International Journal of Animal Science and Technology
2022; 6(1): 6-20
http://www.sciencepublishinggroup.com/j/ijast
doi: 10.11648/j.ijast.20220601.12
ISSN: 2640-1282 (Print); ISSN: 2640-1312 (Online)

Social Dynamics of Exotic Dama Gazelles *(Nanger dama)* on Texas Ranch Land

Elizabeth Cary Mungall[1, *], Susan Margaret Cooper[2]

[1]Second Ark Foundation, Kerrville, USA
[2]Wildlife Ecology, Texas A&M AgriLife Research, Uvalde, USA

Email address:
elizabeth@mungall.us (E. C. Mungall), susan.cooper.uvalde@gmail.com (S. M. Cooper)
[*]Corresponding author

To cite this article:
Elizabeth Cary Mungall, Susan Margaret Cooper. Social Dynamics of Exotic Dama Gazelles *(Nanger dama)* on Texas Ranch Land. *International Journal of Animal Science and Technology*. Vol. 6, No. 1, 2022, pp. 6-20. doi: 10.11648/j.ijast.20220601.12

Received: February 7, 2022; **Accepted**: February 26, 2022; **Published**: March 9, 2022

Abstract: This project examines social dynamics of North African dama gazelles *(Nanger dama ruficollis)* under different combinations in a large, 202 ha, rangeland pasture in Central Texas, USA. There are many wildlife ranches in this part of Texas that keep herds of these critically endangered dama gazelles. Therefore, an increased understanding of how these pasture animals may assort themselves under different social combinations can not only help managers sustain and grow their herds but also bolster the numbers that give the species a better chance to remain viable while status in their native countries remains precarious. Investigated were: (1) 7 adult females with one adolescent male and one young adult male, (2) the same adult females and immature male without any adult males, (3) the same adult females and the young, now maturing, male with multiple adult males. It was shown that multiple adult males can co-exist in large pastures with minimal aggression, even when females are present, provided there is informed management. All the gazelles wore GPS-radio collars (7 adult females, 1 immature male, and 1-to-3 adult males depending on phase of the project). Locations were recorded every 3 hr. Visual observations were made monthly. Project duration was December 19, 2014, until June 30, 2016. Without the initial adult male, the female herd split and association values declined. With new adult males added, 2 divided the pasture, thus, separating spatially. The maturing male kept his core area where the main female group stayed, but now separated temporally. Adult males focused on areas favored by females but did not direct the movements of the females. These males did not associate as closely with females as females did with each other. Estimating maximum possible adult males for a pasture must allow for slope, vegetation density, and sites favored by females. The only two similar studies determined larger core areas under more xeric conditions, but these other studies could not assess group dynamics in detail without collars on more animals.

Keywords: Addra, Africa, Conservation, Core Area, Endangered Species, Texas Ranches

1. Introduction

1.1. Goals of This Study

This study seeks to investigate the population dynamics for dama gazelles *(Nanger dama ruficollis)* kept in different social combinations. This should give managers information on how the population may operate under different scenarios. Most importantly, it shows that the more natural social order of having multiple adult males with females in a breeding pasture is achievable with minimal aggression when certain conditions are met.

The goals of this study were:

1. To increase the sustainability of herds of the critically endangered North African dama gazelle raised as exotics on Texas ranches, USA.
2. To identify home range size, core area size, and placement for dama gazelles sharing a large (202 ha) rangeland pasture.
3. To identify the association and distribution between the gazelles under different social combinations within the population.
4. To describe habitat influences on animal distribution.
5. To estimate maximum number of breeding males possible in this kind of pasture.
6. To provide recommendations for conservation and

management of multiple-male groups of dama gazelles in rangeland pastures.

1.2. Conservation Needs and Status in Texas

Dama gazelles *(Nanger dama)* are critically endangered in their native distributional area in the Sahelo-Saharan Zone of Africa. A total of 300 or fewer are estimated to exist in the wild [1, 2], but there are about 500 to 600 dama gazelles in zoological parks and similar collections worldwide [3], and, most importantly, approximately 1500 on exotic wildlife ranches, mainly in Texas [4] (Figure 1). Many of these dama gazelles in Texas live under semi-free-ranging conditions in rangeland pastures often of 200 ha to even as much as 8900 ha in extent. This means that they provide unique opportunities for conservationists to obtain much needed information on the behavior and ecology of the species. This is especially useful because such information is difficult to obtain from wild populations due to rarity of the species, remote areas in which the remaining wild dama gazelles live, and political upheaval in various North African countries [5].

Figure 1. *Dama gazelle male TM in the settling enclosure (photo by Elizabeth Cary Mungall courtesy of Morani River Ranch, Texas, USA).*

Insight into the social interactions and spatial distribution of dama gazelles within pastures is needed for successful species management and restoration efforts. These exotic populations help ensure the continued survival of the species. Adult male dama gazelles are aggressive towards each other and this causes problems in the breeding and management of the species. In confined areas, males will fight to inflict damage and even kill rivals when females are present [6-8]. Standard management practice is to maintain only one adult male per breeding herd. However, under this system, reproductive output is less than optimal [9]. Keeping males in adjacent fenced pastures appears to improve reproduction but is not an ideal option. The ability to establish groups of dama gazelles including multiple males is a sought-after conservation goal both for management of the species on exotic wildlife ranches and for re-establishment of dama gazelles in protected reserves within their native African homelands.

While a previous West Texas study [10] provided useful information for exotic dama gazelles in an extremely large (8996 ha) semi-arid pasture, most exotic wildlife ranches and even the several fenced African restoration sites cannot provide so much space [1, 10, 11]. The present project examines the associations and spatial distribution of both male and female dama gazelles when kept in a sizeable but less extensive rangeland pasture more typical of areas available for conservation projects involving dama gazelles. Animal home range size is also influenced by resource abundance and distribution on the landscape [12]. Therefore, it is predicted that in a more mesic environment with greater vegetative production, the size of a core area established by dama gazelles will be smaller and the animals can be successfully kept at greater density than in arid landscapes such as West Texas. The opportunity to track the associations and distribution of female dama gazelles as well as males also provides useful insights into behavioral interactions and spatial requirements of breeding groups that can be important for restoration of the species.

2. Study Site

This study was conducted in a 202 ha rangeland pasture on the Morani River Ranch in Uvalde County, Texas, USA (Figure 2). The ranch is located on the southern border of the Edwards Plateau (also known as the “Hill Country”) in Central Texas. This ecoregion is the hub of exotic wildlife activity in Texas and is home to most of the approximately 1500 dama gazelles present in Texas [4].

The climate of this region is classified as humid subtropical, and is characterized by hot, humid, summers and mild-to-cool winters [13]. The warmest month is July with an average temperature of 28.6°C and the coolest month is January with an average temperature of 10°C. Precipitation is highly variable but averages 654 mm/yr. at the closest weather station located at Montell [14].

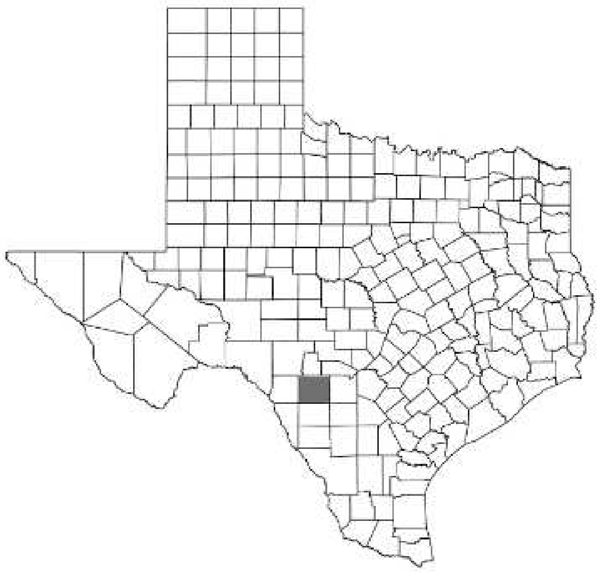

Figure 2. *Uvalde County, Texas, USA, where study was conducted.*

The landscape (Figure 3) was characterized by rocky, limestone hills. Within the research pasture, the elevation range was 332 to 396 m with the steepest slopes on the northern sides of the hills. The dominant ecological site (176 ha) in the pasture fell within the Ector soil series [15] with very shallow, rocky, calcareous, clay loam soil over fractured limestone bedrock. The Ector soil series extends through much of the Edwards Plateau and was also prevalent at the West Texas site previously studied [16]. Within the study pasture, there are also 3 small areas of slightly different composition. The 10 ha area around the ephemeral creek in the narrow eastern arm of the pasture was characterized by Dev soils, consisting of limestone cobbles mixed with very gravelly clay loam soil. In the southwestern corner, a shallow valley was characterized by 11 ha of slightly deeper Eckrant-Kavett Complex soils. Limestone Rockland or exposed limestone occurred in a 4 ha area in the southeast of the pasture and in small areas on the hill tops. Estimated potential agricultural productivity [15] of the dominant Ector soils is low at 1500 kg/ha. Productivity in the valleys is reported at 2000-2500 kg/ha due to slightly deeper soils and greater water availability. In contrast, productivity on the exposed limestone was estimated at only 1100 hg/ha. Actual amount of woody browse produced on these soils exceeded herbaceous production.

