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Original Research Article

The first reintroduction project for mhorr gazelle (*Nanger dama mhorr*) into the wild: Knowledge and experience gained to support future conservation actions

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A B S T R A C T

Reintroductions continue to be an important conservation action for endangered species. Until this, all reintroduction projects for Mhorr gazelle (*Nanger dama mhorr*) had remained at the stage where the animals live in fenced protected areas of different sizes. This study describes the first experience of reintroduction of a group of 24 Mhorr gazelle into the wild in the Safia Reserve, in Southern Morocco. The reintroduction was carried out in two phases: in the first one, the entire group was released; then, after an unexpected dogs attack event, part of them were kept safe until this problem was solved. Seven of the gazelles were monitored with telemetry collars, providing previously unavailable data on time allocation, daily rhythm of activity and social organization for the species in the wild. In addition, post-release movements revealed three patterns: during the first few days after release, small daily movements (average 2.78 km) close to the fence, followed by long-distance exploratory movements (up to 50 km) until establish territories; and finally, daily movements between established territories (average 8.39 km). Exceptional long distances (>50 km/day) were traveled after a poaching event. The study has also revealed the ability of the species to select and settle territories in favorable areas, after being kept for generations under captive or semi-captive conditions. However, their inability to recognize predators was demonstrated in an unexpected attack by dogs, resulting in the

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death of seven released gazelles. This mortality following the dog attack was favored, in part, because the released gazelle remained close to the fence, and therefore suggests that the release procedure should be revised, especially when there are predators in the release site. **This study has confirmed that dogs as predators and poaching continue to be the main threat to reintroduction projects in Southern Morocco**.

1. Introduction

In spite of its uneven success, difficulties and cost, the reintroduction of endangered or disappeared species continues to be a major objective of *ex situ* conservation programs, and the number of reintroduction projects has noticeably increased in the last few decades (Seddon et al., 2012; Sooare, 2013, 2016; Stanley-Price, 2016; Taylor et al., 2017). Among the prerequisites for a reintroduction project to start and to ensure its success are an adequate habitat for the species, the social acceptance by the local population of the species and the project itself, and the elimination of the causes that led to its disappearance (IUCN/SSC, 2013). On the other hand, one of the main factors affecting the success of such projects is the limited or scarce knowledge of basic aspects of the natural history of the species in question that could be essential to tackle the challenges imposed by living in the wild after years or generations of captivity. Among the challenges faced by a species in a reintroduction project are the initial movements and exploratory habits of released animals which could determine their ability to explore and settle in favorable habitats that allow populations to grow (Dunham, 2000; Wronski et al., 2012), the adaptation of their activities and rhythm of activity to the prevailing environment conditions (Hetem et al., 2010; Davimes et al., 2016; Abaigar et al., 2018), and the establishment of a social organization (size and composition) to ensure social cohesion and increase survival. In this case, reintroduction projects represent not only an opportunity to discover basic and fundamental aspects of the ecology and biology of the critically endangered species in freedom, which may disappear without being realized, but the experience gained during reintroduction projects would also help to increase the success of future attempts with the same or other species.

The Dama gazelle (*Nanger dama*) is, at the same time, one of the most singular, threatened and scarcely studied gazelle species of northern Africa. This species belongs to the group of Sahelo-Sahar**i**an Ungulates (SSU), which is characterized by its physiological, ecological and behavioral adaptations to live in the desert and semi-desert areas of North Africa (Durant et al., 2014). The species was formerly distributed throughout the Sahel and Atlantic Sahara region of North Africa (Cano, 1991; Durant et al., 2014; RZSS and IUCN, 2014), but is currently one of the SSU species at risk of extinction in the wild. The only confirmed populations at present are located in Niger, Mali and Chad, and it is considered extinct from Senegal, Mauritania, Sudan and the Atlantic region of Southern Morocco (Cano, 1991; Jebali, 2008; Durant, 2014; RZSS and IUCN, 2014; Wacher et al., 2008). The species is currently classified as Critically Endangered (IUCN red list 2018) and numbers are estimated at fewer than 250 individuals in the wild (RZSS& IUCN, 2014), and around 1000 individuals in captivity across Europe, USA and the Middle East (Senn et al., 2014). Three subspecies were described for Dama gazelle (Cano, 1984): *N. dama rufficolis* or Addra gazelle, occupying the eastern part of their distribution area, *N. dama mhorr* or Mhorr gazelle, in the westernmost section of the distribution area, and *N. dama,* occupying the intermediate zone between these. Most of the general information about habitat selection, diet and social organization of Dama gazelle in the wild has come from early observation in the 40s and 50s (Morales Agacino, 1949; Valverde, 1957) and then in the 70s and 80s (see revision in Beudels et al., 2005).

The Mhorr gazelle is the most colored and western-distributed Dama gazelle subspecies (Cano, 1984). In order to avoid the complete extinction of this subspecies, a captive breeding program was initiated in 1971 in the Sahara Rescue Center at the Estación Experimental de Zonas Aridas (EEZA-National Spanish Research Council) in Almeria (SE Spain) with the last Mhorr gazelles living in the Atlantic region of Southern Morocco (see detail in Cano, 1991; Valverde, 2004; Abaigar, 2018a). According to Cano (1991), the subspecies disappeared from the wild in 1968 and most knowledge about basic aspects of its biology, physiology, geneti**cs** and behavior has come from studies carried out on captive populations (Cano, 1991 and see revision in Mungall, 2018). The importance of the Mhorr gazelle for the cultural wealth of the local population should be stressed; in fact, it is considered to be much more than a gazelle and is called the "Mhorr antelope". Today, there are around 350 Mhorr gazelles living in zoos and breeding centers scattered across Europe, Arabia, and North America (ZIMS360). In addition to captive breeding programs (Barbosa and Espeso, 2005), several projects have reintroduced Mhorr gazelles to fenced reserves in Senegal (Cano et al., 1993; Jebali, 2008), Tunisia (Abaigar et 1997; Weisner and Müller, 1998; Jebali and Zahzah, 2013) and Morocco (Weisner and Müller, 1998; Cuzin et al., 2007). These projects are still in the phase where the gazelles are kept in fenced protected areas in their range states (Stanley-Price, 2016; Abaigar, 2018b).

