarian Dr. Elena Pesci, Dr. Fayiz Abakar of IRED, and Dr. Latifa Sikli of the Agence Nationale des Eaux et Forêts (ANEF) of Morocco on a literature review of diseases pertinent to Sahelo-Saharan antelope in African range states with active reintroduction programs (i.e., Tunisia, Senegal, Morocco, and Chad). This manuscript will compile historical records of diseases relevant to reintroduced oryx, addax, and dama across these countries, and elaborate disease exposure concerns for the reintroduction of these species.

8. Detecting disease status from animal movement

While we expect infection by disease to affect an individual's movements, little direct evidence exists of such effects – largely due to the challenge of collecting simultaneous data on movement and infection status. (But see Delekaita et al. (2023), who found that desert bighorn sheep (*Ovis canadensis nelsoni*) infected with pneumonia exhibited low mean daily movement rates and were significantly less likely to undertake intermountain movements.) We utilized a hidden Markov model (HMM) to analyze oryx movement data after August 2018 (Figure 20), when more than 40 reintroduced oryx died and nine animals tested positive for various co-infections, including Rift Valley Fever (RVF). We analyzed tracking data from 68 reintroduced oryx, including five individuals that tested positive for RVF and three that tested positive for bacterial and parasite infections (Chardonnet, 2019).

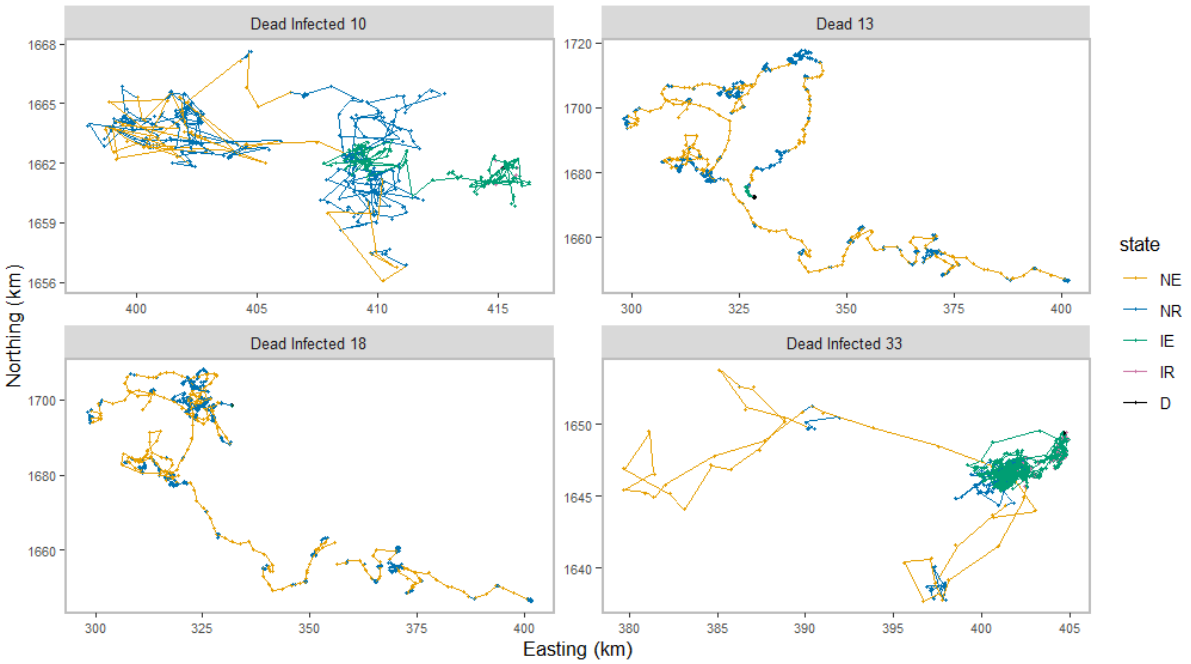

Fig. 20. Inferred states from a 5-state hidden Markov Model for three oryx with known infection status (based on test results) and one presumably infected individual (based on mortality during the study period). Track color indicates the model-assigned state: non-infected exploring (yellow), non-infected resting (blue); infected exploring (green); infected resting (magenta); and death (black).

We also found that oryx preferentially exhibited resting behaviors in areas with greater shrub cover, likely indicating the presence of shade (Figure 21). Model-inferred states were consistent with direct field observations and disease test results (Figure 22), and our final HMM recovered true infection status close in time to time, at which samples that later tested positive were collected.