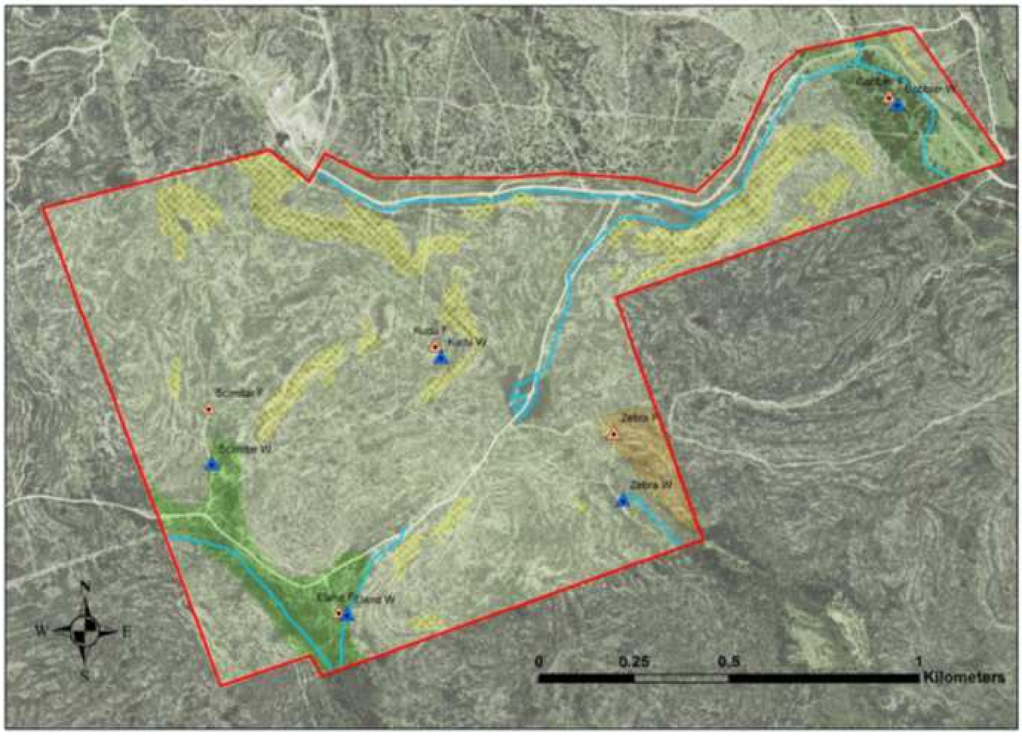

Figure 3. *Habitat map of the 202 ha research pasture inhabited by the dama gazelles.*

Legend: The background is an aerial photograph. Darker areas indicate shrub cover. The pasture boundary is in red, roads and tracks are in white, and drainages are depicted in blue. The predominant ecological (range) site in the pasture is Ector, with areas of Dev soils in the east shaded in dark green, Eckrant-Kavett Complex in the west shaded in lighter green, and Limestone Rockland shaded in brown. Steep slopes are identified by yellow cross hatching. Locations of supplemental feed and water are depicted by orange and blue triangles, respectively.

As described by Mungall and Cooper [16], the vegetation of this rocky pasture was a fairly uniform mixture of species dominated by shrubs. Shrub cover was estimated from aerial photographs to be approximately 50%. On these photographs, dark pixels correspond to woody vegetation and light pixels indicate the more reflective bare ground. Blackbrush acacia *(Vachellia (=Acacia) rigidula*) was the dominant woody plant species and was the most important forage plant for the gazelles. This semi-evergreen, thorny shrub is abundant on rocky ridges in southwest Texas and northern Mexico. Prickly pear cacti, including *Opuntia engelmanni var. lindheimeri* and *O. polycantha,* were also an important component of the vegetation and provided energy rich, edible fruits for the animals. Other common plants on the hillsides were the shrub coyotillo (*Karwinskia humboldtiana*), the leaves and berries of which are highly toxic, and the succulent leatherstem (*Jatropha dioica*). Neither of these plants provided food for the gazelles. In the valleys and along drainages, a more diverse mix of shrubs exists, including Texas persimmon (*Diospyros texana*), Ashe juniper, (*Juniperus ashei*), spiny hackberry (*Celtis pallida*), and catclaw mimosa (*Mimosa borealis*). A few live oak trees (*Quercus* v*irginiana*) grew along the dry creek on the northeast side of the pasture at the lowest elevation. These plant species all provided some food to browsing ungulates, although they are not classified as preferred browse species [17]. Herbaceous cover was sparse and species composition of annual plants was dependent on rainfall.

The diet of the gazelles was derived predominantly from browsing native shrubs. Five feeders situated in the pasture were filled twice a week with high protein pelleted feed, but access was dominated by longhorn cattle and a large population of 35 to 40 scimitar-horned oryx *(Oryx dammah).* Thus, once the gates to the settling enclosure were closed, there was little chance for smaller animals like the dama gazelles to obtain any appreciable amount of the supplemental feed. Hence, the gazelles subsisted almost entirely on native vegetation. Water was available to the animals at 5 concrete tanks, 1 near each feeder. During rainy periods water also drained off the hillsides and collected in rocky pools in the creek bed on the northern edge of the pasture as well as in depressions on rocks throughout the pasture.

Other species sharing the pasture in limited numbers (generally 3 to 22) were aoudad *(Ammotragus lervia),* axis deer *(Axis axis),* blackbuck antelope *(Antilope cervicapra),* common eland *(Taurotragus oryx),* Catalina goats *(Capra hircus),* red lechwe *(Kobus leche leche),* Iranian red sheep (*Ovis orientalis gmelina* hybrid with *Ovis vignei arkal*), common waterbuck *(Kobus ellipsiprymnus ellipsiprymnus),* plains zebras *(Equus quagga),* and American bison *(Bison bison).* Native coyotes *(Canis latrans)* had been fenced out and so did not prey on the animals in the study pasture.

3. Materials and Methods

3.1. Study Animals

The dama gazelles used in this study were of the eastern subspecies of dama gazelle *Nanger dama ruficollis* (also called addra). The main group released into the study pasture to start the project consisted of an established herd of 6 females, 1 adolescent male, and 1 young adult male (probably the offspring of one of the females in the herd) that had been kept in a 1.1 ha enclosure adjacent to the research pasture. For this study, an unrelated adult male from a neighboring pasture and a newly purchased adult female were also added and became part of the study. A further 3 adult males purchased elsewhere were added to the pasture on August 5, 2015, part way through the study (Table 1). All animal handling was approved by Texas A&M Agricultural Animal Care and Use Committee, Animal Use Protocol # 2012-098A.

Table 1. *Dama gazelle subjects for this study.*

Animal ID	Collar Color	Gender	Age Class	GPS collar data	
				Start Date	End Date*
Original Group (all had been in the enclosure adjacent to the study pasture)					
GF	Green	Female	Adult	12/19/2014	12/19/2015
LF	Lime	Female	Young Adult	12/19/2014	12/19/2015
OF	Orange	Female	Adult	12/19/2014	12/19/2015
VF	Violet	Female	Adult	12/19/2014	12/19/2015
YF	Yellow	Female	Adult	12/19/2014	11/04/2015
PF	Pink	Female	Adult	12/19/2014	12/19/2015
Rm	Red	Male	Immature	12/19/2014	12/19/2015
GM	Green	Male	Young Adult	12/19/2014	06/22/2015
Additional Animals Introduced					
BF	Blush pink	Female	Adult	12/19/2014	12/04/2015
YM	Yellow	Male	Adult	12/19/2014	01/11/2015
TM	Teal	Male	Adult	08/05/2015	10/26/2015
BM	Black	Male	Adult	08/05/2015	06/30/2016
NM	Navy	Male	Adult	08/05/2015	06/30/2016

*End dates are when the GPS collar data indicated cessation of movement (i. e. collar shed, animal died, or study period over).