In May 2015, local Moroccan authorities (Haut-Commissariat des Eaux et Forêts et à la Lutte Contre la Désertification) in collaboration with a local NGO ("Nature Initiative") decided to start, for the first time, a project to reintroduce Mhorr gazelle into the wild, using gazelles kept under semi-wild conditions in a fenced protected area in the Safia Natural Reserve. This decision was preceded by a positive evaluation of habitat conditions, the local and official support for the project, the control of the main threat in the area (poaching), and the existence of funds to ensure monitoring after reintroduction. This reintroduction attempt is part of a sustained reintroduction strategy of the Mhorr gazelle in Morocco, and its results essential to continue with successive releases and complete a genuine reintroduction project; the release of just a few individuals into the wild has little chance of success (Fisher and Lindenmayer, 2000; Stanley-Price, 2016).

The aims of this study were both i) to assess the implementation of the Mhorr gazelle reintroduction project in terms of the IUCN requirements and the gazelles' release procedure, and ii) to evaluate the capacity of the gazelles to regain their abilities to live in the wild in terms of their movements, time allocation and rhythm of activity, and also their social organization. As the release area has a favorable habitat (vegetation cover and available food), very long movements before establishing territories were not expected. Regarding the pattern of activity, we expected a similar pattern of activity to the other gazelle species living in the area, the Dorcas gazelle; i.e. predominant activity at sunrise and sunset, but also in the middle of the day. Regarding social organization; we expected to see the typically gregarious social behavior of this species in the area (Valverde, 1957).

2. Materials and methods

2.1. Study area

The Safia Natural Reserve (SNR), 3075 km^2 in scope, is located in the south of the Dakhla-Oued Ed Dahab region, in the province of Aousserd (Southern Morocco). The SNR is border**s** to the **S**outh by Mauritania and to the west by the Atlantic Ocean (Fig. 1). The SNR is characterized by a slightly elevated relief with stone plains, chains of dunes, nebkhas (small sand dunes that form around vegetation), sebkhas (depressions in the sand dunes) and oueds (dry riverbed channels). The climate is arid-Saharan with sporadic rainfall (less than 100 mm/year) mostly occurring in August–September (Valverde, 1957). Vegetation is typically Saharan. *Acacia raddiana* is the dominant tree and the main component of the Mhorr gazelle diet in the study area (Valverde, 1957). There is also a variety of shrubs and annual plant species. Most important among these in terms of food for the gazelles are *Atriplex halimus*, *Capparis decidua*, *Launaea arborescens, Lycium intricatum, Maerua crassifolia*, *Nitraria retusa*, *Panicum turgidum, Salsola* spp., *Stipagrostis* spp., *Ziziphus* sp. *Aizoon* sp., and *Anabasis* sp., There are no permanent human settlements within the reserve, and the only human activity is seasonal livestock grazing by camels and goats. The single roadway maintained within the SNR runs North-South of the West of SNR, connecting Dakhla with the Mauritanian border **(Fig. 1).** The Dorcas gazelle (*Gazella dorcas*) is the only ungulate species still free-ranging in the area after the complete extinction of the Addax *(Addax nasomaculatus)*, Scimitar-horned oryx *(Oryx dammah)*, and Mhorr gazelle in the second half of

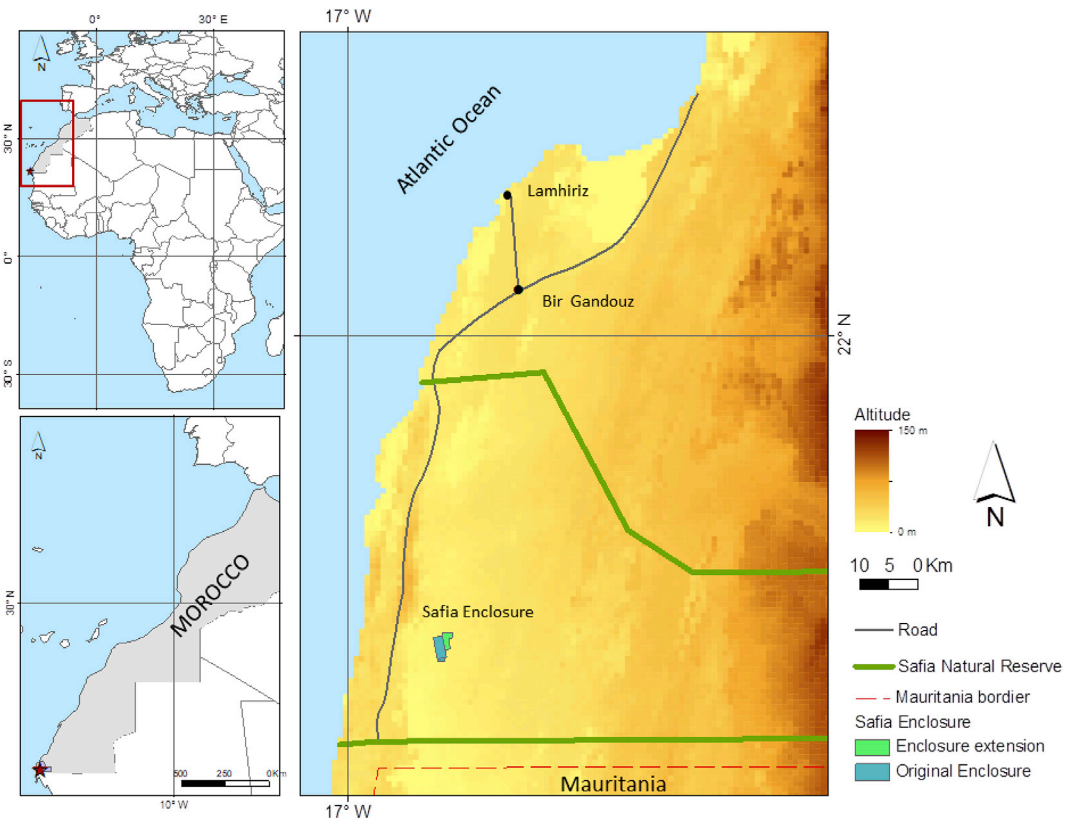

Fig. 1. Study area.

the 20th century (Cano, 1991; Valverde, 2004; Jebali, 2008). Other important species that disappeared from the region were the Red-necked ostrich *(Struthio camelus camelus)* (Jebali, 2008), and the Cheetah *(Acinonyx jubatus), which* disappear**ed** during the 1980s (Auglanier et al., 2017). The African golden wolf *(Canis anthus)* and other small carnivores are still present in the study area (Aulagnier et al., 2017).