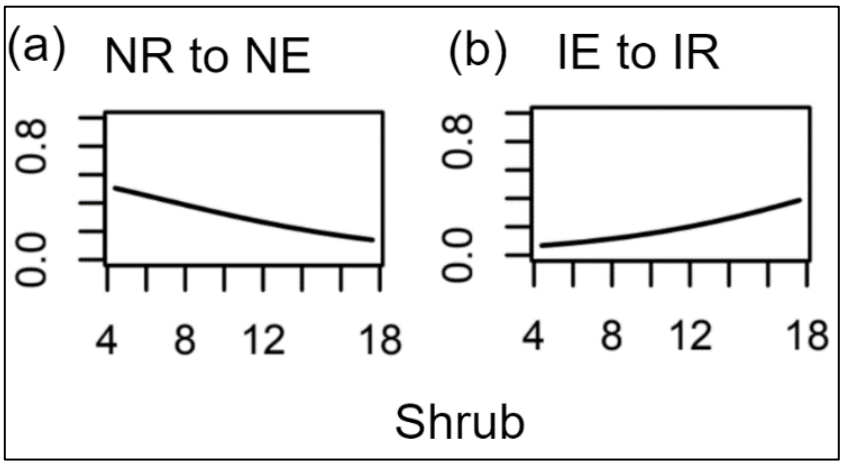

Fig. 21. Transition probabilities as a function of shrub cover between (a) non-infected resting (NR) to non-infected exploring (NE) states, and (b) infected exploring (IE) to infection resting (IR) states. Oryx select a higher probability of shrub cover when transitioning from exploring to resting states.

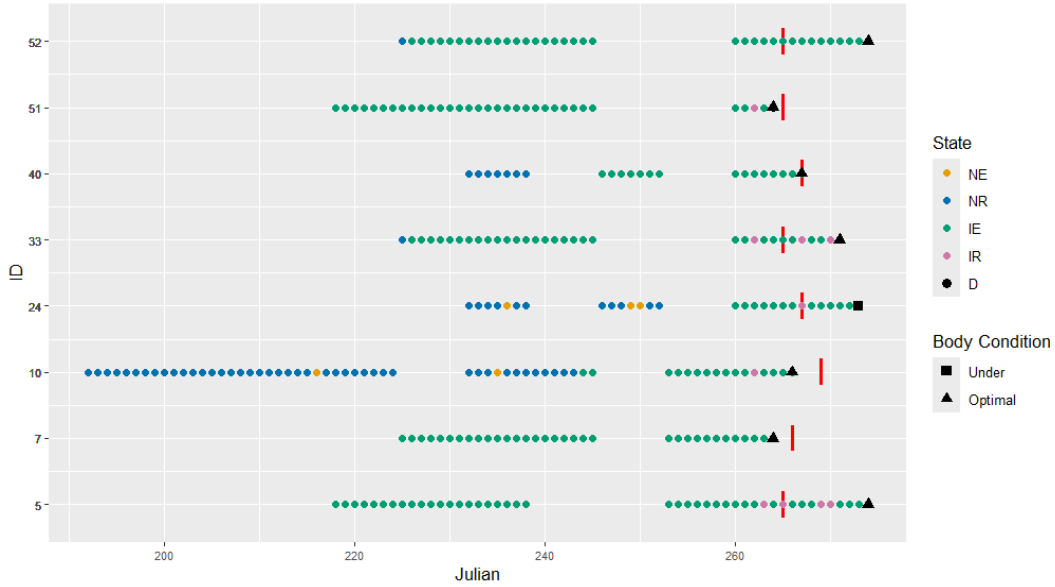

Fig. 22. Daily modal state of infected oryx (n = 8) from the final 5-state HMM. Symbol shape indicates recent body condition, red vertical lines indicate the date tested for infection, and color indicates model-assigned behavioral state: non-infected exploring (yellow), non-infected resting (blue); infected exploring (green); infected resting (magenta); and death (black).

These findings support the expectation that infection generally reduces movement and activity levels in large herbivores and leads to increased resting behavior. This approach can be modified from retrospective to prospective; i.e., our final model can be applied to individual tracks of recent movement data to search for potentially infected animals that may then be targeted for enhanced monitoring, sampling, or *in situ* veterinary intervention.

