Journal of Zoological Research
Volume 3, Issue 3, 2019, PP 1-9
ISSN 2637-5575

Issues and Challenges in the Conservation of the Goitered Gazelle *(Gazella subgutturosa; Güldenstädt, 1780)*

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ABSTRACT

Despite it is listed as a vulnerable species since 2006, the population of the goitered gazelle is continuously declining. Illegal hunting and habitat destruction are considered as the main causes of this decline, even though this species is very adaptable to various ecosystems - especially arid environments - and was highly resilient to intense hunting pressures until the late nineteen century. Important efforts for conservation have been realized by the implementation of protected areas and have even led to re-introduction. However, the design of these protected areas could be improved. Several studies about habitat selection and home range size of re-introduced goitered gazelles have shown that protected areas should be re-arranged or shifted to areas more intensively used by gazelles. Moreover, habitat fragmentation , which can be involuntary reinforced by the design of protected areas, is a real threat for this migratory species. Indeed, isolation, whatever its origin, leads inevitably to lower genetic diversity.

Keywords: *Goitered Gazelle, Migratory Species, Habitat Fragmentation, Genetic Diversity, Isolation, Protected Areas, Conservation*

INTRODUCTION

The goitered gazelle (*Gazella subgutturosa*; Güldenstädt, 1780) is listed as Vulnerable (VU) under criterion A2 since 2006 by the IUCN (2017). According to Mallon and Kingswwod (2001), the population was estimated in the late 1990s at 120,000 to 140,000; the most recent assessment realized in 2016 (IUCN, 2017) estimated from 42,000 to 49,000 the number of mature individuals. This continuing decline is observed in all countries where the goitered gazelle persists (Karlstetter and Mallon, 2014: 27). Even in Mongolia, where the Gobi desert supports the largest population of goitered gazelles, the population is now less than 30,000 (Buuveibaatar et al., 2016), while it was estimated at 60,000 in the early 1990s. In some countries, such as in the Arabian peninsula, the population is now extinct while in other countries, such as in Azerbaijan (WWF, 2019), it survives only in reserves. To some extent this situation is not surprising since it is claimed that large mammals (>20 kg) have been eliminated from more than 80 per cent of the terrestrial ecosystems in which they were formerly present (UNEP/CMS, 2014: 7). As for other migratory[1] species, the causes of this decline are multiple (Rosen Michel and Röttger, 2014). For the goitered gazelle, the two main causes of its decline are habitat loss[2] and intentional mortality (Clark et al., 2006). For the latter, hunting and poaching are mainly motivated by the illegal trade of animals' products, which consist primarily of meat, and to a lesser extent, of skins and horns.

The negative impact of habitat loss and hunting are particularly impressive if one considers the adaptability and the resilience which characterize the goitered gazelle. On the one hand, it is physiologically adapted to a broad range of ecosystems and climates. Indeed, it survives in arid environments under water restriction and extreme heat thanks to cathemerality and heterothermy (Ostrowski, Mésochina and Williams, 2006; Fuller et al., 2014; Hetem et al., 2012). Unlike most other gazelle species, it is also able to survive under continental climate and to altitude close to 3000 m, even though it prefers plains and foothills

[1] A "migratory species" under CMS means "the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries."

[2] As a result of the expansion of agriculture, animal husbandry, human settlement, mining, industries.

(Cichon et al., 2011; IUCN, 2017). On the other hand, the goitered gazelle has been intensively hunted for centuries and even millennia, as it is well attested by travelers' accounts, petroglyphs as well as archaeological records (Macdonald, 2005; Maraqten et al., 2015). The hunting pressure was especially high during the Early Bronze Age, from the Arabian peninsula to the Caucasus, when thousand large traps made of dried stones (the so-called 'desert kites') were used for mass-killing the goitered gazelles along their migration paths (Bar-Oz et al., 2011; Zeder et al., 2013). Despite this intense human predation, as well as the impact of the other predators (wolves, cheetahs...), the population of the goitered gazelle thrived thanks to its physiological strengths, as it is for instance illustrated recently by its breeding success in reserves, with an annual rate[3] of growth of the population equal to 35% (Pereladova et al., 1998).