3.2. Fitting Gazelles with GPS-Radio Collars

A week prior to initiation of the study Operations Manager Cole Reid and his staff transported the dama gazelles from their home enclosure to a pen at the ranch’s ungulate handling facility. On December 15th, 2014, animal handlers sent dama gazelles individually through a system of darkened runways into a drop-floor squeeze chute. Once in the chute, each gazelle was blind-folded. Dr. Elizabeth Cary Mungall of Second Ark Foundation took morphometric measurements of neck circumference and horn dimensions; Dr. Cecil Armin of South West Texas Veterinary Medical Clinic and his assistant Amy Sieckenius took a 5 cc blood sample and recorded it for DNA analysis. Next, Dr. Susan M. Cooper and her team from Texas A&M AgriLife Research fitted each animal with a Global Positioning System (GPS)-radio collar (Model: Lotek GPS3300S, Lotek Wireless Inc. Ontario, Canada). The animals were then transported to a 0.3 ha settling enclosure adjacent to the research pasture.

On December 18th, 2014, an additional unrelated adult female who had been acquired was measured and fitted with a GPS collar while in the ungulate handling facility. Then she was added to the group already in the settling enclosure. The gates of the enclosure were opened on December 19th, 2014, allowing the gazelles to transition into the 202 ha research pasture, yet still have access to water and pelleted feed in the settling enclosure, a location familiar to them. In June 2015, an additional 3 adult male dama gazelles were acquired. These animals were kept in a smaller, adjacent pasture for a month. This was to allow them to get acclimated to their new rangeland environment. Early in the morning of July 14th, 2015, Cole Reid and his ranch General Manager John Fredericks sedated these gazelles for transport to the settling enclosure. At this time, Dr. Mungall took morphometric measurements and Dr. Cooper fitted each male with a GPS-radio collar. These male gazelles stayed in the settling enclosure until the gate was opened on August 5th, 2015, allowing them to transition quietly into the research pasture.

3.3. Data Collection Frequency from GPS Collars

The GPS-radio collars were individually colored for identification of individual animals during subsequent monthly visual welfare checks and to aid associated behavioral observations. Animals were identified by a unique 2-letter code designating the color of their collar and their gender, e. g. GM Green Male, LF Lime Female. Immature animals were designated by a lower-case letter for the gender, e. g. Rm Red male starting the project as an adolescent. The initial set of collars were programmed to take 1 locational GPS fix every 30 min. for the first 8 days after the gazelles were released from the settling enclosure. This was to monitor how the animals dispersed and explored their new environment. Thereafter, the collars collected 1 location every 3 hr. for 1 year providing up to 2,920 locations per animal. This frequency of information permits estimation of habitat use and distances between animals without the mathematical problems of autocorrelation of locations inherent in more frequent regimes of data acquisition [18]. To obtain a full year of data, the locations acquired at 30 min. intervals were trimmed to the appropriate 3 hourly records and included in the annual data set. The collars of the 3 males introduced in August were programmed to take 1 location every 3 hr. with no initial 30-min. data schedule. Animal locations obtained from the GPS collars were accurate to within 2 m. The collars included automatic timed drop-off units that released the collars after 1 year. Thus, collars could be picked up and GPS data retrieved without risking recapture of the animals.

At the end of the study, the GPS collars were downloaded and imported into ArcGIS 10 (ESRI Redlands CA) and all GPS points were reviewed to identify and remove any inaccurate locations. Such errors are usually due to temporary poor configuration of the GPS satellites. Videos were created of the sequential locations of the gazelles during the first 8 days of their introduction to the pasture, and of the early distribution of the newly introduced adult males, in order to provide a descriptive overview of the initial animal movements and associations.

3.4. Animal Association Analysis

Data from the collars were transformed into the Universal Transverse Mercator coordinate system (UTM). Euclidian (straight line) distances were calculated between all pairs of gazelles for each GPS fix time using the formula [Sqrt $(E_1-E_2)^2+(N_1-N_2)^2$ where N=northings, E=eastings]. Because dama gazelles are browsers using scattered bushes as their food source, they typically do not maintain the compact herd formation characteristic of grazing animals. Based on the 95% confidence limits of median values of distances between members of the original group of dama gazelles, we selected an inter-animal distance of 50 m to develop association matrices to identify social groups [19, 20]. When the frequency of animals being within 50 m of each other was equal or greater than 0.5, the animals were considered to be associated in a social group, whereas when the frequency of interactions within 50 m was less than 0.25, the animals were considered to be separated from each other. There were very few incidences of interaction values between 0.50 and 0.25.

3.5. Home Range Size and Core Area Size

Distribution of the gazelles within the pasture was depicted by the fixed volume Kernel Home Range (KHR) calculated in ArcView 3.2. This technique is a standard measure of animal distribution based on the mathematical probability of an animal using an area [21]. Due to pasture size and shape and the distribution of animals throughout the pasture, the 95% KHR did not provide meaningful results. However, the 50% KHR, which distinguishes the core use areas in which 50% or more of all animal locations occurred, was of use in identifying areas most often used by the gazelles. Shared use of the pasture by the animals was examined by the distribution and degree of overlap of annual 50% KHR core use areas. Due to differences in group composition, core use areas were calculated not only on an annual basis but also separately for the time periods with 1 adult male present, no adult males present, and more than 1 new adult male present.

3.6. Pasture Use by the Dama Gazelles

To determine whether the distribution of gazelles in the pasture was influenced by landscape features, such as soil-based ecological sites, hill slope (particularly steep inclines of >11 to 27 degrees or 20 to 50%), natural drainages, and areas of dense vegetation, or man-made features such as roads, boundary fences, feeders, and water troughs, the frequency of occurrence of gazelles within mapped areas, or within 10 m of man-made features, was compared with the distribution of 3,000 random points generated in ArcView 10. Chi-squared goodness of fit test (χ^2) was employed to identify whether the distribution of gazelles relative to these features was different from random distribution. Differences were considered significant at $P \leq 0.05$.

4. Results

4.1. Annual Distribution of Dama Gazelles Within the Research Pasture

Because dama gazelles are browsers feeding on scattered bushes, they spread out into a loose assemblage while foraging. In this Texas Edwards Plateau pasture with approximately 50% shrub cover, the median (most common) distance between members of the original group of dama gazelles was 37±13 m.: (37+13 m (mean + 1 standard deviation)=50 m).

Each of the dama gazelles moved throughout the entire pasture (Figure 4). Thus, the traditional 95% KHR estimate of home range, often used to delineate animal home range, was not applicable to this study because home ranges enveloped the entire pasture.

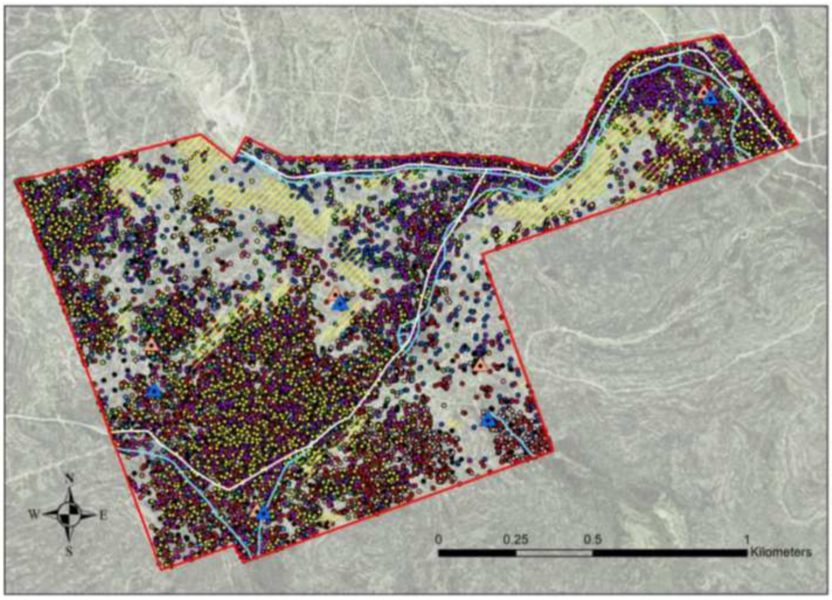

Figure 4. *Distribution of all locations of dama gazelles throughout the study pasture for 1 year.*

Legend: GPS locations of all dama gazelles taken every 3 hours for up to 1 year for each animal. (Yellow cross hatches denote steep slopes that were avoided by the gazelles. Orange triangles show feed troughs, and blue triangles show water troughs.)

The 50% KHRs are used to depict the core areas favored by the gazelles. Core areas are of use in identifying the areas that are most intensively used by the gazelles and in defining shared use of space by individuals (Figure 5).