In 2005, the Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Desértification (hereafter HCEFLCD) established a protected enclosure of 600 ha (hereafter the Safia enclosure) within the SNR. The main objective of the Safia enclosure was to allow the recovery of vegetation and to keep several extinct native species under semi-wild conditions, before future reintroductions into their natural habitat. Between 2008 and 2010, founder populations of Mhorr gazelle from R'Mila Royal Reserve, and Addax and Red-necked ostrich from Souss-Massa National Park, Morocco, were released into the Safia enclosure (Bensouiba, 2013). At the time of this study, the Safia enclosure contained semi-wild population of 41 Mhorr gazelles, 43 Addax, and 21 Red-necked ostriches.

Although hunting is completely forbidden within the SNR, poaching is the main threat for native and reintroduced **ungulate** species. For this reason, since 2005 and in collaboration with the HCEFLCD, regular patrolling has been established by the local NGO "Nature Initiative" and the Spanish CBD-Habitat Foundation. In addition, intensive awareness campaigns were promoted by these organizations with successful results, as proven by the increase in Dorcas gazelle populations in the SNR (unpublished reports).

2.2. Animals and release events

2.2.1. First release

29 (16.13) gazelles from the original group in the Safia 600-ha enclosure were isolated beforehand in an enclosure of about 50 ha located at one of the end of the main area, where they stayed for 11 days before release. Once in the 50-ha enclosure, and previous to individual immobilization, the gazelles were handled using a drive corral (MS1) specifically built for this purpose, being pushed through a series of progressively narrower spaces until they reached an individual crate. Then, each gazelle was manually immobilized by a keeper taking hold of the head at the base of the horn as and pulling the animal toward him. A mask was immediately put on the animal in order to reduce stress, and with the help of two keepers, the gazelles was placed in the shade and immobilized by tying its legs with cords. The capture started early in the morning and finished at 11.15 a.m., when the outside temperature has increased significantly. Four males died during the capture (two after a stampede against the fence of the drive corral caused skull fracture, and the other due to the stress) and one female was returned to the Safia enclosure. For a complete and detailed description on the capture and release see Abaigar (2018c). On May 22, 2015, 24 (12.12) Mhorr gazelles were released from the 50-ha enclosure by opening a section of the fence (48 m in length at a corner) so that the gazelles could exit (see Fig. 2). All of them were adults except for one young male (< 6 m.o.). Of

Fig. 2. Group of Mhorr gazelle (*Nanger dama mhorr*) -before release into the wild; some of them bearing GPS collars.

the 24 gazelles, ten adults (3.7) were equipped with GPS collars and the rest were ear-tagged and marked with colored plastic on the horns to facilitate visual identification (binoculars).

During the first five days after release all the gazelles remained near the release site and only made small movements along the fence, sometimes returning to the 50-ha enclosure. Then, an unexpected surprise attack of a pack of 11 dogs left 7 (6.1) gazelles dead, two of them (1.1) were gazelles equipped with GPS collars. According to the information obtained after the attack, domestic dogs living in the military posts in the area occasionally form packs and attack nearby livestock (goats and sheep). Given this unexpected circumstance, we decided to return the rest of the gazelles to the 50-ha enclosure. This was possible for 11 (4.7) gazelles. The rest, 6 (2.4) in total, had dispersed into three groups: group A: 3 (1.2) with one collared female (gazelle F146) so that this group could be monitored; group B: 1 (0.1), collared female (gazelle FABGAZ); and group C: 2 (1.1): the male without collar and the female equipped with a GPS never worked, so it was impossible to follow and monitor them throughout the study. Once the problem of dogs had been solved (capture) by the regional environmental authorities of Morocco, a second release was carried out. Fig. 3 summarizes the Mhorr gazelle releases, events and the timing of the monitoring.

2.2.2. *Second release*

The second release was two months later (on July 27) following the same process as previously described, namely opening a part of the fence in a corner of the 50-ha enclosure and allowing voluntary dispersal. During this second release, the 50-ha enclosure was immediately closed to prevent the gazelles from returning, and the gazelles were disturbed to move them away from the fence. Five gazelles in this second release group, two males (M510, M520) and three females (F145, F147, F500) wearing GPS collars, were monitored until the batteries ran out or they died.

2.2.3. *Poaching event*

A second unexpected and dramatic event happened the night of October 2 to 3 when a group of poachers broke into one of the main territories of the gazelles causing their flight and dispersion. According to the data provide by the collared gazelles, they dispersed into at least two groups. A group of unknown size and composition but with three collared-gazelles (2 males, M510 and M520, and one female, F145) escaped to the east, towards the Adrar Sotouff Mountains. The second group, also with an unknown composition but one collared gazelle (F147) went to the southeast. The hunters pursued the two groups of gazelles and killed M510, F145 and F147; their GPS collars were never recovered. Fortunately, M520 survived and returned to its territory 12 days later. Two females, F146 and F500, did not suffer any harassment from the hunters because they were in a different area (unpublished data).

2.3. *Data collection*

Three models of GPS collar were used in this study: three gazelles were fitted with Lotek GPS 7000SA (Lotek Wireless Inc. Ontario, Canada) tracked via the Argos satellite platform (F145, F146, F147); another three gazelles were fitted with Sirtrack G5C 375 A) recovered via the Iridium satellite platform (F500, M510, M520), and one gazelle was fitted with a GPS-GSM Ecotone-Guanaco logger (FABGAZ); see Tomkiewicz et al. (2010) for more information about GPS technologies. All collars incorporated a timed drop-off for their programmed, automatic release and had VHF transmitters except the Ecotone model.

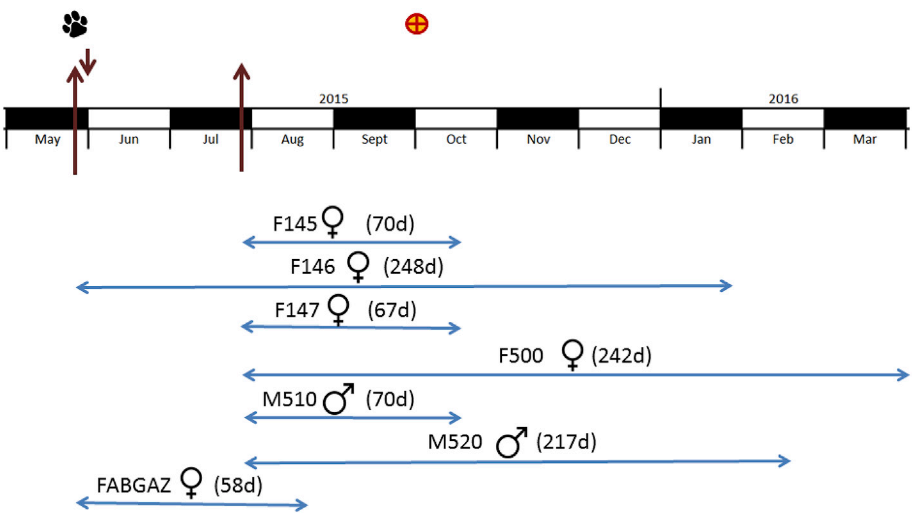

Fig. 3. Monitoring period for all collared Mhorr gazelles (*Nanger dama mhorr*) analyzed in this study and important events: first (May 22, 2015) and second (Jul 27, 2015) release (arrows), dog attack (dog footprint), and poaching (target).

