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Behavioural analysis of reintroduced addax (*Addax nasomaculatus*) in Morocco

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled **Behavioural analysis of reintroduced addax (Addax nasomaculatus) in Morocco** independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 21st April 2022

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Valentina Martínez Salazar

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Abstract

Reintroduction programs have different scopes depending on the reintroduced species. In the case of addax (*Addax nasomaculatus*), a critically endangered species, with decreasing numbers and almost extinct in the wild, reintroduction programs are being held in various countries, with the aim to re-establish this species in its historical range. In Morocco, the current reintroduction program translocated two groups of addax from Souss-Massa National Park to the M'Hamid El-Ghizlane Reserve, the first one in 2019 and the second one in 2020. This study aimed to establish differences in the behaviour of the animals that have been released, given that there is a one-year gap between each herd's release into the wild, and with this analyse the way the animals are adapting to their new environment, and what behavioural changes are present during this adaptation process. The data was collected for one month and included camera traps' recordings and *ad libitum* observations. The results show that the animals adapt quickly to their new conditions, changing the time they spent on their daily activities, and prioritizing different behaviours. The individuals' capacity for adaptation encourages the continuation of the reintroduction program, as it shows the possibility to establish a viable population in the future.

Keywords: activity budget, activity pattern, reintroduction, behavioural changes, camera traps, *ad libitum* observations.

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List of the abbreviations used in the thesis

Addax: *Addax nasomaculatus*.

CT: camera trap.

CTs: camera traps.

D: Drink

E: Eat

F: Fight

GPS collars: Global Positioning System collars

H_0: Null hypothesis.

H_a: Alternative hypothesis.

Herd 2019: refers to the herd that was released in 2019.

Herd 2020: refers to the herd that was released in December 2020.

Herd 2020 (e): refers to the Herd 2020 when it was inside the enclosure.

m.a.s.l.: meters above sea level.

PNSM: National Park Souss Massa.

R: Rest

Rn: Run

Ru: Ruminate

SS: Stop and Stare

U: Urinate

W: Walk

1. Introduction and Literature Review

Extinction is a phenomenon that is not uncommon to either biologists or life on Earth in general. It is known that 5 massive extinction events have already taken place during Earth's history, and in some, more than 90% of all living forms became extinct. Nevertheless, species become extinct every day, right in front of our eyes (Elewa & Joseph 2009; Dorado et al. 2010; Benton 2013).

Human impact has become one of the main factors that contribute to and accelerate the extinction of species. Factors such as indiscriminate hunting, urbanization, modification of landscapes, and monocultures are some of the main causes of species displacement and a possible eventual extinction (Barnosky et al. 2011; Benton 2013).

Species that have been historically hunted by indigenous people and, due to globalization and easier ways to access previously remoted places, have also become a hunting target for outsiders, are at a high risk of imminent extinction, as their populations cannot keep their minimum viable numbers (Barnosky et al. 2011).

One of the strategies to prevent these extinction events from happening is to breed the species in a controlled environment, like a zoo or a reserve, that can be either inside or outside the species' historical range. And then, release the individuals in the wild, in hopes that they can adapt to living in the wild (Robert 2009; Ralls & Ballou 2013; Powell & Zoo 2018).

This process is more than just breeding, transporting, and releasing, given that the individuals being released have had usually more contact with humans than their wild-born conspecifics and can even look for human contact associating it with resources. Also, the breeding programs provide food in quantities that are not always found in the wild, and animals need time to adapt to the new conditions (Robert 2009; Ralls & Ballou 2013).

The period of adaptation is crucial for the success of the reintroduction programs because if the individuals are unable to adapt to their new environment the programs will be useless for preventing the species extinction. It is important to highlight that the adaptation to the environment implies not only the capacity to survive but also to successfully reproduce (IUCN Reintroduction and Invasive Species Specialist Groups 2013; Ralls & Ballou 2013).

To follow the behaviour of the animals during this period is crucial to understand how they are adapting to their new surroundings, and also to adjust, if necessary, to be successful during this transition period.

This behavioural knowledge is important not only for the animals being released in a specific reintroduction program but also for future reintroduction programs, which could have more probability of success if the professionals involved have more information that would help them structure their program's methodology.

1.1. Addax nasomaculatus

Addax nasomaculatus, commonly known as "addax" is an antelope species native to the Sahara Desert. Addax belongs to a monotypic genus and is highly adapted to life in desertic conditions (Dragesco-Joffé A. 1993).

Its wild population is so small that it may be considered the world's rarest hoofed mammal (Chardonnet et al. 2020) and of course, it is one of the rarest antelopes on the planet (IUCN SSC Antelope Specialist Group 2016).

Addax are mixed feeders, grazing and browsing according to the plants present, employing their short, blunt muzzle to graze coarse desert grasses, or browsing on acacias, leguminous herbs, and other plants (Estes 2021).

1.1.1. Addax Distribution

Decades ago, the addax was widespread through the whole Sahara Desert to the west of the Nile valley, in recent years this area has decreased 99%, leaving only one possibly viable population in Termit/Tin Toumma, Niger and some small groups scattered between other regions of Niger and Chad. Sightings have been reported for Mauritania and Mali, but they are not confirmed (IUCN SSC Antelope Specialist Group 2016).

1.1.2. Addax Taxonomy and Description

The addax belongs to the family Bovidae, and it is the only member of its genus (IUCN SSC Antelope Specialist Group 2016).

In appearance, it is a robust, medium-size sexually dimorphic antelope, reaching up to 105- 115 cm height to the shoulders in males and 95-110 cm in females (Halternorth & Diller 1980). And with a weight of 100- 125 kg for males and 60-90 kg for females (Krausman & Casey 2007).

Both sexes have horns with 1.5 to 3 turns of clockwise turns, measuring 762 to 890 mm along the curves. They have very wide half-moon-shaped hooves, adapted to walking on sandy surfaces, and protruding false hooves as well as interdigital glands on fore and hind feet (Halternorth & Diller 1980; Nowak 1991; Kingdon 1997; Álvarez Romero & Medellín Legorreta 2005).

The fur colour changes according to the season, during summer it is sandy or almost white, while during winter it darkens to a greyish-brown tone with thicker, long brown patches of hair on the neck, shoulders, and forehead(Harper 1945; Fisher et al. 1969; Nowak 1991)

Besides from their fur colour, they have white spots on their limbs, hips, abdomen, ears, and face, and there is a circle on the front-upper part of the head that is almost black (Nowak 1991; Kingdon 1997; Álvarez Romero & Medellín Legorreta 2005).

1.1.3. Addax Biology

1.1.3.1. Behaviour

Addax generally live in small herds of up to 15 animals, composed of males and females of all ages (Lhote 1946; Lamarche 1980). The larger groups observed in the past, sometimes numbering several hundred, were probably the result of many smaller herds congregating seasonally and temporarily in grazing areas (Nachtigal 1881; Lavauden 1920; In Tanoust 1930).

Nowadays, due to the low population numbers of the species, the average addax herd size is rarely more than half a dozen individuals (Dragesco-Joffé A. 1993). In Niger, between 1980 and 1991, the average herd size was 2.2 (range=1-5; n=27) (Rapant 1992 and Poilecot 1993 cited in Beudels-Jamar et al. n.d.).

The herd has a hierarchy where it is dominated by an adult male, that establishes his territory and tries to keep fertile females within this area. And also, females have a hierarchy of their own, dominated by the eldest one (Altan 2000).

Having a lifespan of 19 years in the wild and 25 in captivity, they reach their reproductive maturity at around two years old and can have one offspring per year (Kingdon 1997; Altan 2000).