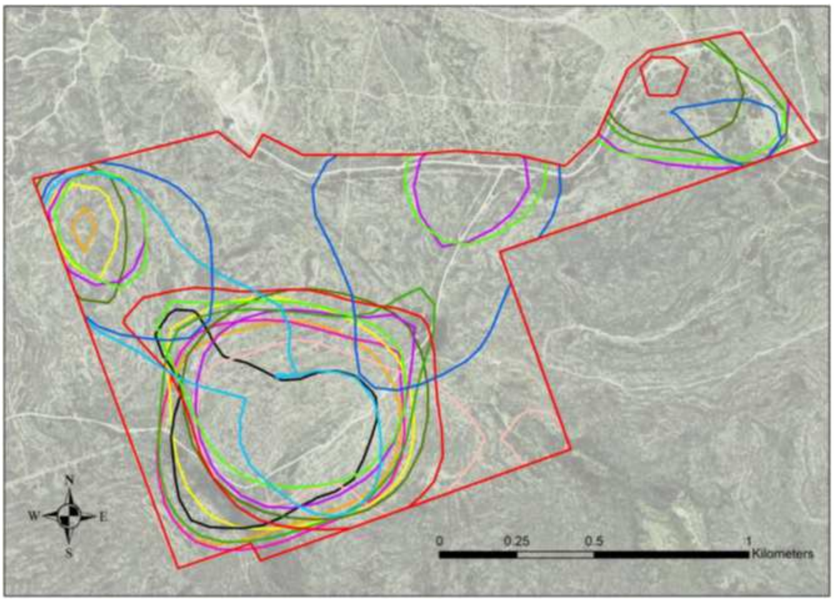

Figure 5. *Annual 50% KHR core areas of all dama gazelles.*

Legend: Annual 50% KHR core areas of each study animal are outlined in the color of their GPS collar. Black, navy blue, teal, and olive green depict adult males. Red is the immature male. The remainder are the females, with light pink denoting the introduced female BF. Individuals may have more than one core area.

The main area incorporated in the annual core areas of the gazelles encompassed the southwestern part of the pasture where the land slopes relatively gently in a sheltered, bowl formation (Figure 6). From this area, several gazelles followed the valley northwards to include the northwest corner of the pasture in their core areas. The other annual core areas, used mainly by the female subgroup of LF, VF, and GF and male NM, were in the northeast arm of the pasture, particularly the northeast area near the ranch entrance.

Figure 6. *Group of dama gazelles in the sheltered bowl of the research pasture (photo by Christian Mungall courtesy of Morani River Ranch, Texas, USA).*

The average size of the gazelles' annual core areas within the boundaries of the pasture was 56.85±12.81 ha with the largest belonging to females LF, VF, and GF and male NM. Divided by gender, average annual core area size was 55.47±9.83 ha for males, including the immature male Rm, and 57.83±14.63 ha for females.

Changes in numbers of dama gazelles in the pasture during the project let us study the population under three different social compositions. To provide more detailed insights into the changing social dynamics of the group, developments during the first and third social compositions are each discussed in two segments:

Initial. Initial dispersal of dama gazelles into the research pasture, December 19, 2014, to December 28, 2014.

Phase 1. Original young adult male present, December 19, 2014, to June 22, 2015.

Phase 2. No adult males present, June 22, 2015, to August 5, 2015.

Phase 3. New adult males present, August 5, 2015, to December 19, 2015.

Final. New males after the females and maturing male Rm had shed their GPS collars, December 19, 2015, to June 30, 2016.

4.2. Initial. Introduction to the Research Pasture, December 19, 2014, to December 28, 2014

The gates to the settling enclosure were opened at 2 pm on December 19th, 2014, permitting the gazelles to transition gently into the 202 ha research pasture. Weather was mild and dry, with temperatures ranging from 3 to 12°C and winds of 10 kmh. Visualization of the sequential GPS points showed that at 2:30 pm all the study gazelles ran out along the main dirt road for a distance of 1246±47 m taking the "Y" turn southwest into the main part of the pasture. For the following 2 days, the group split into various non-consistent subgroups and explored the pasture, but they did not circle the fence lines as some animals do (visual observation by Morani River Ranch staff conveyed by Operations Manager Cole Reid, pers. comm.). At night, the gazelles of the original group came together in an area not far from the road in the southwest part of the pasture. This bowl-shaped valley of 47.5 ha would become a favored location of the gazelles throughout the coming year. The only exception was the female PF. On the outward run, this animal followed the group for 687 m and then stopped in a bushy area half way up the hill. Despite the other gazelles passing nearby, she stayed in this area for 2 days before rejoining the group.

On the night of December 23rd there was a change in the weather. A cold front arrived and temperatures fell to minus 3°C with winds of 11 to 16 kmh gusting to 42 kmh [14]. In response, the gazelles in the original group all moved to the shelter of the valley constituting the northeast arm of the pasture, and at night they were recorded in the settling enclosure where pelleted feed was available. The cold weather continued for 3 days during which these gazelles remained in the northeast arm of the pasture, often crowding along the fence closest to their former home enclosure. Gates to the settling enclosure were left open to ensure their access to supplemental feed, which the animals appeared to use mainly at night.

Introduced animals not from the original group did not fully integrate with the original group during this introductory phase, nor did they create a new group. The adult male YM stayed near the front gate and was observed persistently fighting through the fence with another adult male dama gazelle in the adjacent pasture. In total, he spent 38% of his time within 10 m of the fence. At night, he often returned to the settling enclosure, presumably to eat the pelleted feed. Then, when the original group returned to this area during cold weather, he associated with this larger group. On January 11, 2015, YM was found dead in the northeastern area not far from the fence where he had been fighting. No obvious cause could be determined. The imported female BF initially moved out with the original group. She spent the first 2 nights near, but not in, the original group. When the cold weather arrived, she did not follow the group back to the more sheltered area in the northeast of the pasture. Instead, female BF moved south to the valley below a feeder where she remained alone for the next 3 months.

4.3. Phase 1. Group Associations and Distribution of Dama Gazelles with the Original Young Adult Male Present, December 19, 2014, to June 22, 2015

4.3.1. Association

During the first 6 months of the project, the group of dama gazelles studied in the research pasture consisted of the young adult male GM, immature male Rm, six original females GF, LF, OF, PF, VF, YF, and the introduced female BF. The original group of gazelles remained as a cohesive group with median distances between individuals of 37±13 m. Average group association was 0.58±0.04. Thus, for 58% of recorded locations the animals were within 50 m of each other, 50 being taken as the breakpoint between group membership and non-membership. Strongest associations occurred between Rm and LF and between GF and VF. The introduced female BF remained apart from the herd for the first 3 months, but she gradually integrated and finally joined the group on the 96th day and remained as a consistent group member thereafter (Figure 7).

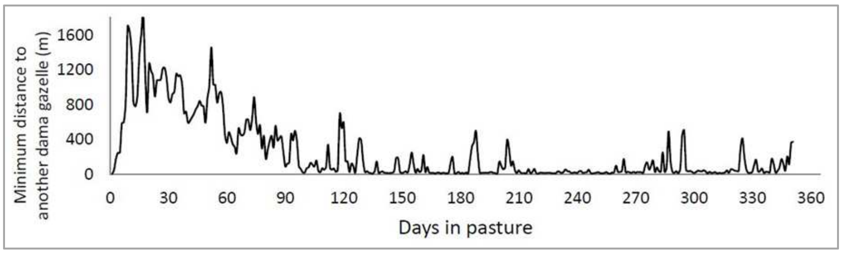

Figure 7. *Incorporation of female dama gazelle BF into the original group.*

4.3.2. Distribution

When the young adult male GM was present, the dama gazelles of the original group established 2 main shared core areas within the pasture (Figure 8). All the gazelles used the main area of approximately 50 ha in the southwest and an area of 19 ha in the northeast. The adult male GM and 2 females, OF and YF, also spent enough time in the northwest corner to create a small 7 ha core area there. The core area of female PF was extended north due to her frequent use of the dense brush patch adjacent to the road. Introduced female BF initially resided in a valley by the feeder in the southeast of the pasture and gradually integrated into the large southwest core area of the original group of gazelles. BF did not spend enough time in the northeast part of the pasture for this area to be included in her core area. The distribution of the male GM and the females was very similar with 88.62±15.38% overlap of core areas. Overlap ranged from 98.14% for Rm to 53.68% for BF. Core area overlap between females of the original group was 86.47±8.83%.