Sirtrack collars were originally scheduled for eight fixes/day (every 3 h). After two months, they were scheduled for four fixes/day (every 6 h) to save battery power. During the poaching event they were modified again, to fix a position every 30 min. Lotek collars were scheduled for 16 fixes/day and it was impossible to reschedule to 4 fixes/day, unlike the Sirtrack. The Ecotone collar provided 24 fixes/day (every hour). Released gazelles were also monitored by direct observation using a very high frequency (VHF) radio antenna (SIKA receiver), once the position of each group had been determined by the GPS collars.

2.4. Data definition

Data positions from the different collars were transformed into UTM coordinates. Moreover, as the different collars have different time resolutions, Argos and Ecotone datasets were standardized at the time resolution of the Iridium collars (6 h with four points per day at 01:00, 07:00, 13.00 and 19:00). To do this we identified the data records, on the Argos and Ecotone collars, that were closest to these 4 different time points within the day and assigned this data as a specific measurement corresponding to this time point. Finally, we estimated the time lag between the original data and the resampled time points, discarding any points that differed more than 1 h. Using the resampled datasets, we calculated the minimum movement between the time points as Euclidian (straight line) distances between two consecutive positions, as well as the distance between all the pairs of gazelles at each time point.

2.4.1. Activity data

Direct observation of the movements and behavior of the gazelles in the study area showed that they traveled along linear routes over this homogenous flat terrain without any topographical obstacles. The activity was therefore defined based on the minimum distance traveled by the gazelles between the fixed time points of 19h (-1d) − 1h, 1h -7h, 7h − 13h, and 13h − 19h (minimum speed; km h^{-1}). This time interval has enough time resolution to pick up different events in the daily cycle of a gazelle whereas it avoids temporal autocorrelation (see revision Boyce et al., 2010). This method is quite similar to the one used by Oven-Smith and Goodall (2014) to determine the daily activity of several ungulate species in Africa.

The 3164 velocity points were classified into four behavioral categories/activities by means of K-means clustering with maximum variance between groups ($F = 8729$ $df = 3$, $p < 0.00$) (MS1): a) activity related to resting, standing up, feeding or slow movement, mean velocity = 0.13 ± 0.08 kmh^{-1} (range: 0 to 0.31 kmh^{-1}); b) normal movement at mean velocity of 0.48 ± 0.13 km h^{-1} (range 0.32−0.78 km h^{-1}); c) running or fast movement, mean velocity 1.09 ± 0.22 km h^{-1} (range 0.79−1.59 km h^{-1}); and d) high-speed escape, mean velocity 2.18 ± 0.5 km h^{-1} (range 1.60−3.67 (km h^{-1}); see Supplementary Material Fig. S2. These ranges of velocity and definition of activities are comparable to those found by Over-Smith and Goodall (2014) for zebra, sable antelope and African buffalo, except that we were also able to identify the instances of complete immobility of animals because of the higher time resolution (1 point per hour).

2.5. Statistical analysis

Using the 3164 activity points, we calculated the overall average daily activity pattern for the Mhorr gazelle as a percentage of the time invested in each activity/behavioral category. X^2 test was used to evaluate differences between individuals in this daily activity pattern. A non-parametric Kruskal-Wallis ANOVA test and subsequent post-hoc comparison of mean ranks between individuals were used to compare the time invested in each behavioral category. Differences between individuals regarding the daily distances traveled by each gazelle were analyzed by means of a log-transformed ANOVA test. Statistical analyses were performed with STATISTICA 7.0 for Windows (Statsoft UK, Letchworth). Finally, we calculated the number of times that each pair of individuals stayed together, assuming the two individuals belonged to the same group if the distance between them was less than 500 m. This distance was established after observing Mhorr gazelle groups in the main Safia enclosure of 660 ha. Using this information, we constructed a social network in which each node represented a collared gazelle and lines represent their interactions (for each pair of individuals, the proportion of records that are in the same group out of the total number of time records during the period with information on the two individuals making up each pair). This meant that, for a pair of gazelles that only co-exists for two months, the total records from when they were in the same group was divided by the total number of records within these two months. Node density was calculated for each gazelle separately and also for the entire network using UCINET 6.258 (Borgatti et al., 2002).

3. Results

3.1. Overall activity

Overall, the Mhorr gazelles spent 61.1% of their time on activities which involved little or zero movement, such as resting, feeding-browsing or standing up (hereafter feeding-resting), 26.7% on movement at moderate velocity (hereafter movements), 9.7% on movement at high velocity (hereafter running), and just 2.4% of the time at very high speed (hereafter escape). However, there were differences between individuals ($X^2 = 89.7$, df = 18, $p < 0.001$). These differences were mainly found in the time spent feeding-resting (K−W test, $H_{6,752} = 39.3$, $p < 0.001$) and in movements (K−W test, $H_{6,752} = 46.2$ $p < 0.001$) but not in the time running or escaping. From the different gazelles, FABGAZ was the individual that invested the

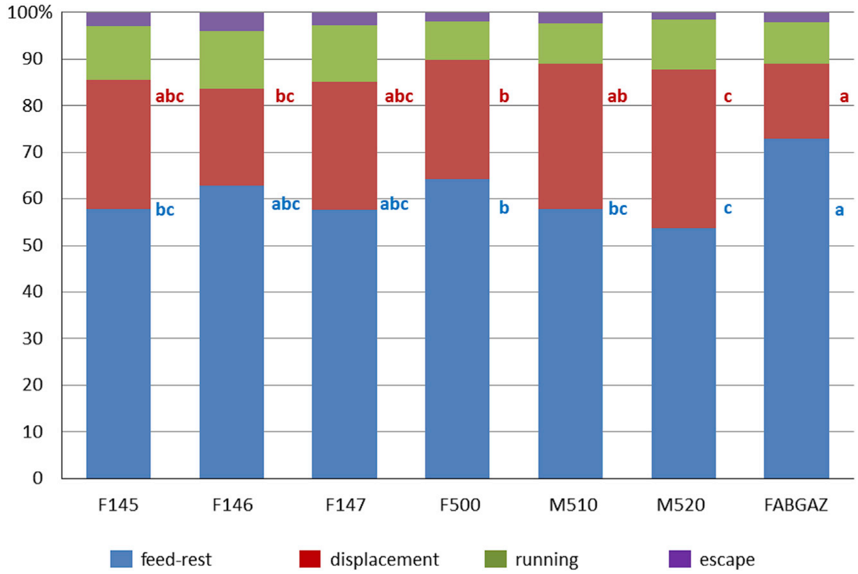

Fig. 4. Percentage of daily time invested by Mhorr gazelles in each activity.

most time in feeding-resting (72.9%) and the least in movements (16.1%), whereas M520 showed the lowest values for feeding-resting (53.7%) and the highest for movements (34.1%; Fig. 4). No monthly variations were found in the distribution of daily activities.

