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Estimation of red deer population and its impact on Tugay forest ecosystem in the Lower Amu Darya State Biosphere Reserve, Uzbekistan

Daniel CORNELIS^{1,2}
Elena KAN³
Valéry GOND^{1,2}
Jean-Daniel CESARO^{4,5,6}
Régis PELTIER^{1,2}

¹ CIRAD
UR Forêts et Sociétés
Campus de Baillarguet
34398 Montpellier
France

² Forêts et Sociétés
Univ Montpellier
CIRAD
Campus international de Baillarguet
Montpellier
France

³ NGO KRASS
14 Khamid Olimjan street
220100 Urgench
Uzbekistan

⁴ CIRAD
UMR SELMET
Campus de Baillarguet
34398 Montpellier
France

⁵ UMR SELMET
Univ Montpellier
CIRAD
Campus international de Baillarguet
Montpellier
France

⁶ ISRA-CRA
Dispositif en partenariat Pôle
Pastoralisme et zones sèches
Saint-Louis, Richard-Toll
Sénégal

**Auteur correspondant /
Corresponding author:**
Régis PELTIER –
regis.peltier@cirad.fr



Photos 1 & 2.
Vegetation Units – Dense Forest: trees cover \geq 60% (photo top);
Semi-Open Forest: 60% > trees cover \geq 30% (photo bottom).
Photos R. Peltier.

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RÉSUMÉ

Estimation de la population de cerfs et de son impact dans l'écosystème forestier de Tugay dans la Réserve nationale de la biosphère de la basse Amu Darya en Ouzbékistan

En 2011, le Gouvernement d'Ouzbékistan a créé la Réserve nationale de la biosphère de la basse Amu Darya (LABR). Cette réserve vise la conservation du Tugay, un écosystème forestier ripicole s'étendant sur les principaux bassins fluviaux des régions sèches d'Asie centrale et confronté à des pressions anthropiques extrêmes. La LABR a réintroduit le cerf de Boukhara (*Cervus hanglu bactrianus*), une sous-espèce endémique en Asie centrale dont la population s'est fortement réduite au cours du XX^e siècle. Le projet de développement de la LABR vise à fournir un appui opérationnel aux autorités ouzbekes dans le cadre de leur candidature pour rejoindre le Réseau mondial des réserves de la biosphère. Sollicité par la GIZ (Société allemande pour la coopération internationale), le CIRAD a été chargé de fournir une évaluation scientifique de la population de cerfs dans la LABR, à l'aide d'une méthode reconnue à l'échelle internationale, afin de formuler des recommandations permettant d'assurer un mode de gestion durable sur les plans écologique et socio-économique. L'inventaire de la population de cerfs de Boukhara a démarré en octobre 2019 sur une zone d'étude de 88 km² selon des transects parallèles rectilignes de 65 km de longueur espacés de 1 400 m. L'inventaire a dénombré 127 observations d'individus ou de troupeaux pour un total de 336 individus observés. Les données ont été analysées à l'aide de l'application DISTANCE 7.3. Les taux de rencontre s'établissent à 1,95 observation/km et 5,17 individus/km. La densité estimée est de 24 cerfs/km² et la population totale est estimée à 2 112 individus [1 320 – 3 344, 95 % CI]. La proportion d'arbres morts, mourants ou gravement compromis est estimée grossièrement à 10 %, et la proportion d'arbres ayant de bonnes chances de survie à 15 %. Dans la zone centrale sud de la LABR, une forte proportion de plantules et de rejets était broutée au point de stopper la régénération. Maintenir une densité de population de 24 cerfs/km² dans la zone centrale sud semble ainsi incompatible tant avec la conservation de l'écosystème de la forêt de Tugay qu'avec la coexistence sans heurts des cerfs avec les populations humaines jouxtant la réserve. Les possibilités permettant d'alléger la pression des cerfs comprennent le transfert sur la zone centrale nord de la LABR ou d'autres zones, et la régulation de la population de cerfs. La densité actuelle est trop élevée pour assurer une bonne conservation de l'espèce à l'échelle locale, même si la population de cerfs est globalement soumise à de fortes pressions à l'échelle de l'Asie.

Mots-clés : *Populus diversifolia*, *Cervus hanglu bactrianus*, écosystèmes ripicoles, cerf de Boukhara, méthode de comptage pédestre par échantillonnage de distances, réserve de la biosphère, Tugay, Karakalpakstan, Ouzbékistan.