Even though its resilience in the wild was strong in the past, the current population is on a continuous decline and therefore conservation efforts have been done. Such efforts are important for the conservation of the species itself but also because the goitered gazelle plays a central role for the development of seed plants and other animals (not only predators) living in arid and semi-arid environments. Several Central Asian countries (such as e.g. Iran, Azerbaijan, Uzbekistan) have therefore multiplied their efforts to create natural reserves, national parks, sanctuaries, and even captive breeding centers (e.g. in Ogurchinsky Island, in the Caspian Sea - Turkmenistan; WWF Russia, 2019).

In these protected areas, human occupation, or at least the exploitation of resources, is limited. Although this protection of the habitat is necessary for the conservation of the species, it is not sufficient. On the one hand several studies (e.g. using GPS telemetry) pertaining to habitat selection and home range[4] size of re-introduced goitered gazelles have shown that protected areas were not well tailored, i.e. should be re-arranged or shifted to areas more intensively used by gazelles (Pereladova et al., 1998; Nowzari et al., 2007; Farhadinia et al., 2009; Durmus, 2010; Bagherirad et al., 2014). On the other hand, as reported by Karlstetter and Mallon (2014, 27), "*The range of the species is steadily shrinking with surviving populations becoming increasingly fragmented*". In other words, in addition to illegal hunting and habitat destruction, habitat fragmentation is also becoming a major threat for the goitered gazelle. While the creation of protected areas prevents to some extent habitat destruction and illegal hunting, it does not hamper - and may even reinforce - habitat fragmentation. Indeed, most gazelles form groups of one to three individuals all year round (Kingswood and Blank, 1996; Blank et al., 2012; Blank, Ruckstuhl and Yang, 2012), and therefore habitat fragmentation is a real threat for this migratory species.

In fact habitat fragmentation reinforces isolation, and therefore prevents gene flows among the population, and this results in a lower genetic diversity (Khosravi et al., 2017; Zachos et al., 2010; Abduriyim, Nabi and Halik,2018). Such isolation can be due to either physical distance, or barriers (including linear infrastructures made by humans, such as roads, railways, pipelines; UNEP/CMS, 2014) or ecological distance, or any combination thereof. A priori, protected areas do not prevent isolation, and the opposite is even likely to occur. Then, the protected areas should also either be located close to natural migration corridors, or allow exchanges of individuals between them in order to prevent loss of genetic diversity.

THE CONTINUOUS DECLINE OF THE POPULATION

In 1996, the goitered gazelle (*Gazella subgutturosa*; Güldenstädt, 1780) was listed as Lower Risk/Near Threatened (LR/NT) and in 2003 it was listed as Near Threatened (NT). Since 2006 it is listed as Vulnerable (VU) under criterion A2acd by the IUCN (2017) because the decline of its population has exceeded 30% in the last 15 years (three generations). In 1900's, goitered gazelles were abundant, found in almost every desert or semi-desert area throughout the Middle East and Central Asia. In the mid-1900's, nearly one million were estimated to have lived in the Soviet Union alone. According to Mallon and Kingswood (2001), the population was estimated in the late 1990s at 120,000 to 140,000. The most recent assessment realized in 2016 (IUCN, 2017) estimated from 42,000 to 49,000 the number of mature individuals. This continuing decline is

[3] This rate is computed for the period 1977 to 1987.

[4] It is defined as the extent of an area with a defined probability of occurrence of an animal during a specified time period.

observed in all countries where the goitered gazelle persists (Karlstetter and Mallon, 2014: 27). Although is listed as vulnerable at the global and at the regional level, there are some regional disparities; according to Clark et al. (2006: 122), while its global status was 'Vulnerable A2ad', the regional status in Mongolia was 'A3cde'. In some countries, such as in the Arabian peninsula or in Turkmenistan, the population is now extinct or close to extinction. In other Caucasian countries, such as in Azerbaijan (WWF, 2019), it survives only in reserves. From a historical perspective, the reality is simply unbelievable: the stock of gazelles in the eastern Caucasus during the first half of the last century declined from tens of thousands to 200 specimens in the 1960s (WWF, 2019). In Mongolia, where the Gobi desert supports the largest population of goitered gazelles, the population decreased by 30% from 1940 to 1960 (Clark et al., 2006: 127). It was estimated at 60,000 in the early 1990s. According to a recent survey realized from 2012 to 2015, the population is now less than 30,000[5] (Buuveibaatar et al., 2016).