As a response to high temperatures, addax prefer feeding during cooler hours and at night, while during the hotter hours they shelter and rest. Excavation of shelter behind vegetation or on the shade side of dunes with both hooves and horns has been recorded (Lamarche 1980; Dragesco-Joffé A. 1993).

1.1.3.2. Habitat Selection

Addax is a nomadic species, well known for its preference for extreme inhospitable arid habitats such as savannahs, grasslands, and desserts that have less than 100 mm of rainfall annually (Newby 2013). Addax are not good climbers; therefore, they do not inhabit truly mountainous areas, but their presence has been recorded in all the other major Saharan habitat types. They prefer harder, packed sands and flatter areas within and between dune fields that support perennial vegetation, and their seasonal distribution and frequentation of traditional sites are often influenced by the presence of shade (Newby 1982, 2013; Dragesco-Joffé A. 1993; IUCN SSC Antelope Specialist Group 2016)

1.1.3.3. Conservation Status

The IUCN assessment for the species is “Critically Endangered” given its small wild population, less than 100 individuals, and its decreasing trend. Also, to this assessment contributes that most of this population is part of a sub-population located in the Termit Tin Toumma region of Niger (IUCN SSC Antelope Specialist Group 2016).

Various conservation programs are working on ex-situ conservation and/or reintroduction programs that count with action recovery plans which include research and monitoring of the programs(IUCN SSC Antelope Specialist Group 2016).

The species is listed in CMS (the Convention on the Conservation of Migratory Species of Wild Animals) Appendix I and CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix I, and included in the CMS Sahelo-Saharan Antelopes Action Plan (Beudels-Jamar et al. 2005). It is protected under

national legislation in Morocco, Tunisia, and Algeria; in Libya and Egypt hunting of all gazelles is forbidden by law(IUCN SSC Antelope Specialist Group 2016).

1.1.3.4. Threats

The biggest threat to former and current addax populations is the indiscriminate hunting that has been present throughout their whole distribution range for many decades, as their meat and skin are highly valued among locals and foreign hunters (IUCN SSC Antelope Specialist Group 2016). The addax is a "short leg" runner and cannot achieve very high running speeds, allowing it to fall prey to faster predators, including human hunters (Altan 2000).

The change in the landscape due to an increase in agricultural activities is a threat not only in terms of reducing the available area for the addax but also it requires the construction of wells to ensure water for the crops, creating even longer periods of drought (Beudels-Jamar et al. 2005; Newby 2013; Chardonnet et al. 2020).

Another form of soil exploitation that represents a threat to the species is the disturbances generated by oil exploration and production and the hunting by military escorts associated with these explorations (Duncan et al. 2014; SCF 2015).

1.1.4. Addax in the reserve M'Hamid El Ghizlane, Morocco

In Morocco, the last wild addax herd was exterminated in 1942 and the last sighting was of an isolated female in 1963 (Beudels-Jamar et al. 2005). Between 1994 and 1997 addaxes from European zoos were reintroduced to Morocco's Souss Massa National Park, which has since become a captive source population of approximately 400 individuals.

As part of the implementation of the National Strategy for the Conservation of Wild Ungulates in Morocco, a 2015-2024 operation plan was created to begin a reintroduction programme of Addax populations from the Rokkein (PNSM) and Safia (Dakhla) reserves in areas where this species has disappeared.

These reserves count with population numbers that make it possible to carry out annual sampling (460 individuals between both reserves) and operations that have as main objectives to repopulate the areas where the addax have gone extinct and to decongest both reserves, particularly Rokkein Reserve.

As part of the Addax Reintroduction Program in the wild in south-eastern Morocco stretching from the M'hamid El-Ghizlane region to the Iriqui National Park, in March 2019, the Moroccan authorities, in the head of the Department of Water and Forests (Département des Eaux et Fôrets) translocated 20 individuals (15 females and 5 males) from Rokkein Reserve to an enclosure of 20 hectares within M'Hamid Natural Reserve, they were released into the wild by the beginning of November that same year.

A second translocation operation was carried out on the 21 and 22 of October 2020, where 20 individuals (13 females and 9 males) were translocated to the M'Hamid Natural Reserve enclosure, and then they were released by the beginning of December. The objective of this operation was to strengthen the population of Addax released in November 2019, in order to reach a minimum viable population by 2025.

Both of the reintroduced groups counted with GPS collars in some of their individuals. Various of the GPS collars had an identification number.

1.2. Camera traps in behavioural studies

Camera traps are cameras that record images of wild animals, they can be set to record or take photos at set time intervals or be triggered by movement. One of the advantages is that these recordings usually happen when humans are not present, minimizing the risk of human disturbance of the study area, which might influence animal behaviour. Between 1994 and 2011 their use for mammalian research increased by 73% due to the introduction of commercial infrared-triggered cameras in the early 1990s (Mccallum 2013; Swann & Perkins 2014)

CTs are used to study many aspects of vertebrate ecology, including the study of nest ecology, research activity patterns and behaviour, document rare species or events, and estimate state variables such as species richness, occupancy, and abundance (Swann & Perkins 2014). The data collected by CTs include not only the visual and audio material but also will offer the date and hour of the recording and coordinates of the place where the camera was set (the initial data set must be arranged by the researcher when placing the camera trap) (Swann & Perkins 2014).

Another advantage of CTs recordings is that in some cases, individuals can be identified by their unique marks (scars, spots, etc.) or by artificial tags fixed by

researchers (O'Brien 2011; Swann & Perkins 2014). Also, the target of CTs recordings can be aimed at the group (one or various species) that the researchers are looking for, by using specific types of bait.

CTs present a list of advantages over other methods to study animal behaviour, these include lower costs and less survey effort for getting the same amount of data that would cost if it was gotten by direct, on-site observations; as well as methodological versatility, fewer behaviour alterations due to human presence and the possibility to re-watch selected events or behaviours (Caravaggi et al. 2020).

The analysis of behavioural changes of the animals can be used as a sign of the impacts and possible consequences for the animals in changing environments, due to the response of the individuals or species to these changes and also, it can show the way for potential conservation interventions as well as showing the current status of ongoing conservation strategies (Caravaggi et al. 2020).

CTs have been used to describe activity patterns and social behaviour of different species and the resultant descriptions have been used to identify changes in the behaviours and patterns and their possible causes. These behavioural changes can affect individual survivorship and fitness and given sufficient frequency and effect size, population dynamics (Caravaggi et al. 2020).

2. Aims of the Thesis

This thesis focuses on the analysis of the behaviour of two reintroduced herds of addax (*Addax nasomaculatus*) in the reserve M'Hamid El Ghizlane located in Zagora Province, Morocco.

The main aim of this is to establish differences in the behaviour of the herd that released in 2019 and 2020, given that there is a one-year gap between each herd's release into the wild.

To achieve this objective, the methodology focuses on studying the activity budget as well as the activity pattern of each herd. And the main objective is divided into two objectives:

First, to establish the activity pattern of both the herd released one year before the beginning of the study and the one that was released during the study.

Second, to follow the releasing process of the herd and establish the changes of behaviour (activity budget and pattern) during the first post-release days of Herd 2020.

3. Methods

3.1. Study area

The study took place in the reserve M'Hamid El Ghizlane located in Zagora Province, Morocco.