3.2. Daily activity pattern

We also found significant differences in the hourly time distribution of activities ($X^2 = 98.02$, df = 9, $p < 0.001$). Overall, early morning (01:00–07:00) was the period of least activity, with 74% of the time invested in feeding-resting. Morning (07:00–13:00), on the other hand, was the time when the highest frequencies of movement were recorded (32.5%). During this part of the day, the Mhorr gazelle spend almost 50% of their time on various types of movement or movement (movements, running and escape; Fig. 5).

Individual analysis of daily activity patterns showed that F500 ($X^2 = 68.3$, df = 9, $p < 0.001$), M510 ($X^2 = 17.5$, df = 9, $p = 0.041$) and M520 ($X^2 = 42.3$, df = 9, $p < 0.001$) had a bimodal daily activity pattern that differed from the overall daily

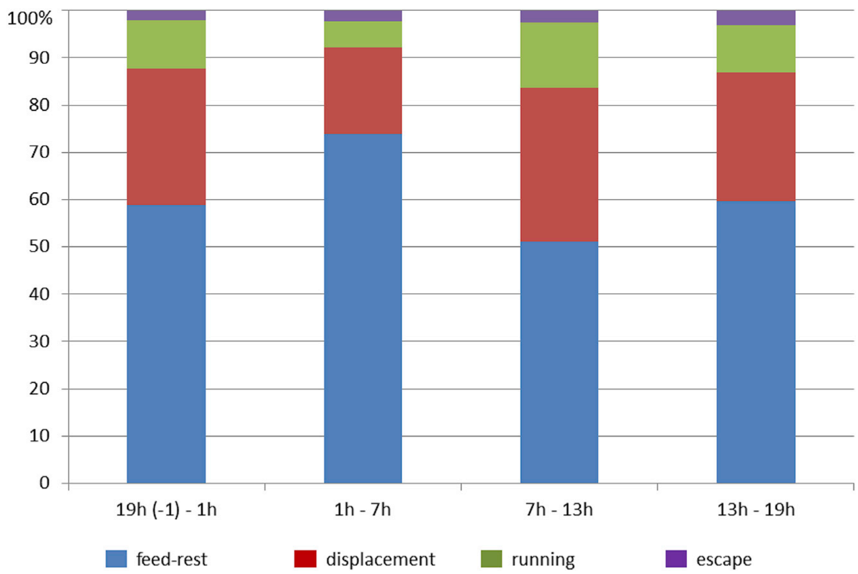

Fig. 5. Hourly pattern of activity of Mhorr gazelle.

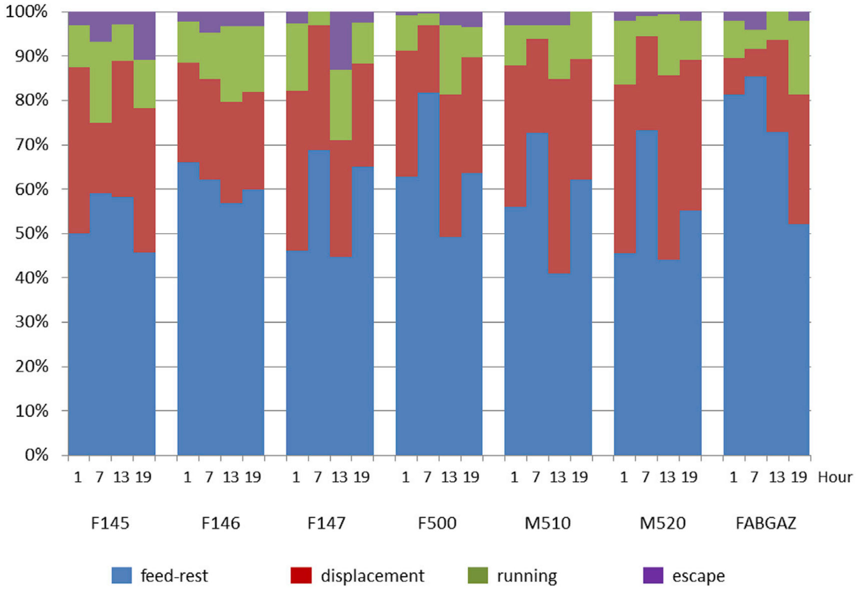

Fig. 6. Interindividual differences in the hourly activity pattern of Mhorr gazelle.

behavior of the group, as shown in Fig. 5. However, in the case of F147, these differences were not significant, probably because of sample size effect. Most feeding-resting activities occurred between 01:00–7:00 h and between 13:00–19:00, whereas movements were more frequent from 07:00 to 13:00 (Fig. 5). FABGAZ also showed a different daily activity pattern ($X^2 = 23.1$, df = 9, p = 0.006), with very large amounts of time invested in feeding-resting during most of the day, with movements being made at sunset. This female was alone during most of the study period, occupying different territories (unpublished data) to the rest of the gazelles.

The differences were also statistically significant when the spread of activities on each hour interval between individuals was compared (at 19h (-1d) -1h: $X^2 = 47.2$, df = 18, p < 0.001; at 1h - 7h: $X^2 = 58.1$, df = 18, p < 0.001; at 13h - 19 h: $X^2 = 58.4$, df = 18, p < 0.001) except for the activities carried out between 7:00 and 13:00 (see Fig. 6).

3.3. Movements

Table 1 show the average and range values of the daily distance traveled by each individual Mhorr gazelle. On average, the seven collared gazelles traveled 8.39 ± 5.71 km per day (range 0.51–36.49 km day^{-1}), although during the first few days after the first release, all individuals (n = 10) remained close to the release point, moving only 2.78 ± 1.48 km per day (range 1.68–3.24 km day^{-1}) along the fence (see Supplementary Material Fig. S3). Out of all the gazelles, the males (M510 and M520) traveled further per day.