ABSTRACT

Estimation of the red deer population and its impact on the Tugay forest ecosystem in the Lower Amu Darya State Biosphere Reserve, Uzbekistan

In 2011, the Government of Uzbekistan established the Lower Amu Darya State Biosphere Reserve (LABR). This reserve aims to conserve the Tugay, an endangered riparian forest ecosystem straddling the main rivers of Central Asia's drylands, which is under extreme anthropogenic pressure. The LABR has reintroduced Bukhara red deer (*Cervus hanglu bactrianus*), a subspecies endemic to Asia whose numbers declined severely over the 20th century. The LABR development project aims to provide operational support to the Uzbek authorities for their application to join the World Network of Biosphere Reserves. GIZ (German Society for International Cooperation) requested CIRAD to provide a science-based estimate of the deer population in the LABR, using an internationally recognized method, and to issue recommendations to ensure ecologically and socio-economically sustainable management. The survey of the Bukhara red deer population began in October 2019. The study area covered 88 km². The survey design consisted of 12 parallel straight lines 1400 m apart; the total transect length was 65 km. During the count, 127 observations of individuals or herds were made and a total of 336 individuals were observed. The data were analysed using DISTANCE 7.3 software. The encounter rates were 1.95 obs./km and 5.17 animals/km. The estimated density was 24 deer/km² and the estimated total population was 2,112 deer [1,320 - 3,344, 95% CI]. The proportion of dead, dying or severely affected trees was roughly estimated at 10%, and the proportion of trees affected but with a good chance of survival at 15%. In the southern core area of the LABR, a very high proportion of seedlings and suckers was being eaten and the forest is no longer regenerating. Maintaining a population of 24 deer/km² in the southern core area of LABR clearly seems incompatible with either the conservation of the Tugay forest ecosystem or the peaceful coexistence of deer with human populations adjacent to the LABR. Options to mitigate deer pressure include translocation to the northern core area of the LABR or other areas, and regulation of the deer population. The density is too high to ensure effective preservation of the species locally, although the deer population is under severe pressure in Asia as a whole.

Keywords: *Populus diversifolia*, *Cervus hanglu bactrianus*, Riparian ecosystems, Bukhara Red Deer, distance sampling foot count method, Biosphere Reserve, Tugay, Karakalpakstan, Uzbekistan.

RESUMEN

Estimación de la población de ciervos e impacto en el ecosistema del tugai de la reserva de la biosfera del bajo Amu Daria, en Uzbekistán

En 2011, el Gobierno de Uzbekistán creó la reserva de la biosfera del bajo Amu Daria (LABR). Esta reserva tiene como objetivo conservar el tugai, un ecosistema forestal ribereño en peligro que se encuentra en las zonas secas de las cuencas de los ríos principales de Asia Central, que están sufriendo una presión antropogénica extrema. La LABR reintrodujo el ciervo de Bujará (*Cervus hanglu bactrianus*), una subespecie endémica a Asia cuya población sufrió un importante descenso durante el siglo XX. El proyecto de desarrollo de la LABR pretende proporcionar soporte operacional a las autoridades uzbeques en su demanda de integración a la Red Mundial de Reservas de la Biosfera. A petición de la GIZ (Sociedad Alemana de Cooperación Internacional), el CIRAD realizó una estimación con base científica de la población de ciervos en la LABR, utilizando un método internacionalmente reconocido y proporcionando recomendaciones para garantizar una gestión sostenible desde los puntos de vista ecológico y socioeconómico. El seguimiento de la población de ciervos de Bujará se inició en octubre de 2019. El área de estudio abarcó 88 km². El diseño del seguimiento consistió en 12 líneas rectas paralelas separadas 1 400 m; la longitud total del transecto era de 65 km. Durante el conteo se realizaron 127 observaciones de individuos o manadas, y se avistó un total de 336 individuos. Los datos se analizaron mediante el software DISTANCE 7.3. Las tasas obtenidas son de 1,95 obs./km y 5,17 animales/km. La densidad estimada fue de 24 ciervos/km² y la población total estimada fue de 2 112 ciervos [1 320 - 3 344, 95 % CI]. La proporción de árboles muertos, murientes o severamente afectados se estimó en el 10 % aproximadamente, y la proporción de árboles afectada pero con una buena probabilidad de supervivencia fue del 15 %. En la zona del núcleo sur de la LABR, una proporción muy elevada de semillas y chupones son comidas y, por tanto, el bosque no se regenera. El mantenimiento de una población de 24 ciervos/km² en el sur de la LABR parece claramente incompatible con la conservación del ecosistema del tugai o con la coexistencia pacífica de ciervos y poblaciones humanas adyacentes a la LABR. Las opciones para mitigar la presión de los ciervos incluyen su desplazamiento hacia el norte de la LABR o hacia otras áreas, así como la regulación de su población. La densidad es demasiado alta para preservar localmente y de forma adecuada a las especies, a pesar de que la población de ciervos se encuentra bajo una fuerte presión en Asia.