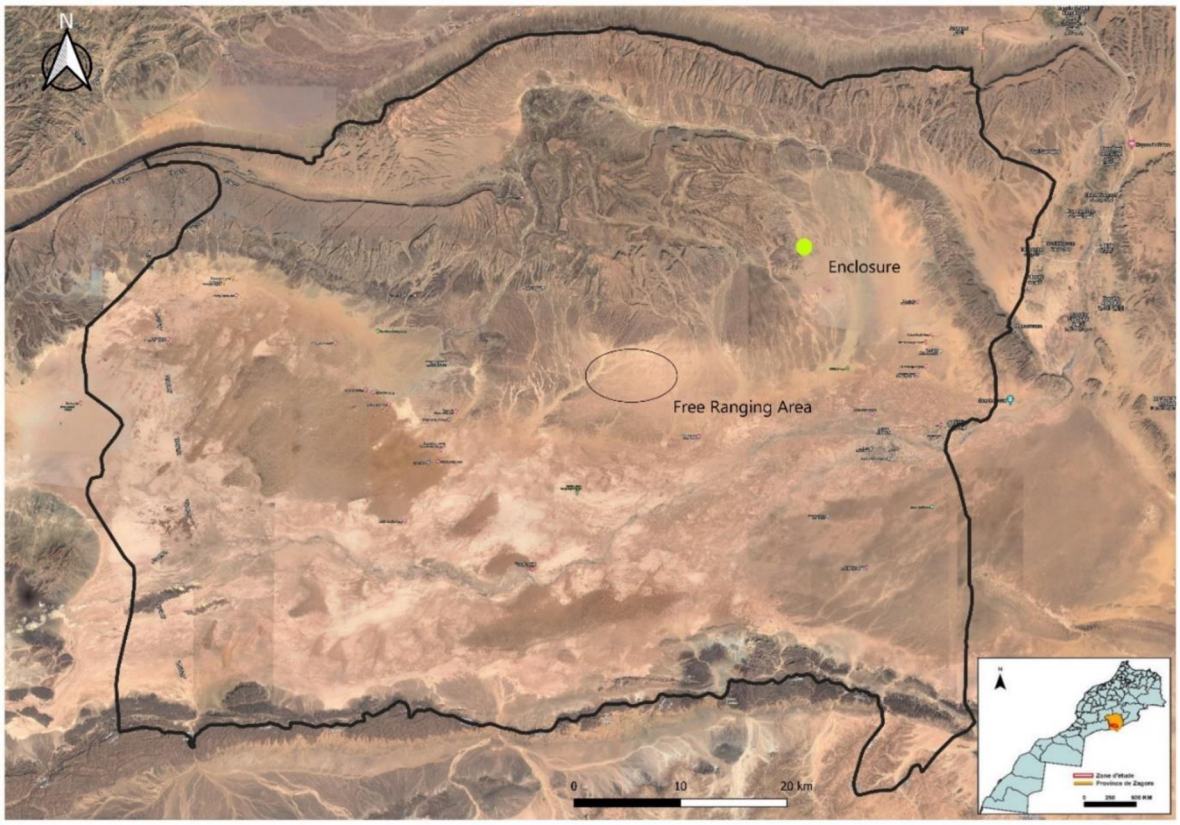

Figure 1. Map of M'Hamid El-Ghizlane Reserve (highlighted in red and the outline), located in Zagora Province (in yellow), Morocco. "Free-Ranging Area" was the place where the addax stayed after the release. Figure credit: Mohammed Ait Brick and Corrie Rushford.

The region is located in southwest Morocco and is predominately a Saharan desert ecosystem, although it is located over the Draa river valley. Its weather is classified as a "Hot desert" on the Köpen Climate Classification (Arnfield 2020), and its average elevation is 724 m.a.s.l. The rain is almost inexistent with an average rainfall of 56 mm per year, and an average temperature of 23 °C, but ranging from 6 to over 40°C during the year (Climate-Data.org n.d.).

M’hamid El-Ghizlane is a Permanent Hunting Reserve covering an area of 450,000 ha. The site consists mainly of an ecosystem of *Acacia raddiana*, which is an important woody species, due to its capacity to tolerate extreme droughts (mean annual rainfall < 200 mm) (Floc’h & Grouzis 2003), and *Tamarix spp.* which are species known for their efficiency at obtaining water from drying soil as well as conserving water during drought (di Tomaso 1998). The reserve also presents various areas of dunes in different locations.

Figure 2. The common landscape of the M’Hamid El-Ghizlane reserve, and enclosure area. Photo courtesy of the Moroccan Department of Water and Forests.

For the purpose of the reintroduction programme of Addax, Dorcas gazelle (*Gazella dorcas*), and Red-necked ostrich (*Struthio camelus*), as well as the breeding of Houbara bustard (*Chlamydotis undulata*) for its later hunting; in 2018 a 20ha enclosure was created to serve as an acclimatization place for the animals, before being released into the wild.

The enclosure counts with three waterpoints placed in different parts of the area, open areas, areas with vegetation, and a smaller roofed enclosure for the bustards and two gates.

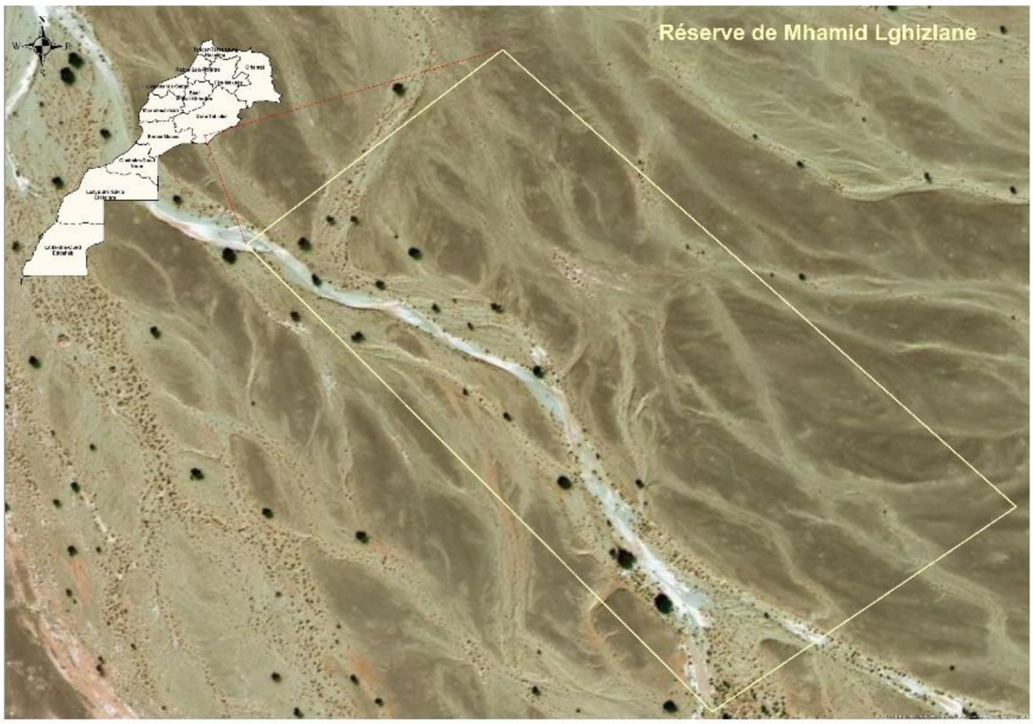

Figure 3. Area of the enclosure. Image courtesy of the Moroccan Department of Water and Forests.

3.2. Data collection

The data collection took place between November and December 2020. During this period, *ad libitum* observations summed to eight Bushnell CTs recordings were taken to analyse the animals' behaviour.

Figure 4. Camera trap placed in a bush.

For the first part of the study, one of the two herds was inside the acclimatization enclosure, while the other herd (which was released the previous year) was roaming freely in the reserve.