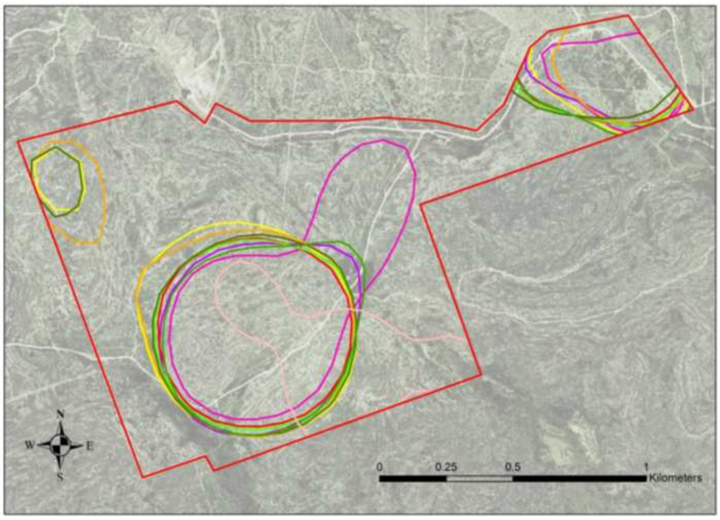

Figure 8. *Core areas of female and immature male dama gazelles with the original adult male (dark green outline) present.*

4.4. Phase 2. Group Associations and Distributions of Dama Gazelles When No Adult Males Present, June 22, 2015, to August 5, 2015

4.4.1. Association

For six weeks during the summer when there was no adult male dama gazelle in the pasture, cohesion of the group of dama gazelles declined. Mean association score fell to 0.42±0.23. Three females, LF, VF, and, to a lesser extent, GF, tended to separate from the main group and spent more time in the northeast arm of the pasture. Association within this subgroup was less consistent than within the main group. Female LF was often alone or with VF. Female VF also reduced association with other members of the original group but retained close association with GF. Meanwhile, GF was associated with both the main group and with VF in the subgroup. Introduced female BF was now fully integrated into the original group. The immature male Rm remained in the main group which now consisted of OF, PF, YF, and BF. His association score with these 4 females was 0.66±0.08.

4.4.2. Distribution

The distribution of the group of dama gazelles at this time highlights the developing rift in the female group once there was no longer an adult male present (Figure 9). Overlap of individual core areas within the group declined to 58.06±32.12% (range 100 to 2.38%). All the gazelles used the main core area in the southwest of the pasture. However, the subgroup of the 3 females LF, VF, and GF tended to use the northern side of the pasture more, and they expanded the core area in the northeast arm of the pasture.

Core area overlap of the five animals restricted to the southwest of the pasture remained high at 84.19±15.19%. Core use overlap between animals in the subgroup was lower at 62.84±18.52%. This lower degree of spatial overlap within the subgroup was due to the more extensive movements of LF. Overlap of core areas of GF and VF was 83.77% but their overlap with the core areas used by LF was only 52.37%.

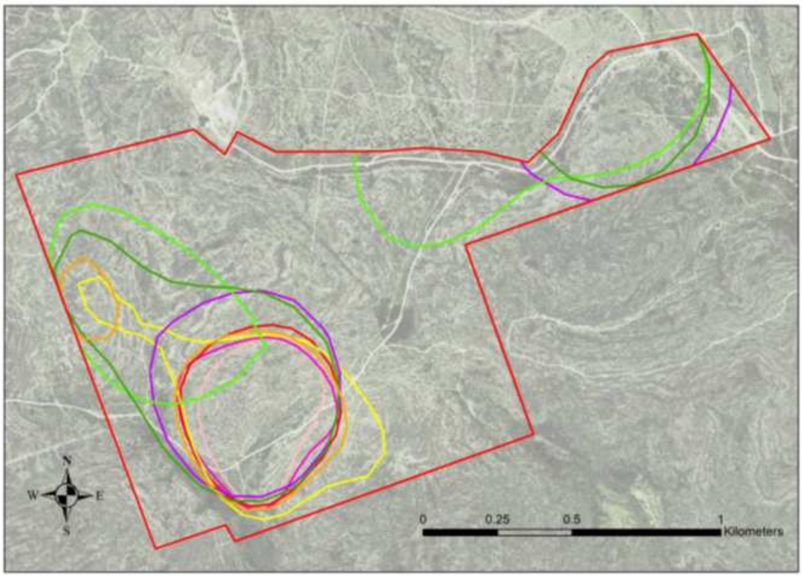

Figure 9. *Core areas of female dama gazelles and immature male (red outline) when no adult males were present.*

4.5. Phase 3. Group Associations and Distributions of Dama Gazelles with New Adult Males Present, August 5, 2015, to December 19, 2015

4.5.1. Association of Females

Three new adult males were introduced to the pasture on August 5, 2015: BM, NM, and TM. Once the new adult males were added, young male Rm, now a subadult, no longer had close association with any of the females. His association score with the females decreased to 0.07±. 0.05. The split in the female group continued to strengthen, as the two females LF and VF spent more time on the north and east sides of the pasture. Association between these two animals increased from 0.36 to 0.75 and they now had little interaction with the larger group of females. GF mainly stayed with the group of 4 females. Hence, the frequency of her association with VF declined. Association score within the main group of females also declined to 0.45±0.15, slightly below the threshold for being considered a cohesive group. Strongest associations were between members of the original group, OF, PF, and YF.

4.5.2. Association of Males

The 3 new males were introduced as a group but did not stay together. This is even though they had stayed close together (with an established group of Thomson's gazelles that stayed by a feeder) when in the adjacent pasture while acclimatizing before introduction to the research pasture. After introduction to the research pasture, median distance between these males was 501 m. The male with the widest horns, BM, who looked best developed and so may have been older, tended to be associated with the main group of 4 to 5 females. Median distance between BM and these females was 172 m, and mean association score was 0.35±0.05. NM was most closely associated with the 2 females LF and VF in the north and east part of the pasture with a similar association score of 0.31±0.03 and median distance of 316 m. These association scores were well below the threshold of 0.50 which was taken as the threshold indicative of consistent member of a group. The third adult male, TM, had little close contact with any females, with an association score of 0.12±0.02 and a median distance of 555 m from females. TM had most contact with subadult male Rm and male NM, although the association score of 0.29±0.01 was not high enough to constitute formation of a bachelor group.

4.5.3. Distribution

In the 4 months after the 3 new adult males had been introduced to the pasture, the distribution of most female gazelles remained relatively unchanged although spatial separation of the main and subgroups became more defined. This was mainly due to the core areas of VF expanding in the northwest and northeast to match those of LF (Figure 10). The core areas of these 2 females now overlapped by 85.52%. Together, these 2 females had minimal overlap of 3.52±3.82% with the main group of 4 females in the southwest of the pasture. Female GF continued to associate with both the main group and the subgroup so had 2 core areas. Her core areas overlapped 52.39±27.42% with the main group of 4 females and 44.86±7.19% with the subgroup. The 4 females YF, BF, OF, and PF maintained the same core use area in the southwest of the pasture, although the size increased from 26 ha to 41 ha. Overlap of their individual core areas was 80.40±9.70%.

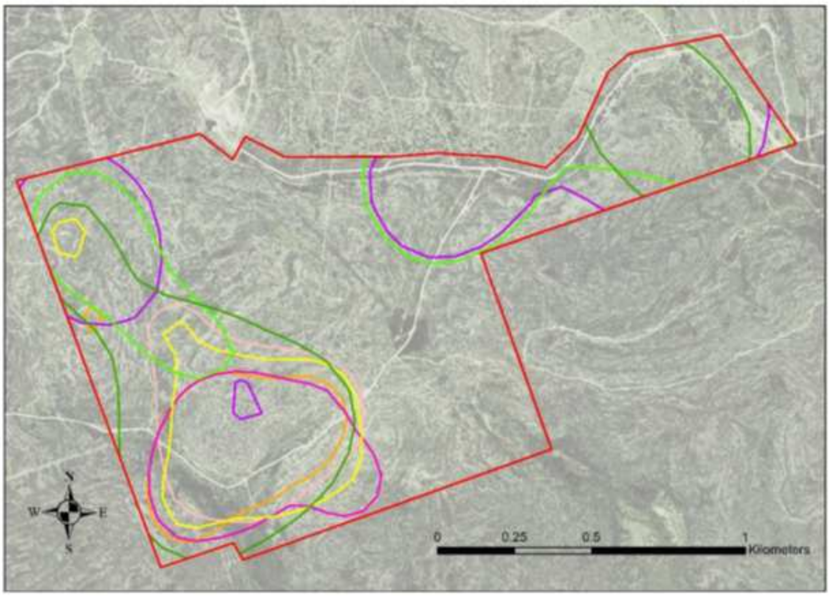

Figure 10. *Core areas of female dama gazelles after the introduction of three new adult males, August 5, 2015, to December 19, 2015.*