Palabras clave: *Populus diversifolia*, *Cervus hanglu bactrianus*, ecosistemas de ribera, ciervo de Bujará, método de muestreo a distancia por conteo andando, reserva de la biosfera, tugai, Karakalpakstan, Uzbekistán.

Introduction

In 2011, the Government of Uzbekistan established the Lower Amu Darya State Biosphere Reserve (LABR). This protected area aims to conserve the Tugay, an endangered riparian forest ecosystem straddling the main rivers of Central Asia which is facing extreme anthropogenic pressure (Saiko and Zonn, 2000; Schlüter and Herrfahrtdt-Pähle, 2011). The former Baday-Tugay Natural Reserve, integrated as the core zone of LABR, is also home to a reintroduced population of Bukhara red deer (*Cervus hanglu bactrianus*), a subspecies endemic to Asia, whose range was severely reduced over the 20th century (Pereladova, 2013).

At present, LABR is only recognized under Uzbek law. Despite the inclusion of “Biosphere Reserve” in its name, LABR’s status has not been officially recognized by the UNESCO Man & Biosphere (MAB) Programme. To join the World Network of Biosphere Reserves, national authorities must meet several criteria regarding the reserve and its management (Reimov and Pulatov, 2016).

The project, called “Ecosystem-based land use and preservation of ecosystems in the lower section of the Amu Darya” and operated by GIZ (2018-2020), aims to provide Uzbek authorities operational support to submit an official application to join the network.

In this context, GIZ requested CIRAD to produce a land use – land cover map of LABR and its immediate vicinity with a 30-year retrospective analysis (1988-2018) (Cesaro *et al.*, 2019). This product will provide policymakers and institutions a comprehensive understanding of land cover change and interactions between actors and factors of land use changes. This product also will provide a functional management and planning tool to the LABR teams.

GIZ also requested CIRAD to provide a science-based estimate of the deer population ranging in LABR using an internationally recognized method, and to provide recommendations aiming to ensure ecologically and socio-economically sustainable management. The survey of the Bukhara

red deer population was implemented in October 2019 (Cornelis *et al.*, 2020).

The Bukhara deer in Central Asia and Uzbekistan

Taxonomy

Bukhara deer is an endemic form of red deer inhabiting riverine woods and thickets in Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan and northern Afghanistan. For many years, the Bukhara deer (along with European, North African and North American red deer) was considered to be a subspecies of a single red deer species (*Cervus elaphus*) under the following nomenclature: *Cervus elaphus bactrianus* Lydekker, 1900 (Marmazinskaya, 2012).

Recent genetic analysis of the *Cervus* group suggested that deer populations from Bukhara region (*C. e. bactrianus*), Yarkand-Tarim region in Xinjiang, China (*C. e. yarkandensis*) and Indian Kashmir (*C. e. hanglu*) form a full taxonomic group (Lorenzini and Garofalo, 2015; Mukesh *et al.*, 2015; Kumar *et al.*, 2016). Lorenzini and Garofalo (2015) suggested their elevation to the status of species, recognized as the Tarim red deer (*Cervus hanglu* Wagner, 1844). On this basis, *Cervus hanglu* was elevated to the species level in the framework of the IUCN Red List assessment in 2016. At that time, the total population size of Tarim red deer was approximately 2,500 individuals (Brook *et al.*, 2017).

The last nomenclature thus considers the Bukhara deer as a subspecies of Tarim red deer (*Cervus hanglu*), referred to as *C. h. bactrianus*. It is worth noting that Brook *et al.* (2017) emphasize that future clarification on genetic relatedness and a more formal morphological description may lead to further revisions to the taxonomy of this provisional subspecies. For the purpose of this article, we will use the term “Bukhara deer” in reference to the subspecies *Cervus hanglu bactrianus* (previously named *Cervus elaphus bactrianus*).



Photos 3 & 4.

Vegetation Units – Open Forest: 30% > trees cover \geq 10% (photo left);
Dense Steppe: shrubs and grass cover \geq 60%, 10% > trees cover (photo right).
Photos R. Peltier.