Initially, four camera traps were installed inside the enclosure. The cameras were set on the recording mode and the places where they were positioned, were selected with the help of the people in charge of taking care of the animals, as they already knew some of the movement patterns of the herd.

Other four cameras were set outside the enclosure, to observe the already released herd, again with help of the rangers, who pointed to the places where it was more likely to catch the animals. These CTs were distributed like this: one was set on the closest water point to know how often the addax went there to drink, the other was set at the feeding point where the animals were fed every evening, and the other two were placed in two different paths that the rangers said were used for the animals on their daily movements.

The *ad libitum* observations were done at the same time that the camera traps were recording (except during the night), the first days of the study the information collected was used to establish the hours of the *ad libitum* observations.

To avoid double recoding of the data, the hour of each behavioural event was recorded and later compared to the behaviours recorded on camera, so no data was written two times.

Figure 5. Ad libitum observations inside the enclosure. The red circle shows the position of the observers. Photo taken by a CT.

When the herd inside the enclosure was released, the cameras were reallocated in the places where the others had been successfully recording the animals. In the end, four cameras were set to record both herds, while the other four were set to record other fauna in the zone.

Figure 6. Female addax with a GPS collar inside the enclosure. Photo by Beatríz Rubio Alonso

The cameras were revised every three days, to make sure the batteries were still working, and the memory still had space. The batteries were changed when needed and the videos were downloaded to USB memories.

For recording the data, a format (Appendix 1) was filled while observing the animals, this format was filled in a physical (paper and pencil) way and was then transcribed to an Excel sheet. To add the camera traps information, the videos were played, and the behaviours registered on the same excel sheet as the *ad libitum* results.

It is important to highlight that, even though the format was the same, there was a different sheet for each herd, meaning that at the end there were three formats.

3.3. Data analysis

Results were obtained separately for each herd, to make them comparable with each other, the overall result of each one was the one being compared. This means that there was no comparison between particular days but of the final result for each herd.

The data were analysed using Excel statistical tools and dynamic tables.

3.3.1. Activity budget

Once the data were organized in the format, all the behaviours were summed, and the overall total was obtained. This total was taken as the 100% of activities for each herd, and then the percentage of each behaviour was calculated.

With the resulting percentages, graphics were made to show the results more visually.

This was also done for females and males from the Herd 2020 before and after release. For this, the behaviours that were considered were the ones that were done individually or by a reduced group, meaning that, for example, if the whole group was eating the “Eat” behaviour won’t appear in these results, but if the majority of the herd was resting and only a few individuals were eating, then that would be a behaviour that would make part of these results.

3.3.2. Activity pattern

The daily activity of each herd was analysed based on the number of behaviours the animals had per hour, R behaviour was excluded from this analysis as well as the W behaviour of a particular male individual of the Herd 2020 (e), given that this was not normal behaviour and could lead to wrong conclusions.

Both the camera traps recordings and the *ad libitum* observations were used to determine the activities per hour of data collection. Once the counting was completed for all days and hours, the total was divided into the number of sampling days to obtain the mean value, and these means were represented using histograms.

4. Results

Between the CTs recordings and the *ad libitum* observation, the study counted with 128 camera trap days plus 5 days of *ad libitum* observations, divided into 8 hours/day, giving a total of 3192 hours. The effective sample time, where the information for the study was collected, was 499 hours or 20.8 days.

Most of the recordings of the camera traps were triggered by plants and sand moved by the wind; other fauna, like birds, donkeys, foxes, and dromedaries, and even human activity from the nomads that collected water at the water point that was closest to the Herd 2019, and where a camera was placed to know how often the animals went there to drink.

Herd 2019 was seen together only for feeding time, during the day it was only possible to find small groups scattered in an area where they were being monitored. These groups would change their members and size daily and would be seen on CTs recordings eating at the feeding point.

Herd 2020 (e) was usually seen as a big group, where members will move, eat, rest, and do most of their activities together.

After the release, the Herd 2020 was followed closely both in person and with the camera traps. The group stayed relatively together the first two days after the release, and then it separated into smaller groups.

4.1. Activity Budget

The percentages of time (registers) spent in each behaviour varied across the different herds. Each herd was analysed separately, resulting in three different results: Herd 2020(e) (**Table 1**), Herd 2019 (**Table 2**), and Herd 2020 (**Table 3**). The D behaviour was only present for Herd 2020(e).

Table 1. Number of registered activities for the Herd 2020(e).

Activity	Registers	%
Run	5	1%
Drink	20	3%
Eat	53	8%
Fight	10	2%
Rest	**155**	**24%**
Ruminate	108	17%
Stop and Stare	**128**	**20%**
Urinate	18	3%
Walk	**138**	**22%**
Total	635	100%

Figure 7. Activity budget Herd 2020 (e)**.**

The Herd 2020(e) spent most of its recorded time either resting, walking, or in SS behaviour, which could be defined as a vigilant state, as shown in Table 1. The group was usually seen all together.

One male presented a stereotypical behaviour, and while all the other individuals were resting, he was walking non-stop near the fence of the enclosure. All his activity

was recorded but was excluded from the general results of the group, as it would significantly affect the outcome.

Table 2. Number of registered activities for Herd 2019.

Activity	Records	%
Run	2	1%
Eat	**117**	**44%**
Fight	10	4%
Rest	30	11%
Ruminate	28	11%
Stop and Stare	4	2%
Urinate	4	2%
Walk	**68**	**25%**
Total	**263**	**100%**

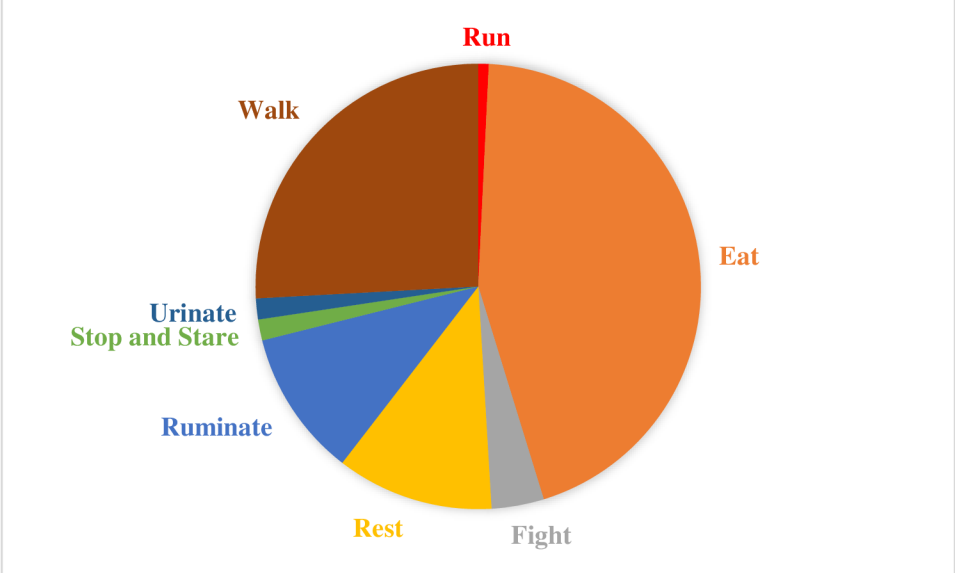

Figure 8. Activity budget Herd 2019.

Members of Herd 2019 spent most of their time eating, followed by walking. The group was usually divided into smaller groups, that changed their members regularly. These groups would start gathering at 17:00 - 18:00 hr near the place where they were fed daily, as this was the regular feeding hour.

Throughout the whole study, the camera trap placed by the nearest water point did not record any individual drinking, although they were recorded passing by.