A few days after release, the gazelles explored different regions before establishing territories. All the collared gazelles, except FABGAZ, established their territories 20–30 km north of the release point. FABGAZ, which remained alone, established her territory at 50 km northeast of the release site. See Fig. 7 where the daily distance from the release point and the percentage of time dedicated to each activity is shown for each gazelle. The longest distances traveled by all the gazelles correspond to movements, either alone or in groups, from the different territories to the enclosure. No time pattern was detected for these approaches and the time they remained near the fence was also irregular. Sometimes they made the round

Table 1
Average, min. and max. daily distances traveled (km) by Mhorr gazelle. Different letters indicate significant differences between individuals (ANOVA, $F_{6,736} = 6.07$, p < 0.0001).

Gazelle	n	Daily distance traveled (km)		
		average ± std	max.	min.
FABGAZ	60	7.42 ± 0.73^{b}	26.01	0.62
F145	31	8.60 ± 1.02gecco_680_gr6_3c.tif - ^{ab}	21.03	1.44
F146	119	7.56 ± 0.52^{b}	27.98	0.6
F147	28	8.89 ± 1.07^{ab}	22.79	1.87
F500	237	8.01 ± 0.37^{b}	36.49	1.24
M510	66	9.21 ± 0.70^{a}	26.11	1.27
M520	202	9.24 ± 0.40^{a}	35.50	1.99

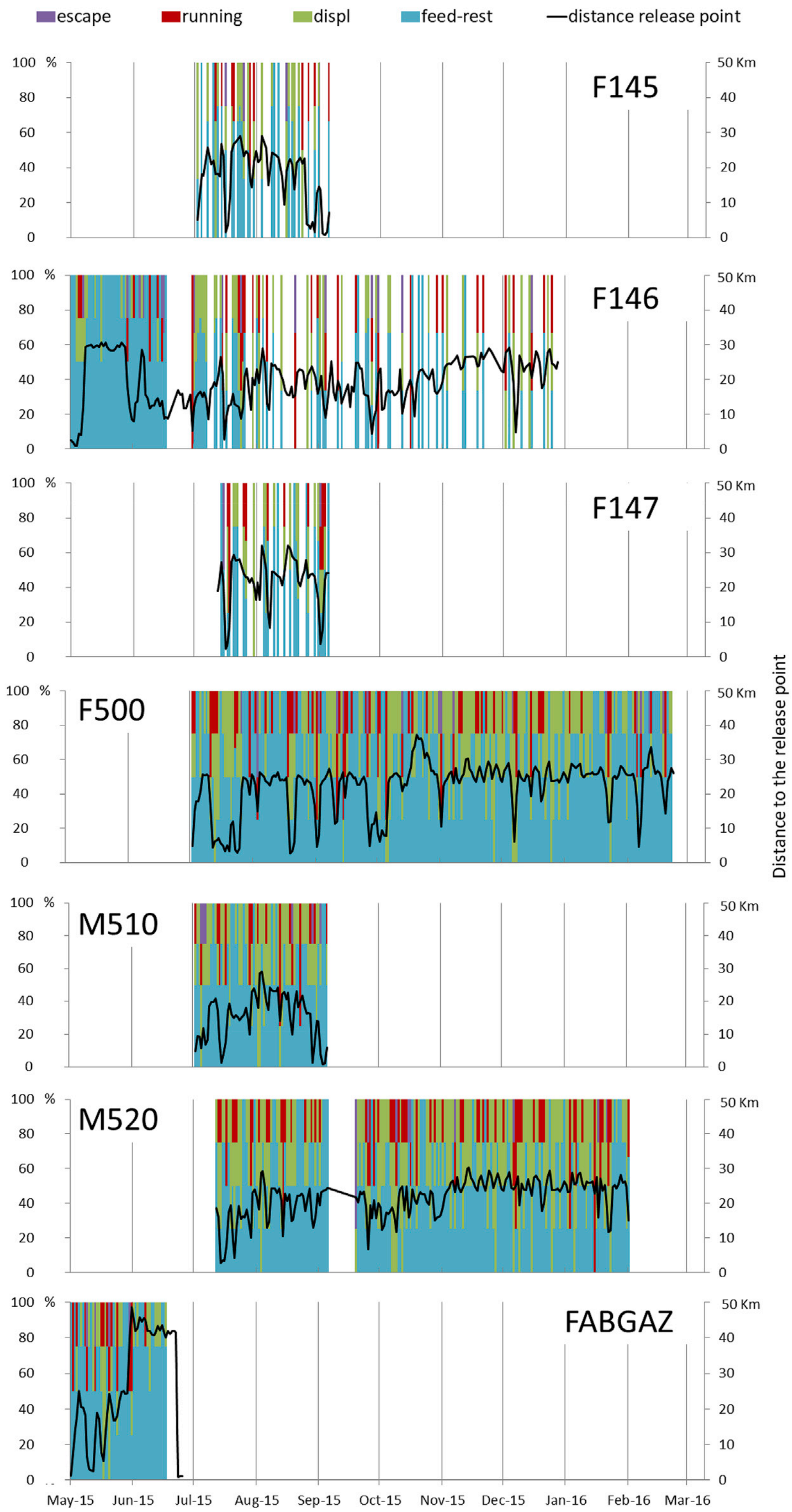

Fig. 7. The daily distance from the release point (km) and the percentage of time dedicated to each activity is shown for each gazelle.

trip (from/to their territories) in a single day, while at other times they stayed in the surroundings of the enclosure for several days. In these approaches the gazelles arrived at the fence by moving along in an apparent attempt to return to the enclosure or establish contact with the gazelles inside the 600-ha enclosure (see Supplementary Material Fig. S4).