9. Conclusions and recommendations

9.1 Restrict animal releases to the rainy season and the early cool, dry season

Based on previous dispersal behavior and reliance on supplementary resources by oryx released in January 2017, poor body condition scores observed during the first dry season for addax released in January 2020, and the elevated mortality rates observed in oryx and addax released in January 2024, we recommend that future releases be restricted to the rainy season or the very early cool, dry season (i.e., by October 31).

9.2 Establish standard practices for sampling animal mortalities

We recommend developing standard sampling protocols for non-veterinary personnel, sample transport times and routes, and *in situ* and laboratory tests that can be used when an elevated mortality rate is observed among reintroduced oryx, addax, or dama. The ecological monitoring team received training in field necropsy procedures in 2018, 2019, and 2021; however, many members joined the team after these trainings. We recommend (1) working with veterinarians at partner organizations to develop a standard sampling protocol that can be readily implemented by non-veterinarians on carcasses more than 24 hours after death, (2) identifying a local point of contact for potential veterinary field missions, and (3) implementing an annual inventory of materials on site, conducting a brief review of necropsy methods, and a brief review of sample collection methods, for monitoring team members. These actions will increase the project's capacity to rapidly obtain actionable information when mortality is discovered in the field.

9.3 Revise population viability analyses for reintroduced oryx and addax

We recommend revising the population viability analysis for oryx performed in 2013 with (1) data from the reintroduced population, such as the observed sex ratio, fecundity, and survival; (2) parameters derived from recent genetic analyses of the EAD population; (3) other parameters derived from analyses of Tunisian oryx populations; and (4) both realistic and catastrophic environmental scenarios, including severe dry seasons and regional climate change predictions.

9.4 Maintain a "long-term monitoring group" of 50 oryx

Based on a previous power analysis, 50 animals represent the minimum sample size necessary to detect actual differences in survival rates across four example oryx releases. In field missions conducted between 2020 and 2023, joint teams across partner organizations efficiently captured, sampled, and collared 34 free-roaming oryx. However, many collars have fallen off these animals, and several individuals have died. We recommend planning for 10 to 15 field recaptures per year alongside other field activities. A long-term monitoring cohort of 50 oryx will standardize monitoring efforts and strengthen the project's ability to detect population and demographic trends.

9.5 Collect DNA samples from wild-born calves via buccal swab

The primary opportunity to collect biological samples from wild-born oryx and addax occurs soon after birth, when calves may be reliably captured and ear-tagged. In March 2022, personnel from the University of Edinburgh demonstrated a protocol developed by RZSS that uses a buccal swab to collect DNA from ear-tagged calves. DNA samples from Chad-born calves may provide insights into

parentage, population genetics, and disease exposure. These analyses may also pave the way for future monitoring using non-invasive DNA samples.

9.6 Continue integrating multi-species monitoring efforts

Monitoring reintroduced oryx, addax, dama, and ostrich has become more complex over time and now requires detailed planning, strategic decision-making, and intensive data management. Quarterly meetings to assess whether the current fieldwork strategy meets monitoring targets, and the maintenance of at least two vehicles for use by monitoring team members each day, are essential to achieve monitoring objectives for all species.

9.7 Increase non-invasive monitoring of the reintroduced oryx and addax

Recent analyses by partners at the University of Edinburgh and RZSS have shown the high value of fecal samples for investigating diet contents and the gut microbiome community. Related experiments have shown that relatively fresh fecal samples collected in the field may be stored in containers at room temperature without the need for preservative agents or cold chain. We recommend adding the collection of non-invasive fecal samples to standard monitoring protocols to support investigations into diet (particularly the degree of overlap among reintroduced antelope, as well as with livestock), population genetics (including estimating the size of the effective breeding population), and parasite and/or disease load.

9.8 Deploy camera collars on a subset of reintroduced oryx and addax

A previous collaboration among SC, FRWC, and NZCBI showed that the additional weight of a camera attached to a GPS/satellite collar (ca. 600 g) does not negatively impact oryx health. Camera collars thus represent a cost-effective tool to evaluate spatial overlap with livestock and wildlife – and thereby potential human-wildlife conflict. Moreover, the images and videos recorded by camera collars are extremely useful for outreach and communication efforts. We thus recommend that select oryx and addax in good body condition be fitted with camera collars for ca. 6-month deployments.