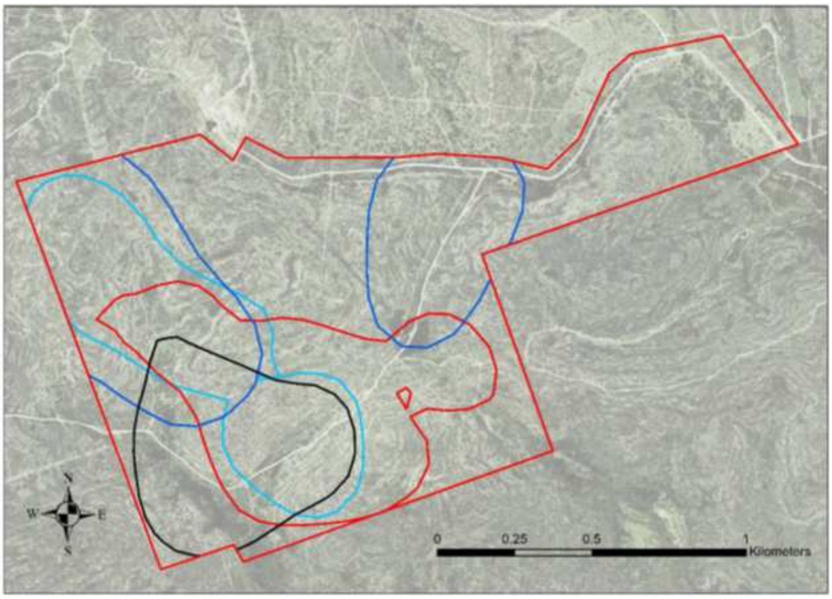

Figure 11. *Core areas of the four male dama gazelles (3 new adult males and 1 maturing young male) from August 5, 2015, to December 19, 2015.*

Initially, the new males moved over the entire pasture but soon began to develop distinct core areas (Figure 11). BM established his 36 ha core area in the southwest of the pasture while NM utilized 65 ha in the northern regions of the pasture, distributed over 2 core areas. Over time, NM developed 3 core areas in the northern part of the pasture (Figure 12). These included the northwest and northeast core areas of the initial male GM, plus a large area of 42 ha in the north central region extending toward, but not overlapping with, the core area of BM. Males BM and NM had the most separate core areas with only 16.18±6.64% of overlap. The third adult male, TM, utilized 48 ha on the west side of the pasture. His core area overlapped extensively with those of the other males by 50.69±11.05%. The maturing male Rm occupied a large 58 ha core area in the south of the pasture, which overlapped with the core areas used by the introduced adult males by 44.76±17.11%.

The core area of adult male BM overlapped 88.37±7.46% with the core areas of the 4 females OF, PF, YF, and BF and overlapped the core areas of GF by 46.13%. He did not spend much time in the north and east parts of the pasture so had little contact with the subgroup LF and VF. Overlap of their core areas was minimal at 2.42±1.55%.

Since NM mainly used the northwest and north central parts of the pasture, his core areas overlapped with those of LF and VF by 55.89±3.74% and GF by 32.13%. Overlap by NM with the core areas of the other 4 females was only 16.25±5.61%.

Although the third adult male TM and maturing young male Rm had little close association with females, their home ranges overlapped extensively with those of the females. The core area of TM overlapped 59.03±6.99% with the main group of 4 females, 46.15% with GF and 34.71±6.88% with the subgroup of LF and VF. TM was found dead on October 26, 2015, in spite of seeming fine when observed the previous day. The core area of Rm had 73.63±7.18% overlap with the main group of 4 females, 42.46% overlap with GF and only 8.26±6.93% with LF and VF. Nevertheless, examination of location timing showed that Rm was temporally separate from the females even though his core area overlapped with theirs so substantially.

4.6. Final. Association and Distribution of the New Adult Males After the Females and Maturing Male Rm Had Shed Their GPS Collars, December 19, 2015, to June 30, 2016

4.6.1. Association

The 2 introduced adult males BM and NM retained their GPS collars for slightly more than 6 months after the females and Rm had shed their collars. During this time, these males remained separate with an association score of only 0.03. Frequency of close contact, within 10 m, between the 2 males was only 1.35% or 21 recorded instances. The median distance between these two adult males was 884±475 m.

4.6.2. Distribution

The 2 introduced adult males established separate core areas with minimal overlap of only 1.08 ha (2.52±1.36%). Although these males moved around the whole pasture, BM had a compact 50% KHR core area of 31 ha in the southwest part of the pasture while NM had more diffuse split core areas totaling 80 ha along the northern side. Thus, the males effectively divided the pasture into two separate sections (Figure 12). Visual observations indicated that BM continued to associate with the larger group of 4 females in the southwest while NM remained in the north and expanded his core area into the northeast to overlap the area used by the female subgroup of LF, VF, and occasionally GF.

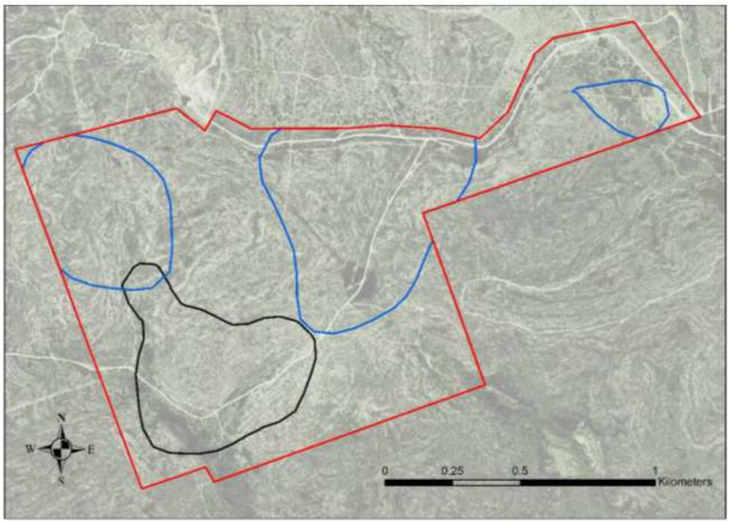

Figure 12. Six-month core areas of 2 introduced adult male dama gazelles, BM and NM, after the females and maturing male Rm had shed their GPS collars, December 19, 2015, to June 30, 2016.

5. Discussion

To promote our understanding of how dama gazelle populations operate under different social combinations, data was gathered under three main social situations: (1) adult females with one adolescent male (Rm) and one young adult male (GM), (2) the same adult females and immature male (Rm) without any adult males, (3) the same adult females with one maturing male (Rm) and multiple adult males. As part of this investigation, it was shown that a pasture of this size can have multiple adult males with minimal aggression provided there is informed management.

5.1. Home Range Size, Core Area Size, and Interaction Between Male Dama Gazelles

In our previous project [10], we showed that in an exceptionally large semi-desert West Texas pasture (8996 ha) contact between adult male dama gazelles was minimal due to their maintaining extensive home ranges each incorporating a non-overlapping 50% KHR core area of about 440 ha. In the current study, the entire pasture size of 202 ha is more typical of the space available for maintaining dama gazelle herds on Texas rangeland [11] but is less than the size of the core area of male dama gazelles in the West Texas study. Thus, greater contact between males, and greater potential for conflict, can be expected in pastures like the 202 ha study pasture.

In this study, both male and female dama gazelles moved throughout the entire pasture, making it their home range. Within the boundaries of the pasture, the core area size of male and female core areas was similar. Thus, gender did not appear to influence core area size. Size of both male and female dama gazelles averaged together was 57±13 ha.

Although both males BM and NM ranged over the whole pasture, their separate core areas served to limit the frequency with which they came into contact with each other. Once these core areas were established, only 3% of paired GPS locations placed these males within 50 m of each other. While this frequency of close contact is higher than contact rates between males in West Texas (0.20% within 100 m for a 9-month West Texas sample, [10]), it is still strongly indicative of adult males maintaining social separation.

The third introduced adult male (TM), was only present in the pasture for 3 months. TM behaved more like a non-breeding, subadult male in that his core area on the west side of the pasture overlapped extensively with the core areas of the other males (as seen for the subadults in West Texas, [10]), yet TM had relatively little contact with them. The young male Rm, who had shared distribution with the initial adult male GM, was nearing adulthood by the time the 3 new males BM, NM, and TM were introduced. Once the newly added adult males were introduced to the pasture, this young male was no longer able to associate with the females. As already mentioned, Rm still kept a core area substantially overlapping with the females but now he separated from them temporally. Despite extensive spatial overlap of core areas, the rate of contact of Rm with the dominant 2 adult males BM and NM was less than 1%, which is indicative of his avoiding contact with these males.

5.2. Association Within the Female Group and Interaction with Males

While the young adult male GM was present, the female group plus GM remained together, and association within the female group was greatest. The animals stayed within 50 m of each other for 58% of the time. However, the females did not always move as a cohesive group and, hence, the size and shape of core areas of individual females varied slightly. Once this male was no longer in the pasture, a split started to develop within the group of females. Three females gradually separated out to form a subgroup inhabiting the north of the pasture. Composition of this subgroup was not consistent, since 1 female (GF) regularly moved between this subgroup and the main group. The adult female introduced to the pasture at the beginning of the study (BF) gradually integrated into the main group after a period of approximately 3 months, showing that unrelated females can eventually be integrated into established groups.