Table 3. Number of registered activities for Herd 2020.

Activity	**Records**	**%**
Run	1	1%
Eat	**63**	**40%**
Fight	2	1%
Rest	**34**	**23%**
Ruminate	17	11%
Stop and Stare	16	10%
Urinate	2	1%
Walk	21	13%
Total	**156**	**100%**

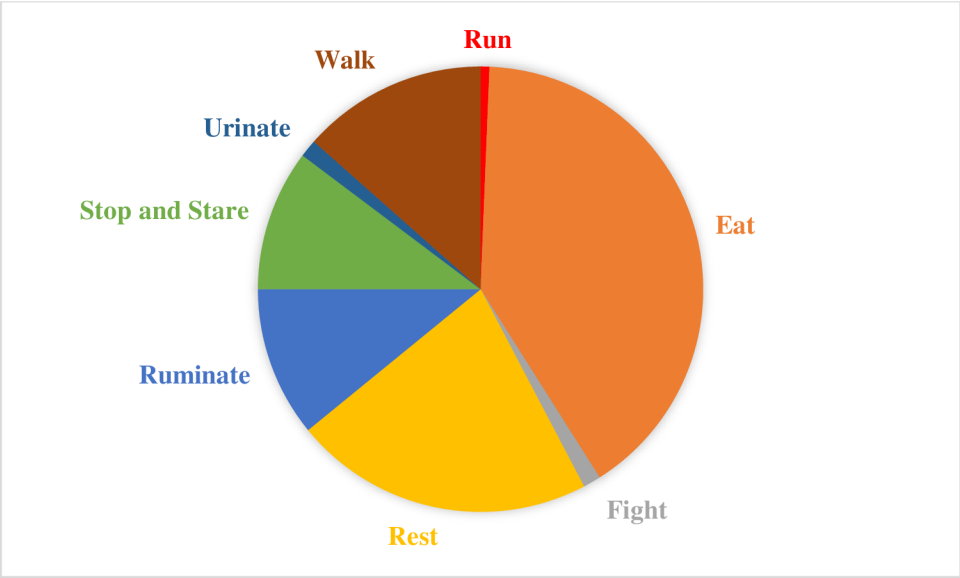

Figure 9. Activity budget Herd 2020.

After being released, Herd 2020 spent most of its time eating, which contrasts with the recordings shown in Figure 7 for Herd 2020(e) and is closer to the results for Herd 2019 as shown in Table 2.

Same as in the Herd 2019 results shown in Figure 8, the drinking behaviour was absent, although they were also recorded nearby the water point.

4.1.1. Chi-square Goodness of Fit Test

The Chi-square test was used to see whether the differences in the time spent on each behaviour were statistically significant among the three herds.

As the main interest was seeing the difference in the activity budget of the Herd 2020 before and after being released, in Table 4 the expected results were set as the values obtained for the Herd 2020(e) before release, and in Table 5 they were the results of the Herd 2019, as it would be expected that the released animals would behave similarly.

H_0: There is no significant difference in the percentages of each recorded activity among the herds.

H_a: The herds present a significant difference in their activity budget distribution.

Table 4. Chi-square results for the comparison of the activity budget of the Herd 2020 (e) with both the Herd 2019 and the Herd 2020 after release.

Activity	Herd 2020 (e)	Herd 2020 After release	Chi2	Herd 2019	Chi2
Run	1	1	0.00	1	0.00
Drink	3	0	3.00	0	3.00
Eat	8	40	128	44	162.00
Fight	2	1	0.50	4	2.00
Rest	24	22	0.16	11	7.041
Ruminate	17	11	2.12	11	2.12
Stop and Stare	20	10	5.00	2	16.20
Urinate	3	1	1.33	2	0.33
Walk	22	13	3.68	26	0.73
		Total	**143.79**	**Total**	**193.41**

The calculated Chi-square for the comparisons of the activity budget of Herd 2020 (e) with both the same herd after release and herd 2019, was higher than the critical Chi-square chosen for the analysis with the parameters $\alpha = 0.05$ and eight (8) Degrees of Freedom, which is 15.507. With this, we can reject H_0.

These big differences show that the time the Herd 2020 spent on each behaviour before being released, changed drastically after its release into the wild.

Table 5. Chi-square results for the comparison of the activity budget of Herd 2019 and Herd 2020.

Activity	Herd 2019	Herd 2020 After release	Chi2
Run	1	1	0.00
Eat	**44**	**40**	**0.36**
Fight	4	1	2.25
Rest	11	22	11.00
Ruminate	**11**	**11**	**0.00**
Stop and Stare	2	10	32.00
Urinate	**2**	**1**	**0.50**
Walk	26	13	6.50
		Total	**52.61**

For this result, the critical Chi-square value is 14.67, as a result of seven (7) Freedom Degrees and $\alpha = 0.05$. The resulting Chi-square is higher than the critical one, and with this, we reject H_0 and accept that there is a significant difference between the activity budget of both these herds.

4.1.2. Activity Distribution by sex

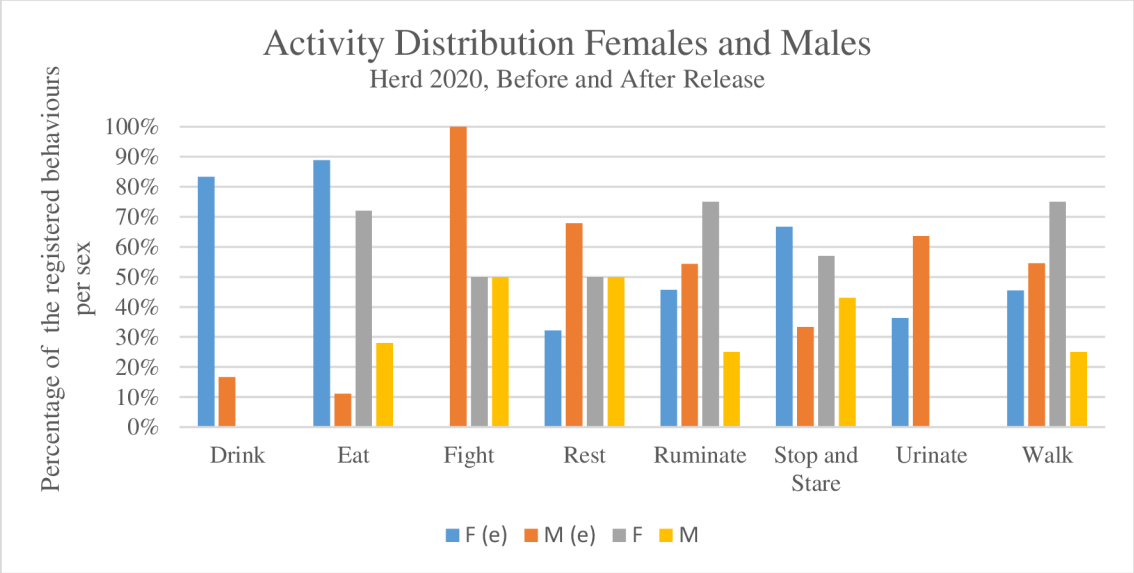

Figure 10. Distribution of the registered behaviours for the Herd 2020 before and after releasing, where F (e) and M (e) are Females and Males before releasing and F and M are Females and Males after releasing.

The behaviours shown in Figure 10 are the result of the recordings of the animals doing these behaviours separately from the group, meaning that, for example, the group was resting, and few individuals, or just one, were vigilant or eating. Also, if the group was doing various different activities at the time, the proportion of sexes doing each behaviour was recorded and is shown in the results.