In all countries the goitered gazelle is protected by law; however the enforcement of the law is uneven from one country to another. Hunting is illegal except in few countries (Iran, Mongolia) in which trophy hunters can purchase hunting licenses. Despite this protection, the decline of the population is continuous. To some extent this situation is not surprising since it is claimed that large mammals (>20 kg) have been eliminated from more than 80 per cent of the terrestrial ecosystems in which they were formerly present (UNEP/CMS, 2014: 7). As for other migratory species, the causes of this decline are multiple (Clark et al., 2006; Rosen Michel and Röttger, 2014).

Habitat destruction is one of the main cause of this decline. It mainly results from the expansion of agriculture and animal husbandry (consisting primarily of goats and sheep). The impact of the latter is particularly strong in arid environments where water resources and pastures are rare; therefore, the competition with domestic flocks can lead gazelles below their minimum of subsistence.

Habitat loss is also the result of human intrusions and disturbance, related to either urbanization or the development of industrial activities. Although the goitered gazelle is well adapted to extreme heat, climate change and extreme weather can damage the population. This is especially the case of severe winters when grazing is hampered by either ice crust on the surface of the soil or by the snow blanket when it exceeds 15-20 cm (Karlstetter and Mallon, 2014: 28). Because the goitered gazelle is a migratory species, it is also endangered by specific threats (Rosen Michel and Röttger, 2014). Indeed, as for other migratory species, linear infrastructures are an important threat (UNEP/CMS, 2014). They include fences associated with national boundaries, railways, and roads. In Central Asia, the recent economic development of previously remote regions has boosted the building of transportation[6] and services corridors, which therefore are becoming an emerging threat for all migratory species. As for other nomadic species, wars, and especially mining, are also a threat.

Besides habitat loss, the other main threat is intentional mortality resulting from hunting and poaching. The latter are mainly motivated by the illegal trade of animals' products, which consist primarily of meat, and to a lesser extent, of skins and horns. According to Cichon et al. (2011), a single goitered gazelle yields between 12 and 18 kg of meat and 0.6 to 0.7 m^2 of hide. With the end of the cold war in the late 1990s, several previously republics of the USSR became independent countries; while most their consumption, including foodstuff, was provided regularly and at lower cost by the central authority, these flows were suddenly reduced and even stopped.

These food shortages incentivized the development of an illegal market, especially for expensive products such as meat. Such incentives, with the help of cars, artificial lights and modern firearms, induced a strong increase of illegal hunting in all these newly independent countries. Horns are wanted as trophies[7] and can also be used in traditional medicine. Another motive of illegal hunting is to eliminate the gazelle because they are considered as pest. Herders perform illegal hunting because gazelles compete with their flocks for pastures

[5] It is estimated at 28,462 (95% CI; 21,326-37,987).

[6] E.g. the trans Mongolian railroad corridor, fenced on both sides.

[7] While females of this species are mostly, although not always, hornless, males boast long, elegantly curved, lyre-like, black horns that diverge outwards and turn back in at the tip.

as well as water resources. For instance, Xu et al. (2012) have recently provided a study (in Xinjiang, China) measuring the dietary overlap between goitered gazelle (*Gazella s. yarkandensis*) and domestic sheep (*Ovis aries*). These authors have demonstrated that in winter goitered gazelle and domestic sheep are in strong food competition with an overlap in diet of 0,77. An additional reason for herders to hunt gazelles is to reduce the risk of infectious disease transmission to their herds since the goitered gazelle is host of numerous species of parasites. Farmers can also hunt gazelles because they can damage agricultural plants such as cotton, barley shoots and chickpeas. It is also reported that some people are interested to live catch new born gazelles in order to keep them as pets, since they are graceful and docile.

TAXONOMY AND ECOLOGICAL ADAPTATION OF THE GOITERED GAZELLE

The goitered gazelle (*Gazella subgutturosa*; Güldenstädt, 1780) has 3 subspecies unevenly distributed on all over the world. The goitered or Persian gazelle (*G. s. subgutturosa*) is widely distributed, from Turkey to China, and is especially present in Central Asia. The Mongolian or Hillier's goitered gazelle (*G. s. hillieriana*; Heude, 1894) is present in Mongolia and China. The Yarkand or Xinjiang goitered gazelle (*G.s. yarkandensis*; Blanford, 1875) is only present in China. Until recently it was believed that the Arabian or sand gazelle (*G.s. marica*; Thomas, 1897) - present in southeast Turkey and the Arabian peninsula - was a fourth subspecies (Kingswood and Blank, 1996); however it has been proven (Wacher et al., 2010) that it is genetically distinct and is now regarded as a separate species *Gazella marica*.