Social disruption by male GM may have been minimal because he was already established within the group before the study began (he had been born into this group), and his incomplete change to permanent dentition showed that he was still not fully adult. No offspring were seen in the research pasture during the year and a half of the study, so he left no issue.

When new adult males were introduced to the pasture, the larger horned male (BM) established his core area in the southwest overlapping the main group of 4 to 5 females, and the other (NM) was found mainly in the northern area. Initially he was in the northwest and north central areas, but then he expanded his core area usage into the northeast area frequently used by the subgroup of 2 to 3 females. Although the males used the same core areas as groups of females, the association scores indicate that the relationship between the new males and the respective female groups was nowhere near as close as that of the original male. During the 4 months that both females and new males all had working GPS collars, the association scores of the females generally did not increase. In fact, some decreased, suggesting that the males were not keeping the female groups together. Video of animal movements indicated that males tended to follow females rather than directing their movements. However, despite the low association scores between males and females, some breeding did eventually occur. In the following months of 2016 after the project, 3 to 4 offspring were produced (C. Reid, pers. comm).

5.3. Habitat Influence on Dama Gazelles in the Research Pasture

The distribution of gazelles within a pasture is unlikely to be controlled entirely by social interactions. Habitat preferences and the distribution of critical resources also shape animal distributions. As discussed in the habitat paper by Mungall and Cooper [16], the most obvious and consistent habitat selection displayed by the dama gazelles was avoidance of steep, rocky, slopes (χ^2=69.00, df 10, P < 0.001) with inclines of 11 to 27 degrees (20 to 50%). Avoidance of the north facing ridge of steeper slope that bisected the pasture between the northwest and east most likely helped define the separation of the core areas used by the 2 adult male dama gazelles BM and NM sharing the pasture (Figure 4).

The relatively uniform, soil-based ecological site characteristics and vegetation throughout most of the study pasture appeared to have relatively little effect on the overall distribution of dama gazelles (χ^2=1.42, df 3, P > 0.05) [16]. Similarly, the gazelles did not show selection for or against more densely vegetated areas plotted from aerial photography of the ranch (χ^2=14.55, df 10, P > 0.05).

In this rocky pasture, the gazelles were often seen using the smooth caliche dirt road to move across the pasture. In thorny shrubland habitat, it is not uncommon for animals to use ranch roads for ease of travel [22]. Both the original group of dama gazelles, and, later, the newly introduced males followed the roads when first released into the study pasture. As the study progressed, animals using the larger western part of the pasture did use the roads but only in proportion to their extent within the habitat (χ^2=12.79 df 8, P > 0.05) [16].

Also as noted by Mungall and Cooper [16], the gazelles frequenting the western part of the pasture showed no overall attraction the to the creek and drainage areas (χ^2=3.27 df 8, P > 0.05). As a desert adapted species, the gazelles probably obtained much of their water from the vegetation and from rainwater pools on the rocks. Access to the feeders spaced at 5 locations throughout the pasture was routinely blocked by the aggressive presence of longhorn cattle and a large herd of scimitar-horned oryx with which the dama gazelles shared the pasture.

5.4. Comparison with Information from Native Habitat

The only ecological studies of dama gazelles in the wild are from the 2015 release of 12 male and 12 female mhorr gazelles, the western subspecies of dama gazelle *(Nanger dama mhorr),* from a reintroduction center in Safia Natural Reserve, Southern Morocco [23, 24]. These animals were part of a herd that had been living in an enclosure of 600 ha of native habitat. Similar to the case of Morani River Ranch, all the mhorr gazelles who could be monitored with their working GPS collars joined up in a shared area, except for one female who remained alone. At Morani River Ranch, there was the single adult male with the initial group plus an adolescent male. At Safia, there were 2 adult males with working collars, 1 of whom registered more interactions with his conspecifics than did the other male. At both sites, the gazelle groups concentrated on less rugged areas of more favorable forage: denser Acacia raddiana for Safia and easily accessible Vachellia (=Acacia) rigidula (blackbrush acacia) at Morani River Ranch. In neither population was the home range or core area size statistically different by sex. This was in spite of the Safia gazelles, unlike the ranch population, having unlimited space available and using much more area as they continued their explorations. In the more xeric environment at Safia, the mhorr gazelles probably needed more room in order to find enough food. Maximum possible group sizes for these two study populations were similar. At Safia, 3 gazelles were tracked for more than 6 months and as many as 13 gazelles could have been together depending on survival of gazelles released without collars (or without a working collar). At Morani River Ranch, 8 to 9 gazelles were in the group for the first 6 months and 8 to 10 could be together for the later phases of the study. All of these possibilities are within the range of 2 to 15 observed by Valverde [25] for mhorr gazelle associations in the wild. Thus, as far as the available information goes, the situation at Morani River Ranch appears to be a reasonable reflection of what would be expected for *N. d. ruficollis* in the wild.

5.5. Assessing Number of Adult Males Possible in a Pasture

To determine how many adult breeding males a single pasture can accommodate, a manager can start by dividing the pasture size by the average annual size of adult male core areas as determined for that pasture: in this case 202 ha ÷ 55.47 ha=3.6 possible adult breeding males. Nevertheless, animals are not expected to fit according to an exact mathematical plan. As already pointed out, certain land forms such as steep slopes need to be subtracted from the calculation. In addition, the distribution of these characteristics needs to be taken into consideration, like the way the line of steep slopes across the present pasture let BM and NM split the pasture between them. And importantly, the way the females distribute themselves across the pasture encourages males to spend time where the females spend time. Dama gazelle males do not restrict females to a particular place to form a harem.

A manager can look at where the females have their core areas, look at the sizes of these areas in relation to the core area size for females in the pasture (in this case range 43.20 to 72.46 ha), look at how frequently females use these areas, and look at distribution of meaningful characteristics such as slopes, screening cover, and forage productivity. Consequently, 3 adult breeding males would be the maximum expected for the study pasture: the southwest bowl as the prime area, the northwest corner which is screened from the favored bowl by both slopes and cover, and the northeast arm of the pasture which is distanced from the other two areas and nearly cut off by slopes. Additionally, the gazelles have access to a north central zone, and this area did show some core area use, but it was more a pass-through area than a permanent site.

A further aspect to be considered is that some males are more aggressive than others. The high level of aggression shown by the initial male YM towards another male in the neighboring pasture suggests that not all males may be suitable for inclusion in multiple-male situations. As already mentioned, dama gazelles are a species among whom males not only fight with rivals but fight to kill [8]. It may have helped that the 3 new males added in August had been kept together as a bachelor group (in association with a Thomson’s gazelle group of an aggressive herd male with females) for a month prior to their release into the research pasture, so these new dama gazelle males may already have established their social ranking more peaceably in the absence of dama gazelle females. Nevertheless, the sudden death of one of these males, TM, could have been due to an interaction which become lethal.

The present study reinforces the previous Edwards Plateau Central Texas finding that dama gazelle males are flexible in the amount of space a dominant male may have as a core area and can treat as a territory [8]. Even in the present study pasture not larger than a single core area used by a dama gazelle male in semi-arid West Texas, 2 adult males (BM and NM) partitioned the pasture into separate core areas and, thereafter, had very little contact with each other. The way these two males divided the pasture, there was not enough space for the then newly adult male (Rm) to have a core area separate from the fully adult males.

However, he was able to avoid the other males temporally. The abundance of dense screening cover helped. With BM and NM in their prime, the research pasture was only able to accommodate 2 territorial breeding males. Three less assertive males could probably co-habit with minimal aggression.

5.6. Recommendations for the Conservation and Management of Multiple-Male Groups of Dama Gazelles in Large Rangeland Pastures.

This project has shown that dama gazelles can be kept in multiple-male herds within a pasture as limited as 202 ha. Sharing of medium or large pastures by adult males on the Edwards Plateau of Central Texas is likely aided by the greater productivity of land as opposed to the semi-desert areas of our previous study in West Texas. Greater vegetative productivity provides better food resources and better visual screening cover for competing males. At the conclusion of this project, there were only 2 fully adult males and one newly adult male (Rm) in the pasture. As this newly adult male, or other males maturing in this population in the future, vie for territories in this pasture, managers may need to withdraw males because of excessive harassment from established males. For keeping a productive population of dama gazelles, it has been shown that having multiple males promotes increased reproduction [9]. This makes it worth the investment of management personnel and time to monitor a multiple-male group instead of the usual Texas pasture grouping of 1 breeding male with females and young. Wherever dama gazelles are kept confined to pastures, having larger groups and enhancing reproduction by accommodating multiple males should encourage the sustainability of this critically endangered species.