Males and females, both before and after release, showed some differences in the time they spent on the registered behaviours. For example, overall, in the D records, more than 80% was done by the females, and also more females were seen eating on their own, not when the whole group was eating, than the males.

After being released, none of the individuals was seen drinking, but the females were also involved in fighting, which didn't occur inside the enclosure. The R time that

was predominated by the males inside the enclosure, was fairly divided between the sexes after the release and the SS behaviour of males increased outside, even though it kept being more present in the females.

Although urinating was present in Herd 2020, the sex identification of the animals was not possible and for this reason, this data does not appear in Figure 9.

4.2. Activity Pattern

The activity pattern was determined for both herds and, in the case of Herd 2020, before and after release, to compare them.

The R behaviour was excluded from the data used in this analysis, as it was considered an inactivity period.

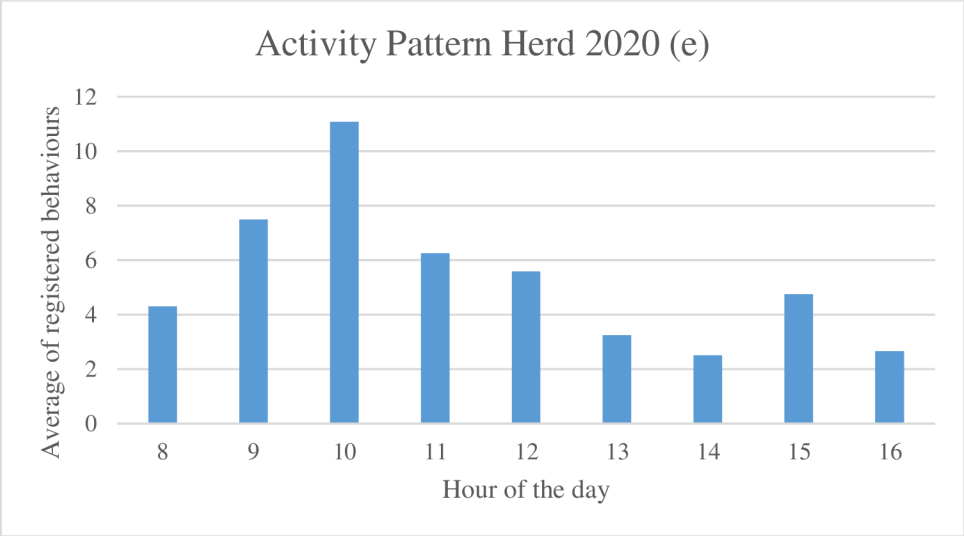

Figure 11. Average of registered behaviours per hour for Herd 2020 (e).

Before being released, the Herd 2020 showed its diurnal activity peak between 9:00 and 11:00. They were usually fed around 9:30 but started to walk to the feeding point minutes before.

During the middle of the day, the group was usually resting, excepting some vigilant individuals that would be changing “shifts” during these hours, and the group

would start being active again around 15:00 when they usually walked to the bushes to eat.

The in-person *ad libitum* observations were established until 17:00 hr and there is no information about the nocturnal activity as there were no CTs' recordings during the night, even though they were changed of place around the enclosure trying to catch the nocturnal movements of the animals.

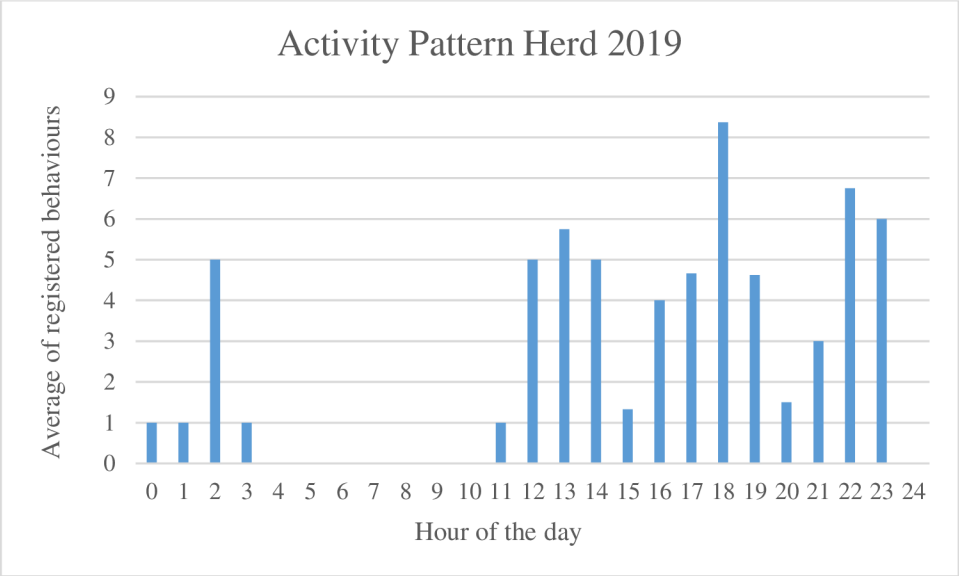

Figure 12. Average of registered behaviours per hour for Herd 2019.

For Herd 2019, the activity peaks were distributed during the day but were more present during the night and early morning. The highest peak was at 18:00 hr which was the hour when they were fed, and most of the behaviour recorded during the hour before was related to the movement to the feeding point.

The majority of the data that appear in Figure 12 are the result of the CTs that recorded the animals along the places indicated by the rangers as the usual locations of the herd.

During the day, except at the feeding hour, small herds were seen along some parts of the reserve, but the rangers kept them in the Free-Ranging Area in Figure 1. The data collection design tried to include as many individuals as possible, by going from a smaller group to another while collecting data.

There are no recordings of the animals presenting any behaviour, besides R from 4:00 to 10:00 hr.

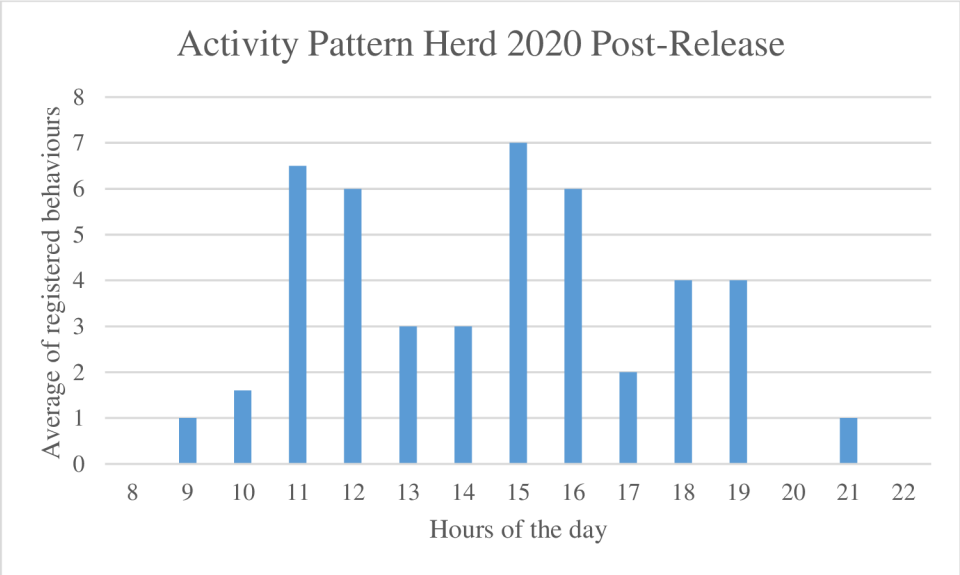

Figure 13. Average of registered behaviours per hour for Herd 2020.