Individuals of these three subspecies roam widely and move long distances in search of food, but the extent to which they are migratory is unclear. Recent studies in Kazakhstan confirm that the Persian gazelle is migratory (Blank et al., 2012), i.e. Persian gazelles gather into large groups of several tens of individuals and move in continuous waves consisting of several hundred gazelles.

It has also been observed that, for the Persian gazelle, large congregations occur for the Spring migration (from the end of March to early April) and Autumn migration (in October) and mixed-sex groups (i.e. including male and female) are most numerous during migrations (Blank et al., 2012: 317). The negative impact of the ongoing habitat loss is particularly impressive if one considers the adaptation which characterizes the goitered gazelle. Indeed, it is adapted to a broad range of ecosystems and climates. The goitered gazelles inhabit various types of desert and semi-arid terrain occurring in foothills and valleys. Their habitats range from clayey and sandy soil to basalt deserts or salt flats. They can occupy areas virtually absent of vegetation to areas that support grasses, forbs, and shrubs. Unlike most other gazelle species, it is able to survive under continental climate and to altitude close to 3000 m, even though it prefers plains and foothills (Cichon et al., 2011; IUCN, 2017).

In addition, it survives in arid environments under water restriction and extreme heat thanks to cathemerality and heterothermy (Ostrowski, Mésochina and Williams, 2006; Ostrowski and Williams, 2006; Fuller et al., 2014; Hetem et al., 2012). Indeed, in desert and semi-desert environment characterized by heat, aridity, food and water scarcity, gazelles adapt their behavior. Several morphological, physiological and behavioral adaptations buffer species against the effects of adverse environments. Morphological and physiological adaptations of ungulates exposed to high ambient temperatures, or in situations of water or energy limitations, are quite numerous.

These include changes in pelt color and selective brain cooling. Among these adaptations, it has been shown that ungulates may store the heat that otherwise would have been lost by evaporation during the day. This results in wide fluctuations in daily body temperature, a phenomenon called 'heterothermy' (Hetem et al., 2012). Among these adaptations there is, in the warm-wet season, a progressive shift to bimodal feeding activity during crepuscular peaks. Crepuscular animals are active during twilight, the latter being the illumination of the earth's lower atmosphere when the sun itself is not directly visible. In other words, they are matutinal (active between dawn and sunrise) and vespertine (active between dusk and sunset).

During the hot-dry season, there is an additional shift to nocturnal activity. Such observations mean that for desert ungulates the adjustments of diurnal activity do not lead to lethargy. Indeed they are accompanied, as defined by cathemerality, by an increase in nocturnal activity. Bimodal feeding activity has been observed for gazelle (*Gazella s. yarkandensis*) (Xia et al., 2011).

Resilience to the Intense Hunting Pressure until the Late Nineteen Century

The goitered gazelle has been intensively hunted for centuries and even millennia, as it is well attested by travelers' accounts, petroglyphs as well as archaeological records (Macdonald, 2005; Maraqten et al., 2015). In the mid to late 1300s, muslim armies under the command of Timur Leng[8] were noted hunters of goitered gazelles, killing an estimated of 40,000 each year (Cichon et al., 2011). The hunting pressure was especially high during the Early Bronze Age, from the Arabian peninsula to the Caucasus, when thousand large traps made of dried stones (the so-called 'desert kites') were used for mass-killing the goitered gazelles along their migration paths (Bar-Oz et al., 2011; Zeder et al., 2013; Svizzero and Tisdell, 2018b). On September 01, 2017, 5809 kites were inventoried (Globalkites Project, 2017) in South-West Asia, from the Arabic peninsula, to the Levant, the Syrian desert, the Caucasus, and up to the vast steppe of Central Asia. It is worth noting that kites were built whereas animal husbandry was widespread for millennia in all the concerned regions. We believe that the reasons why kites were used for hunting during the period of their utilization changed in response to socio-economic development (Svizzero and Tisdell, 2018a). Even if targeted prey remained unchanged - mainly the goitered gazelle - as well as the hunting techniques which were species-specific, the goals of hunters may change, and may even be diverse during a given period of time. Therefore, we contend that from the Epipaleolithic to the Early Bronze Age, hunters had evolving goals which led them to build and use kites in all sub-periods. Although these goals evolved with the passage of time, several could have coexisted during some periods. Beyond the Bronze Age, kites were used; indeed, there is a number of travelers' accounts (e.g. Burckhardt, 1831), from the sixteenth to as late as the twentieth century which described kites as structures used for hunting. It is only from the late nineteen century, when firearms became widespread, that these devices were given up.