6. Conclusion

1. Adult male dama gazelles shared use of a large (202 ha) pasture by concentrating their activities in spatially separate areas. This minimized potential conflict.
2. Core area overlap in the pasture does not necessarily indicate close association of all the animals using the area.
3. When there is not enough room for males to have separate, non-overlapping core areas, they can avoid each other by temporal separation. This was shown by the maturing male Rm.
4. Keeping multiple-male groups of dama gazelles in large pastures is feasible if there are adequate resources and visual screening cover for the males to achieve spatial and temporal separation from each other.
5. Female dama gazelles associated in loose groups, into which a new female was able to integrate, although only after a long time apart (3 months in this case). Subgroups of females could break off and re-join.
6. While the presence of an established male may have aided cohesion of the female group, the introduction of new males did not influence the distribution of female groups.
7. Core area size was similar for both male and female dama gazelles.
8. This study only included a maximum of 3 adult males and 1 maturing male at any one time. Depending on distribution of natural barriers such as screening vegetation and steep slopes, and the number and distribution of females, the average 55.47±9.83 ha size of adult male core areas and the similar average 57.83±14.63 ha size of female core areas suggests that a maximum of 3 adult breeding males might be able to inhabit a pasture the size of this 202 ha study site. This assumes that none of these males would be as aggressive as adult male YM who spent 38% of his time within 10 m of the fence where he was seen persistently fighting through the wire with a dama gazelle male in an adjacent pasture.

Acknowledgements

This GPS-radio collar investigation of dama gazelles has been a project of the Second Ark Foundation in collaboration with the Exotic Wildlife Association. The support which allowed this project to go forward came from the Bisbee's Fish & Wildlife Conservation Fund (Wayne Bisbee and Brian White), with added support from Fossil Rim Wildlife Center (Pat R. Condy). Kevin and Cole Reid generously offered their Morani River Ranch in the Texas Hill Country as a study site.

Susan M. Cooper and her team of Shane Sieckenius and Andrea Silva from Texas A&M AgriLife Research in Uvalde, Texas, did an expert job fitting the collars and then were instrumental in the tracking and data analysis. Working with Cole Reid for the collaring sessions and later were Principal Investigator Elizabeth Cary Mungall and photographer-analyst Christian Mungall for the Second Ark Foundation, the AgriLife team, ranch General Manager John Fredericks, ranch personnel Johnny Flores, Kenneth Haynie, Logan Bostic, and Tim Crumley. Special videographer for the initial collaring session was Anthony Della Flora assisted by John Britt. Veterinarian was Cecil Armin, DVM, assisted by Amy Sieckenius. Throughout the project, the positive and supportive attitude of Director Daniel I. Leskovar at the Texas A&M AgriLife Research and Extension Center in Uvalde, Texas, was much appreciated.

References

[1] RZSS & IUCN Antelope Specialist Group. 2014. Conservation review of the dama gazelle *(Nanger dama)*. Royal Zoological Society of Scotland, Edinburgh, UK.

[2] Mungall, E. C., ed. 2018a. The Dama Gazelles: Last Members of a Critically Endangered Species. Texas A&M University Press, College Station, TX, USA. 252 pp.

[3] Mallon, D. 2018. Introduction. *In:* E. C. Mungall, ed. The Dama Gazelles: Last Members of a Critically Endangered Species. Texas A&M University Press, College Station, TX, USA. Pp. xiii-xiv.

[4] Mungall, E. C. 2018c. Species numbers through the years. Exotic Wildlife. 6: 61-62.

[5] Brito, J. C., S. M. Durant, N. Pettorelli, J. Newby, S. Canney, W. Algadafi, T. Rabeil, P-A. Crochet, J. M. Pleguezuelos, T. Wacher, K. de Smet, D. V. Gonçalves, M. J. F. da Silva, F. Martinez-Freiría, T. Abáigar, J. C. Campos, P. Comizzoli, S. Fahd, A. Fellous, H. H. M. Garba, D. Hamidou, A. Harouna, M. H. Hatcha, A. Nagy, T. L. Silva, A. S. Sow, C. G. Vale, Z. Boratyński, H. Rebelo, and S. B. Carvalho. 2018. Armed conflicts and wildlife decline: challenges and recommendations for effective conservation policy in the Sahara-Sahel. Conservation Letters. 11: e12446. https://doi.org/10.1111/conl.12446.

[6] Barbosa, A., and G. Espresso. 2005. International Studbook Gazelle dama mhorr. Consejo Superior de Investigaciones Cienrificas Press, Madrid, Spain.

[7] Mungall, E. C. 2014. SAF project update: help reduce fights. Exotic Wildlife*,* Summer. P. 13.

[8] Mungall, E. C. 2018d. Territoriality. *In:* E. C. Mungall, ed. The Dama Gazelles: Last Members of a Critically Endangered Species. Texas A&M University Press, College Station, TX, USA. Pp. 55-61.

[9] Mungall, E. C. 2018b. Growing up and growing old: Physical and social development. *In:* E. C. Mungall, ed. The Dama Gazelles: Last Members of a Critically Endangered Species. Texas A&M University Press, College Station, TX, USA. Pp. 62-88.

[10] Mungall, E. C., and S. M. Cooper. 2021. Home range size of male dama gazelles, *Nanger dama,* in an *ex situ* population in West Texas. African Zoology. 56 (2): 124-132. DOI: 10.1080/15627020.2021.1908845.

[11] Mungall, E. C. 2004. Dama gazelle phone census. Exotic Wildlife, January−February. Pp. 11–12.

[12] Ofstad, E. G., I. Herfindal, E. J. Solberg, and B-E. Sæther. 2016. Home ranges, habitat and body mass: simple correlates of home range size in ungulates. Proc. R. Soc. B 283: 20161234. http://dx.doi.org/10.1098/rspb.2016.123.

[13] Larkin, T. J., and G. W. Bomar. 1983. Climatic atlas of Texas. LP192. Department of Water Resources, Austin Texas. http://www.twdb.texas.gov/publications/reports/limited_printing/doc/LP192.pdf. (Accessed Oct. 2, 2021).

[14] Weather Underground. 2016. http://www.wunderground.com/history. (Accessed Oct. 2, 2021).

[15] USDA Natural Resource Conservation Service Soils. 2014. http://websoilsurvey.nrcs.usda.gov/app/ (Accessed Oct. 2, 2021).

[16] Mungall, E. C., and S. M. Cooper. 2020. Habitat selection by exotic dama gazelles *(Nanger dama ruficollis)* in Texas. Texas Journal of Science. 72 (1): 101-129. DOI.org/10.32011/txjsci_1_Article7.

[17] Wright, B., R. Lyons, S. Cooper, and J. Cathey. 2002. White-tailed deer browse preferences for South Texas and the Edwards Plateau. Texas Cooperative Extension Publication B-6130.

[18] Perotto-Baldivieso, H. L., S. M. Cooper, A. F. Cibils, M. Figueroa-Pagán, K. Udaeta, and C. Rubio. 2012. Detecting autocorrelation problems from GPS collar data in livestock studies. Applied Animal Behaviour Science 136: 117–125.

[19] Ginsberg, J. R., and T. P. Young. 1992. Measuring associations between individuals or groups in behavioural studies. Animal Behaviour 44: 377-370.

[20] Whitehead, H. 2008. Analyzing Animal Societies: Quantitative Methods for Vertebrate Analysis. University of Chicago Press, Chicago. IL.

[21] Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology. 77: 2075–2085.

[22] Cooper, S. M., H. L. Perotto-Baldivieso, M. K. Owens, M. G. Meek, and M. Figueroa-Pagán. 2008. Interaction between white-tailed deer and cattle in a semi-arid grazing -system. Agriculture, Ecosystems and Environment, 127: 85-92.

[23] Abáigar, T., E. Rodríguez-Caballero, C. Martínez, Z. Amaouch, M. L. Samlali, F. Aparicio, T. El Balla, A. Essalhi, J. Fernández, F. García, M. Haya, A. M´Bareck, H. M´Bareck, L. M. González, and P F. de Larrínoa. 2019. The first reintroduction project for Mhorr gazelle (*Nanger dama mhorr*) into the wild: knowledge and experience gained to support future conservation actions. Global Ecology and Conservation. 19: e00680. https://doi.org/10.1016/j.gecko.2019.e00680. (Accessed Sept. 23, 2021).

[24] Abáigar, T., C. Martínez, Z. Amaouch, M. Alifal, A. Lemdimigh, S. El Makki, M. El Mokhtar, M. L. Samlali, P F. de Larrínoa, and E. Rodríguez-Caballero. 2020. Habitat requirements of the mhorr gazelle: What does this species need to survive in the wild? Global Ecology and Conservation. 20: e01389. https://doi.org/10.1016/j.gecco.2020.e01389. (Accessed Sept. 24, 2021).

[25] Valverde, J. A. 1957. Aves del Sáhara español; studio ecológico del desierto. *In:* Instituto de Estudios Africanos. Consejo Superior de Investigaciones Científicas, Madrid.