As shown in Figure 13, there were various peaks of activity, contrasting with the only activity peak that was present inside the enclosure (Figure 11)**.** The animals were seen walking and eating more and also going to the feeding point at 18:00 hr with Herd 2019.

4.3. Additional observations

Although the following observations were not measured, it is important to mention them to set a precedent for the observed behaviours.

4.3.1. Interaction of addax with other species

- The Herd 2019 was seen feeding with donkeys regularly.
- The Herd 2020 (e) was sharing the enclosure with a group of ostriches and a herd of gazelles. It was never seen interacting with the latest but at feeding time, ostriches and addax were eating nearby, and this generated conflict. It was usual to see small fights between both species.

- The Herd 2020 (e) had a small interaction with a herd of goats that were feeding outside the enclosure, but near the fence where the addax usually went to rest. The vigilant behaviour of the addax increased during the first moments of the encounter but then decreased to its normal frequency.
- The Herd 2020 had its first encounter with a group of dromedaries a few days after being released, both species were eating and continued doing so without paying attention to the other.

Figure 14. Herd 2020(e) with ostriches. Photo credit Beatriz Rubio Alonso

Figure 15. Herd 2020 on its first encounter with a group of dromedaries. Photo credit Beatriz Rubio Alonso

4.3.2. Change of shifts during "Stop and Stare" behaviour

The SS or vigilant behaviour of the Herd 2020 (e) was done by a few individuals, while the others were resting, nevertheless, it was usually performed by the same group of individuals that would "change shifts" by coming to one of the individuals that were resting and move the head towards it, this individual would stand up and the other would usually take that place to rest, while the other remained vigilant for some time.

This process took place constantly, with shifts of different lengths, but it was observed that not all individuals were targeted as the receiver of the "shift signal", and also not all the individuals that received the signal accepted it, it was usually the same individuals changing shifts every day, and this vigilante group was mostly formed by females.

4.3.3. Interaction with humans

Both herds had continuous contact with humans during their time inside the enclosure, this contact decreased once they were released but did not completely disappear.

A difference in the reaction that human presence generated was seen between the herds, and even on Herd 2020 once it was out of the enclosure.

- Herd 2019 did not have any problem approaching humans while it (the herd) was moving towards a place but would run when humans approached them.
- Herd 2020 (e) would accept the human presence nearby when they were being fed, and one could easily walk among them without generating any reaction.
- Herd 2020 inside and out of the enclosure would walk away from humans, Herd 2019 would run.
- For both Herd 2019 and Herd 2020 after release, it was easier to get closer to them inside a car.
- One male from Herd 2019 showed aggressive behaviour towards the cars.
- Herd 2019 ran when listening to the sound of a motorcycle approaching.
- Herd 2019 recognized the truck where the food was transported and would come towards it.

4.3.4. Calves

For Herd 2019, it was known that after their release, 10 calves were born, but none of them survived. During the data collection period, 3 calves were born for Herd 2020, and then 1 more was registered by the rangers. There were no reports of any calves born for Herd 2019 that year.

Figure 16. Addax calves born from Herd 2020. Photo credit M'Hamid El-Ghizlane rangers.

For the Herd 2020 calves, the first one was born the day of the release (or during the previous night), but it was premature and did not survive. Its mother had an injured limb days before the release that stopped her from walking, and she was attended to and was recovering prior to the opening of the gate. It was discussed that the stress caused by the injury and the handling could have provoked the early delivery of the calf.

The other 2 calves were born when the data collection was still happening, the first one was removed from the mother and taken back to the herd some days after, but she was found dead in the upcoming days. The second one was left with its mother and as far as it is known, it survived.

Figure 17. Addax calves born from Herd 2020 resting together. Photo credit M'Hamid El-Ghizlane rangers.

The fourth known calf for Herd 2020, was born after the data collection finished and the last update showed both surviving calves together.

Figure 18. Addax female from Herd 2020 nursing her calf. Photo credit M'Hamid El-Ghizlane rangers.

5. Discussion

The result of the difference in the distribution of the activity budget of each herd was significant after applying the Chi-square test. As shown in Table 4, the two calculated Chi-square were big enough to reject H_0. Nevertheless, the difference was bigger when comparing Herd 2020 (e) and Herd 2019, than Herd 2020 (e) and Herd 2020.

Also, in Table 5, the calculated Chi-square rejected the H_0, but the difference between Herd 2020 and Herd 2019 was not as big when compared with the results obtained in Table 4.

As for how the different behaviours changed among the herds, one of the most notorious differences was the dominant behaviours, meaning the behaviours with the highest percentage. In Herd 2020 (e), three behaviours (R, SS, and W) were presented in similar percentages, while for Herd 2019 the predominant behaviour was E, with 44% of the total activity budget of the herd, followed by W with 26%, and then the extant budget was spent in other behaviours. Herd 2020 changed the proportions that were registered inside the enclosure and E became the most recorded behaviour taking up 40% of the budget, while R maintained its percentage and SS behaviour was reduced to half.

These differences show the fluctuation in priorities that the herds may have depending on the situation they are in, and in this way, their capacity to adapt to new environmental conditions. For example, when the Herd 2020 was released, it stopped having its normal feeding hour in the morning, and its eating behaviour increased, while the SS behaviour was reduced, among other changes in how the herd spent its daily activity budget.

One of the most notorious changes was that, even though D was only present in Herd 2020 (e), the individuals outside the enclosure were also registered urinating (U), but with less frequency (see Tables 1, 2, and 3). This species is highly adapted to dry environments and from what was seen, Herd 2019 knew the water point location, and later on, Herd 2020 was also registered passing by it. One possible explanation for this could be that it was winter during the period when the data collection took place, and probably, the addax do not normally need more water than what they can get from their diet during this time. The presence of this behaviour in Herd 2020 (e) could be attributed to the environmental, but mostly human, pressures that this herd was under, and that made

it present a significant difference in its general behaviour when compared to the Herd 2019, and even to the same Herd 2020 after being released.

The females ate more but at the same time were more active than males, at least in vigilant behaviour inside the enclosure.

The animals adapted quickly to their environment after being released, and their behaviour was closer to the behaviour of the previously released herd in a matter of days than it was inside the enclosure, in other words, the enclosure was changing the herd dynamics and their behaviour more than the release into the wild.

The activity budget was also different between the sexes, as shown in Figure 9. During their time inside the enclosure, females were more vigilant than males, representing more than 60% SS while males had a higher percentage for R, taking up almost 70% out of the total. Also, females were seen E outside of the group more than males, and all the F behaviour was present only in males. Some of the other behaviours did not show big differences between males and females.

One interesting observation is that, while females did most of the drinking, males had a higher U behaviour percentage.

Once outside the enclosure, females keep on representing most of the E and SS recordings but the percentage gap with males was smaller. R stopped being dominated by males and had the same percentage for both sexes, as for F, it was equally present in females and males. W was mostly performed by females after the release, while inside the enclosure males had the highest percentage for this behaviour.

These differences in the activity budget of males and females could have many explanations, two of them could be, first the different stages in which the individuals are, for example, some of the females were pregnant. The second, but not exclusive, explanation is the Forage-selection hypothesis, proposed by Mayne *et al.* (1996) and explained in Pérez-Barbería *et al.* (2007), also known as the "Sexual dimorphism body-size hypothesis", which states that allometric differences in body size, lead to larger individuals with fewer energy requirements per body mass unit, this also enables larger individuals to have more food retention time in the digestion tract and thus they are more efficient digesting fiber.

The activity pattern also differed among the herds. The Herd 2020 (e) was only registered in the daytime, as the camera traps did not register any nocturnal activity, although they were placed in different spots once the first recordings were empty.