Despite this intense human predation, during millennia, and based on traditional hunting techniques, the population of the goitered gazelle thrived. Such resilience is likely the result of its adaptability, i.e. of its morphological, physiological and behavioral features. Thanks to these features, the growth of population can be quite impressive. This is illustrated, for instance, recently by the success in the Bukhara breeding center (Uzbekistan) implemented in 1977, with an annual rate of growth of the population equal on average to 35% for the period 1977-1987 (Pereladova et al., 1998).

Conservation Efforts: Species Re-introduction and Protected Areas

Even though its resilience in the wild was strong in the past, the current population is on a continuous decline and therefore conservation efforts, based on re-introduction and the implementation of protected areas, have been done.

Such efforts are important for the conservation of the species itself, but also because the goitered gazelle plays a central role for the development of seed plants and other animals (not only predators) living in arid and semi-arid environments. Indeed, it has been shown that gazelle's grazing exerts a positive influence on vegetation development, especially in sandy desert environment (WWF Russia, 2019). In the latter, the absence of ungulates leads to formation of a solid crust on the surface of the soil, especially in case of high salinity. Vascular plant seeds are unable to sprout through this crust, leaving a cover of black moss to develop that prevents the normal development of an ecosystem. Then, even the moderate grazing pressure of gazelles is much better for ecosystems than the complete absence of ungulates. In this circumstance, the main reason for reintroduction is not so much to save the species itself, but to rehabilitate degraded ecosystems such as the area surrounding the Aral Sea, which now primarily constitutes newly developed deserts.

Moreover gazelles are important component of ecosystems as prey species for large predators. They were the major prey for the extinct Asian cheetah and can be one of the important prey species of leopard in the mountain foothill areas. That is why some activities on goitered gazelles restoration were initiated in the frame of WWF leopard conservation project (WWF Russia, 2019). Besides that, in case of successful development of the population, gazelles can

[8] He was a conqueror and the founder of the Timurid empire in and around modern-day Iran and Central Asia.

return to be a regular game animal, and an additional resource for local people, as it had been for centuries in the history of Central Asia.

Several Central Asian countries (such as e.g. Iran, Azerbaijan, Uzbekistan) have therefore multiplied their efforts to create natural reserves, national parks, sanctuaries, and even captive breeding centers (e.g. in Ogurchinsky Island, in the Caspian Sea - Turkmenistan; WWF Russia, 2019). In these countries, the population is now stable and even increasing, as illustrated by the two examples below.

In Azerbaijan, the population was reduced to only 200 specimen in the 1960s. Measures were stepped up to conserve the gazelle and they did indeed stop the decline in the population. The establishment of the Bandovan, Absheron, and Korchay sanctuaries and Shirvan reserve followed. By 1972 the gazelle population had increased to 1,500 and 10 years later was around 3,500. In 2003 an area of some 54,000h was declared the Shirvan National Park with the main aim of gazelle conservation. The park now has some 6,000 animals (WWF, 2019).

In Turkmenistan, captive breeding centers were created and species re-introduction initiated. Attempts to establish gazelle breeding centers were undertaken in the 1980s in Western Kopetdagh and Gyaurs, but the most successful results were obtained as a result of animals relocation to Ogurchinsky Island in the Caspian Sea, using the sea waters as a natural fence. Some dozens of animals were set free here and population grew up to about 800–1000 (which is the carrying capacity of the island). Once the population exceeds this threshold, some specimens are re-introduced elsewhere in Turkmenistan (WWF Russia, 2019).

THE REQUESTED IMPROVEMENTS: INCREASING HABITAT SUITABILITY OF PROTECTED AREAS AND REDUCING HABITAT FRAGMENTATION

Although the protection of the habitat is necessary for the conservation of the species, it is not sufficient. In fact the conservation effort is facing two main challenges: conservation strategies have to focus on both, the preservation of adequate habitat areas, and the spatial distribution of these areas throughout the landscape.