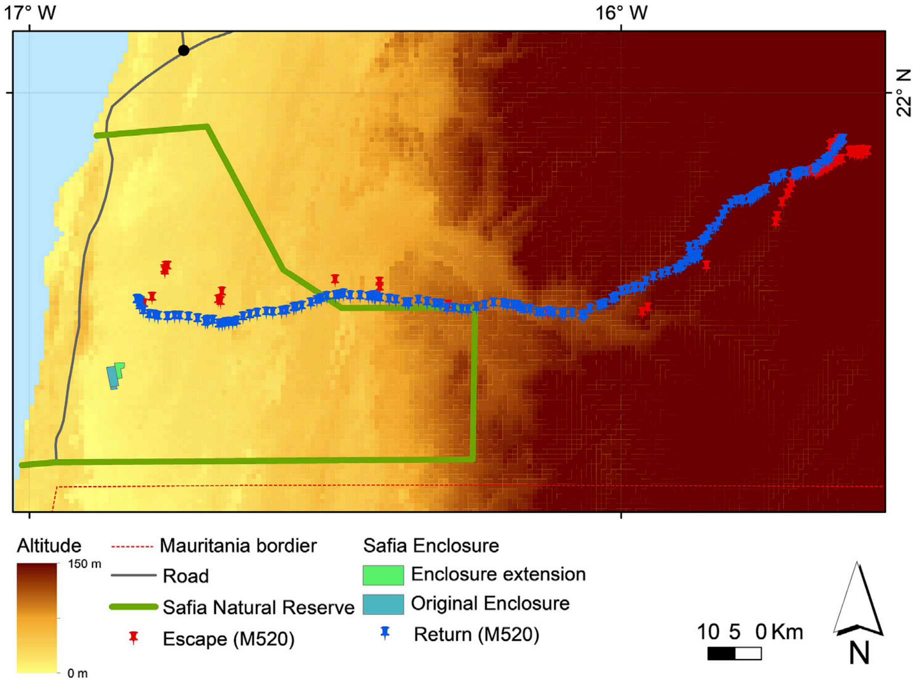

Fig. 8. Locations and path followed by M520 during his flight -and return-after a hunter event.

3.4. Poaching event

After hunters broke into their territories on October 3, some gazelles dispersed and fled. During the escape, they were apparently persecuted by poachers (with vehicles), as can be deduced by an analysis of the daily distances traveled by the gazelles and their trajectories. It was possible to follow the movements of 4 collared gazelles: F145, M510, M520 and F147. F147 fled to the southeast, traveling 75 km in four days and dying close to the Mauritanian border. Although it was impossible to find the carcasses or other remains, locals confirmed the death of this gazelle. It is still not known whether this female fled alone or in a group. The other three gazelles formed a group escaping to the east, reaching the Adrar Sotouff Mountains about 180 km away in six days (30 km per day). During the first three days, they traveled ~125 km, the third day recording the longest distance traveled in a single day (50-53-60.5 km). The three gazelles followed the *oueds* and remained together during most of their escape, although sometimes they were 15 km apart. Once they reached the Adrar Sottouf Mountains, the three gazelles followed different trajectories. Two of them (M510 and F145) died while M520 managed to escape from the hunters. After two days in the mountains, this male returned to his territory in the Safia reserve after traveling for five days and using practically the same path as on the way out (Fig. 8).

3.5. Social organization

Fig. 9 shows the social network of the 7 collared gazelles reintroduced in the SNR. Except for FABGAZ, which dispersed on its own and established separate territories (data not shown), the rest of the gazelles formed a big group in which M520 showed the highest interaction density (25%), M510 the lowest (13%) and F500, F147, F145 and F146 with intermediate values. In any case, all of them interacted with each other to a greater or lesser extent and none occupied a leading place in this network of relationships (PRGM, centralization 31.87%).

4. Discussion

This study presents the first data on the time allocation and rhythm of activity of Mhorr gazelle in the wild, which differ slightly from what has been observed of the species under semi-wild conditions. Whereas, under semi-wild conditions, Mhorr gazelles spend 72—77% of the time on resting and feeding activities and just 20—25% on movements (Bouchri, 2016), when free they spend about 60% of their time on maintenance activities related to resting and feeding, and the remaining time (40%) on activities related to movement between territories, mostly at moderate-slow velocities. It seems that the main reason for this different pattern of activity could be related to the limited space available within the enclosure, precluding the establishment of distant territories and consequent movement. A deeper analysis of the daily activity pattern of the different Mhorr collared gazelles under wild conditions showed that this species carried out most of its resting-feeding activities

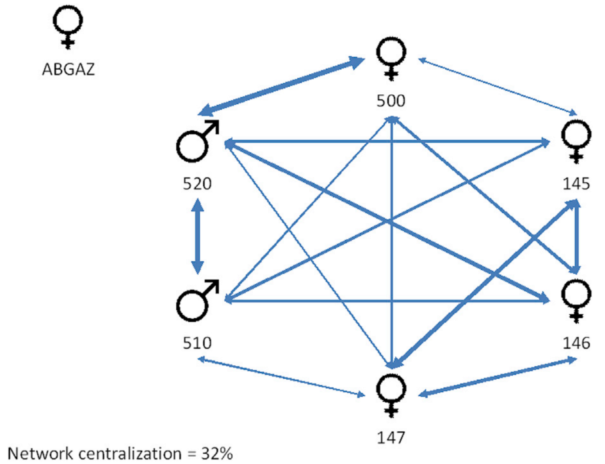

Fig. 9. Network of relationships of released Mhorr gazelles. Arrow thickness represents interaction intensity between gazelles (nodes) at both extremes of the line.

during the late night-dawn hours, whereas the peak of locomotion occurred before noon. This general pattern is individual-dependent. For example, four out of the seven collared gazelles showed a bimodal pattern with peaks of feeding activity at dawn and dusk, which is the typical daily activity pattern of sympatric Sahelo-Saharan ungulate species (Abaigar et al., 2018; Seri et al., 2018), whereas the other 3 showed a different daily behavior. Curiously, the gazelle showing the most different pattern of activity was a female (FABGAZ) which remained isolated, far from the group. In the absence of direct observations, we speculate that this was an extremely stressful situation and a probable reason why the gazelle spent most of the day resting-feeding. This behavior would not be surprising bearing in mind that the Dama gazelle is a social species that lives in groups in the wild (Valverde 1957; Wacher and Newby 2010; Wacher et al., 2014), as also demonstrated in the current study. Consequently, for a female, being alone must be an extremely stressful situation. The lack of monthly or seasonal variations in the time allocation could be explained by the fact that there were few environmental variations, both in terms of the availability of food and also in temperature in the study area; both factors are main drivers determining time allocation and daily activity patterns in ungulates (Xia et al., 2011; Massé and Côté, 2013; Yihune and Bekele, 2012). The perennial *Acacia tortilis* tree, considered a "keystone species" in the study area (Mills et al., 1993), is the main source of nutrition for Mhorr gazelle and its phenology ensures there is a continual supply of food throughout the year, eliminating the need for long-distance movements or migrations. On the other hand, the closeness of the location to the Atlantic Ocean means that temperatures remain mild throughout the year, avoiding the extremes (cold and heat) that occur in more continental areas of the inner Sahara desert.