The activity peak of this herd coincided with the time they were fed with the supplementary food; the animals would start being registered by the CTs pointing at the feeding spot minutes before the person in charge would come and provide the food.

Before that, they could be seen walking and eating from the bushes inside the enclosure, but the level of activity will increase greatly when the food was provided. On the other hand, Herd 2019 also had its highest peak at their feeding time in the afternoon but presented other activity peaks throughout the day.

Both herds presented periods of inactivity, the main difference was that Herd 2020(e) usually had SS individuals standing, while the SS individuals were lying.

As mentioned before, no activity was registered during the night for Herd 2020(e), but this could have happened due to the misplacing of the cameras, even though Herd 2019, and later Herd 2020, were seeing coming back to the feeding point during the night and early morning.

For Herd 2020, more hours of activity were recorded, as well as more activity peaks. In this case, there are differences with both Herd 2020 (e) and Herd 2019, with the first one, once outside the enclosure the animals were seen having their first activity peak later in the morning as well as more activity in the afternoon, mostly when they went to the feeding point together with Herd 2019, and also, they were registered coming back to this place during the night.

When comparing the three patterns, it is clear that Herd 2020(e) was transitioning between the conditions inside and outside the enclosure, being more active during the morning than Herd 2019, as they were used to be fed during the morning, so it was normal that they were looking for a larger quantity of food than what they could find by themselves but the lack of it made them increase their activity during the whole day. Later in the afternoon they were seen going together with Herd 2019 to the feeding point.

Other changes in behaviour that are interesting to discuss were, for example, the herd composition dynamics. While Herd 19 members were found mostly scattered during the day and night, only coming together at feeding time, Herd 2020(e) was seen together

as just one group the whole day; also, the subgroups of Herd 2019 were not composed by the same members every day, and while literature points out that the herds have a dominant male and have a size of up to 15 animals (Beudels-Jamar et al. 2005), there were various groups of only females and others that had various males at the same time.

Once released, Herd 2020 was taken to Herd 2019 and, although no F behaviour was reported, some Herd 2020 members separated from the herd and found a place in other groups. The first day after the release most of Herd 2020 was seen together, but the next day it scattered and, in some cases, mixed with Herd 2019.

The interaction with other species present in the enclosure and outside can be considered neutral, except for the hour of feeding inside the enclosure, where there would be a conflict with the ostriches. In this last scenario, after the food was over, both species would stop interacting until the next day at feeding time.

Concerning the interaction between addax and humans, once outside the enclosure the animals were more reticent to human proximity, but accepted cars to come closer. At the feeding point, they did not mind human presence, as they associated it with food, as well as when they saw the car that usually transported the food, to the latest they would even follow it. Inside the enclosure, the situation did not change much, although the animals allowed closer human presence, at the same time they were more alert due to the constant interaction for different reasons, for example: filling the water points, which required a big truck coming inside the enclosure while making a lot of noise, people coming inside to feed and check on the bustards and also, there was a small herb garden that was used by the people in charge of taking care of the enclosure, and they would enter to collect herbs regularly.

The interaction with motorcycles was different as the animals living outside were used to being herded by them, they would react faster to their presence, starting to move when they heard it coming, for the individuals of Herd 2020, they reacted stronger on their first encounters with the motorcycle as they were not herded like that before.

The two calves born for Herd 2020 that survived were seen together on their own small herd inside their mothers' herd (Figure 16). The other two died, one because it was premature and could not even reach for its mother's udder, the other was born after the release, but soon after the animals were herded back to the Free-Ranging Area (Figure 1), from where they have walked away, and the calf was left behind, as nobody saw her, then

the rangers picked her up, thinking that the mother has abandoned her. In this aspect, it is important to point out that the addax is a “Hider type species” meaning that the mother hides her calf and stays at some distance from its hiding place, and it is the calf the one that comes out looking for the mother (Lent 1971). It was discussed that this behaviour was seen as abandonment by the rangers, that then tried to raise the calves, but were unsuccessful in doing so, the information about Mother-Calf behaviour was explained to them to avoid future extraction of the calves.

As mentioned before, there were no calves for Herd 2019, and the females that gave birth from Herd 2020 came pregnant from PNSM, meaning that the animals from these groups are not reproducing after the reintroduction, and it could be due to the stress generated by human presence and activities concerning the animals.

5.1. Constraints

The data collection was restricted due to the management of the animals, mostly outside the enclosure, where they were being fed every day, altering the normal behaviour they would have if they were in the wild.

Another constraint was that outside the enclosure the animals were kept together in a restricted area, that was not fenced, but was delimited (Figure 1), and rangers would make sure the animals stayed in that area, bringing them back when they went too far. The method was following them on a motorcycle and herding them in the desired direction while using the claxon. This reduced the time of data collection because taking this as normal behaviour was not possible, and some time was needed for the animals to go back to a behaviour worth studying.

5.2. Recommendations

For further studies it is recommended that the behaviour would be followed for a longer amount of time, as well as studying the behaviour of the animals that are being bred in Sous Masa National Park, to have a broader view of the behavioural fluctuations during the reintroduction process.

For future behavioural studies of the species, it is recommended to add other behaviours, such as "Foraging" and "Grooming", to the data collection. These behaviours were noticed when watching the recordings but left outside the study as there was no way to add them to the notes taken while doing the *ad libitum* observations.

It was discussed that establishing individual personalities of the animals would be interesting and, perhaps in the future, useful for enhancing the success of reintroduction programmes. For this, new behavioural studies of the species could include this topic.

For the management of the animals, once they are out of the enclosure, the feeding period should be shorter, as the first released herd was being fed even a year after the release, and that influences the behaviour and spatial distribution of the animals. Also, the animals should not be forced to stay in one place, but rather be left to walk freely along the reserve, given that the methods for moving the animals were causing alterations in their normal behaviour and slowing down their adaptation to the new environment.

Studies in other animals show that soft and hard releases do not interfere with the animals' survival and fitness(de Milliano et al. 2016), even if the hard release shows quicker alterations in animals' body condition during the first stages of the release. Having this in mind, and after the results of the study, it is suggested that the animals of future release processes are not put inside the enclosure but directly into the reserve area, but with supplementary food at the beginning, that is still considered soft release but with less intervention.

The final, and considered highly important by the author, recommendation is to avoid as much as possible the contact between humans and addax's calves, this includes touching, feeding, or getting too close to them, especially when the mother is not around.

6. Conclusions

The herds presented significant changes in both their activity budget and pattern, showing that they can adapt to different situations, and do it quickly.

Newly released addax seemed to be adapting well to their new conditions, changing their activity budget and pattern accordingly to their surroundings.

The decrease in the energy spent in being vigilant that was observed in Herd 2020 after being released gives an *a priori* conclusion to this study, pointing out that the animals' behaviour is more altered, and probably they were more stressed, from being inside the enclosure than for their introduction in the wild.

Human presence and direct intervention should be reduced in this reintroduction program, as the animals' behaviour is altered by these factors.

Reintroduction programmes like this one aim to establish viable populations and the surviving calves, that were not present in the previously released herd, show that the reintroduction program is starting to be successful, at least in terms of surviving. Time will show if these calves can reproduce and help establish the desired population.

This study not only showed the fluctuations in behaviour that are present during a reintroduction process but also brought to light possible external factors that could jeopardize the success of the program.

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Appendices

List of the Appendices:

Appendix 1: Data collection form

Herd:		Number of individuals				
Day	Hour	Female	Male	Unknown	Activity	Comment

The table used to collect the behavioural data of Herd 2020 (e), Herd 2019, and Herd 2020.