On the one hand several studies (e.g. using GPS telemetry) pertaining to habitat selection and home range size of re-introduced goitered gazelles have shown that protected areas were not well tailored, i.e. should be re-arranged or shifted to areas more intensively used by gazelles (Pereladova et al., 1998; Nowzari et al., 2007; Farhadinia et al., 2009; Durmus, 2010; Bagherirad et al., 2014). For existing as well as future protected areas, it is therefore important to study the habitat suitability. The aim of these studies is to identify the environmental factors - including human presence - that explain the distribution of the gazelle and then to predict the highly suitable areas for the conservation and the management, inside and outside the protected areas. In some circumstances, such studies may lead to develop a plan for reconnection of the habitat patches in the area, and also to re-design the boundaries of the area. As pointed out by Bagherirad et al. (2014: 134) in their concluding comment pertaining to the study of habitat suitability of Golestan National Park in Iran, "...poachers from adjacent villages (to the area) seem to be the main threat to the gazelles".

On the other hand, as reported by Karlstetter and Mallon (2014, 27), "*The range of the species is steadily shrinking with surviving populations becoming increasingly fragmented*". In other words, in addition to illegal hunting and habitat destruction, habitat fragmentation is also becoming a major threat for the goitered gazelle. While the creation of protected areas prevents habitat destruction, it does not hamper - and may even reinforce - habitat fragmentation. Indeed, most gazelles form groups of one to three individuals all year round (Kingswood and Blank, 1996; Blank et al., 2012; Blank, Ruckstuhl and Yang, 2012), and therefore habitat fragmentation is a real threat for this migratory species.

In fact habitat fragmentation reinforces isolation, and therefore prevents gene flows among the population, and this results in a lower genetic diversity (Khosravi et al., 2017; Zachos et al., 2010; Abduriyim, Nabi and Halik, 2018). As it is well known, gene flow is important to avoid inbreeding of the population, depression of population fitness[9] and an increase in extinction risk. Such isolation can be due to either physical distance, or barriers (including linear infrastructures made by humans, such as roads, railways, pipelines; UNEP/CMS, 2014) or ecological distance, or any combination thereof.

[10] Due to the random loss of heterozygosity.

There are a variety of approaches for assessing the extent of isolation, but most involve the notion of landscape resistance (i.e. the impediments to gene flow) caused by landscape features. Under the classic model of Isolation by (physical or geographical) Distance (IBD), the resistance value is defined by Euclidean distance between two sites. Essentially, the surface over which the individual is roaming is based upon a uniform value (whatever the spatial unit being used) and is homogeneously spread across the intervening landscape. Then, Euclidean geometry provides the shortest path.

Isolation by Barriers (IBB) is a model in which some discrete boundary on the landscape changes the resistance value (e.g. the presence of linear infrastructures). Isolation by Resistance (or ecological distance)(IBR) takes into account that the landscape consists of a heterogeneous mix of resistance values depending upon what features the individual must traverse (e.g. forest, desert, savannah..). Some may be impenetrable (a very large resistance value), some may be just accumulate larger than normal resistance values.

A priori, protected areas do not prevent from isolation, and the opposite is even likely to occur. Then, the protected areas should also either be located close to natural migration corridors, or allow exchanges of individuals between them in order to prevent loss of genetic diversity, as suggested by Khosravi et al; (2017). The importance of this conclusion is reinforced by the fact that some recent genetic studies realized on free-living and wild populations of goitered gazelle have already revealed a low level of genetic diversity.

Zachos et al. (2010) observed that gazelles from the Sohrein plain (Iran) had a very low nucleotide diversity and concluded that a bottleneck in the most recent past cannot be ruled out, even though the Sohrein population does not seem to have experienced a particularly dramatic decrease in effective population. Almost the same observation and conclusion were reached by Abduriyim et al. (2018) from a study of goitered gazelles living in North-western China (Xinjiang).

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Citation: *Serge SVIZZERO, "Issues and Challenges in the Conservation of the Goitered Gazelle (Gazella subgutturosa; Güldenstädt, 1780)", Journal of Zoological Research, 3(3), 2019, pp: 1-9*