The average daily distance traveled by all the collared Mhorr gazelles suggests three patterns of dispersal behavior. During the first few days after release, most movements were short trips around the fence, during which time they remained close to the release point. This behavior is quite common for released ungulates reared under captive or semi-captive conditions (Dunham, 2000), and it is commonly favored by managers to improve their control of the initial phases of reintroduction. However, this initial period of short movements close to the release point could entail a risk for the animals' survival, as will be described below. Once they had explored the area surrounding the fence, they conducted several long exploratory trips (up to 50 km per day) related to the establishment of their territories. Similar exploratory behavior has been described for others gazelle species such as the Mountain gazelle (*Gazella gazella*). However, in this case the distance traveled was only 12.1 km per day (Dunham, 2000). According to Dunham (2000), dispersal distances of released mountain gazelles are related to the quality of the habitat, but also to the age, sex and breeding experience of each individual. Once the territories had been established, the average daily distance traveled by the Mhorr gazelle dropped to 8.39 km and was higher for the males, with occasional long-distance returns to the release point.

The exceptional event of hunters breaking into the gazelle territories and their subsequent flight revealed four exceptional abilities in this species: 1) the ability to travel long distances in a single day (up to 60 km); 2) the ability to find a favorable escape route by the oueds; 3) the ability to identify the mountains as a safe haven, and 4) according to the data provided by the surviving gazelle, the memory to return to their territory (once the danger has passed). This experience shows the capabilities of this species to survive, even after generations of life in captivity or under semi-captivity conditions.

The release procedure followed in this project (a progressive, voluntary and stress-free release of the animals and keeping the release site open) is a common procedure previously followed in several ungulates reintroduction projects, since it allows animals to come back to a "safe" place, if necessary (see the revision in Moehrenschalager and Lloyd, 2016). However, this experience has shown the fatal consequences that may occur when the animals stay close to the fences or to the point (enclosure) of release. The Mhorr gazelles may have been attracted to the fences for two main reasons: an "erroneous" perception of security, as a fence marked the limit of their safe territory before their release; and because some of their relatives had remained inside the Safia enclosure (since not all the gazelles were released during the project). When the dog attack happened, instead of fleeing into the open countryside, the gazelles approached the fences and were cornered by the dogs. Consequently, future reintroduction projects with this species should consider releasing all the animals in an enclosure at once, as well as introducing elements that disturb the gazelles and force them to move away from the release point and establish territories far from it. We believe that the gazelles would have had the same flight behavior had they been attacked by hunters at the release point instead of the dogs.

Most of the predators of the Mhorr gazelle and other North African ungulate species have disappeared (lion, IUCN, 2018) or are very scarce, such as the leopard, cheetah, striped hyena and caracal (IUCN, 2018, see Aulagnier et al., 2017 for the status of these species in Morocco). Only the African golden wolf (Canis anthus) is still abundant and widespread. In addition, the Golden eagle (*Aquila chrysaetos*) is a predator of gazelle calves. Before the reintroduction project, in the SNR only the Golden wolf and the Golden eagle were identified as potential predators of Mhorr gazelles. However, this project has shown the threat of dogs as a real predator for reintroduced ungulate species. Previous information about dog attacks on Dorcas and Cuvier gazelles in Moroccan fenced reserves **(**Cuzin et al., 2007) and Senegal (no published data) and on wild Barbary sheep (*Ammotragus lervia*) populations in Tunisia (M. Petretto, pers. comm.). This experience supports concerns regarding the lack of ability of long-term captive-reared species to recognize predators and the need to implement predator recognition training (McLean et al., 1999; Griffin et al., 2000; Shier and Owing, 2007; Moseby et al., 2012). In view of the current study and other experiences, the presence of dogs in a reintroduction area could be categorized either as one of the stochastic events compromising the success of the reintroduction project or dogs can be included as a predator. Future reintroduction projects in the SNR should include dogs as a predator species and assess their threat by the area's degree of human presence, given that the presence of dogs in the SNR is linked to humans (settlements, livestock, garbage dumps).

Despite the apparent effectiveness of hunter controls, and the social acceptance of the reintroduction of Mhorr gazelle in the SNR, the fragile success of reintroduction projects has once again been demonstrated (Spalton et al., 1999). The action of just a few people over a short period of time is enough to destroy the efforts of an entire community (see revision in Stanley-Price, 2016). Patrolling, political commitment, effective control of poaching, and education and sensitization programs are indispensable measures to eliminate the main threat that first led to the extinction of numerous species in the region and can impede the success of nature conservation measures implemented by stakeholders and the entire community.

The use of GPS satellite collars to monitor released Mhorr gazelles has once again shown the importance of this device for reintroduction projects. Not only because they provide valuable information about the species' natural history (movements, activity), but because they are essential for locating animals and knowing whether they are alive or dead, which, in short, is a measure of the success of the project (see revision on methods and purposes of post-release monitoring in Gitzen et al., 2016.). However, they are too expensive for some projects. Depending on the circumstances and objectives, an acceptable alternative could be use VHF-collars, which are approximately one-tenth of the GPS′ cost (Thomas et al 2011). However, the use of VHF has its disadvantages: a) it requires at least two people with a vehicle to locate the animals; b) it is of limited reach (distance) in areas with pronounced relief; in our case, and given the absence of relief, the signal range was 2.5–3 km; c) they provide limited and nonspecific information on animal behavior and activity. Thus, in order to increase the number of monitored individual on projects with budget limitation we recommend combining some GPS collards with VHF collars that at least provides information on the survival of the animals and their approximate location. Finally, Although it was not an objective of this study to compare the effectiveness of different models of GPS collars, this first experience with Mhorr gazelle to the wild has shown the Sirtrack collars to be more effective than the Lotek. The main problem with the Ecotone collar was the lack of regular data transmission due to its solar batteries not recharging.

5. Conclusion

This first experience of reintroduction of Mhorr gazelle into the wild has helped not only to increase our basic knowledge of the natural history of the disappeared Dama gazelle subspecies, but has also served to evaluate the practical application of the IUCN/SSC recommendations, as well as the most commonly-used procedures for reintroductions. The results in terms of habitat suitability and the ability of the Mhorr gazelle to recover most of their behavioral capacity to live in freedom, after generations of living in captivity or under semi-captive conditions, have been positive. However, the mortality resulting from the presence of an unexpected predator, a pack of dogs, has revealed either the gazelles' inability to recognize predators or failures in the release procedure used, or both. Future release attempts with this species should consider establishing a wild population farther from their previous captive or semi-captive sites. Finally, this experience has confirmed that poaching continues to be the main threat to reintroduction projects in Southern Morocco.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2019.e00680.

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