**Photos 5 & 6.**

Vegetation Units - Semi-Open Steppe: 60% > shrubs and grass cover \geq 30%, 10% > trees cover (photo left); Open Steppe: 30% > shrubs and grass cover, 10% > trees cover (photo right).
Photos R. Peltier.

Descriptive notes

The Bukhara deer is a relatively small deer (skull length 390 mm; shoulder height 120 cm), with medium-size antlers weighing between 3.4 and 5.5 kg (Geist, 1998). In contrast with other forms of red deer, antlers usually have no crown, which is considered a primitive morphological trait relative to *Cervus elaphus* species (Pereladova, 2013). Unlike western red deer populations, which emit low-pitched vocalizations during rut, Bukhara deer emit a high-pitched bugle, similar to the call of other Asian (sika) and American (wapiti) populations (Geist, 1998).

Bukhara deer inhabit riparian-forested corridors surrounded by desert and steppe environments. Some significant groups of *C. h. bactrianus* inhabit reed bushes with very limited tree cover (Marmazinskaya, 2012). Although the main habitats of Bukhara deer are riparian forests, their diet includes grasses, sedges, shrubs and tree shoots. Their diet is very limited most of the year (e.g., when inhabiting reeds and bushes) (Pereladova, 2013). Comparative

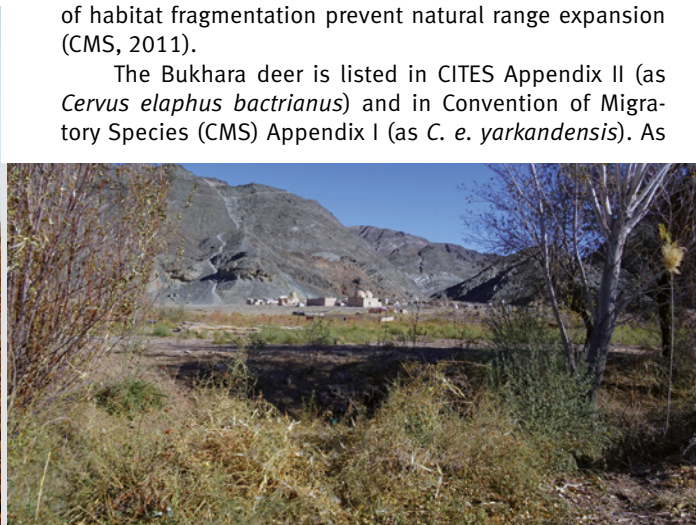
analyses with other red deer populations have shown that Bukhara deer possess specific physiological adaptations to the arid conditions of Central Asia, most notably to the very limited supply and quality of food resources.

Although Bukhara deer populations do not undertake regular seasonal migrations, some populations were reported to leave their usual home range in response to intra-specific competition or temporary unavailability of their habitat (e.g., seasonal flooding) (Pereladova, 2013). Since about 30 to 50% of all populations were estimated to migrate every year and to cross national borders, the Bukhara deer was registered in the International Convention on Migratory Species (CMS or Bonn Convention) in 2002 (see below).

International and national status of Bukhara deer

The Bukhara deer is threatened by the conversion of natural habitats, alteration of local water systems (irrigation, dam building), and illegal hunting (Wilson and Mittermeier, 2011; Pereladova, 2013; Vagg, 2015). High levels of habitat fragmentation prevent natural range expansion (CMS, 2011).

The Bukhara deer is listed in CITES Appendix II (as *Cervus elaphus bactrianus*) and in Convention of Migratory Species (CMS) Appendix I (as *C. e. yarkandensis*). As

**Photos 7 & 8.**

Vegetation Units – Agriculture (photo left); Rocky areas (photo right).
Photos R. Peltier.

mentioned above, the Bukhara deer was recognized until recently as a *Cervus elaphus* subspecies and the taxonomic revision published by the International Union for Conservation of Nature and Natural Resources (IUCN) now recognizes it as *Cervus hanglu bactrianus* (Brook *et al.*, 2017). Under this new nomenclature, the IUCN status of Bukhara deer is currently assessed as “Least Concern” (LC). To our knowledge, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and CMS have not yet endorsed or updated the taxonomic revision (*Cervus hanglu bactrianus*) proposed by IUCN (Brook *et al.*, 2017). As already noted by Mallon (2013), such taxonomic and nomenclatural issues in the region have potential implications for CITES.

At a regional (central Asian) level, the Bukhara deer is listed in the Red Data Books of all range countries (CMS, 2011). A CMS MoU on “Conservation and Restoration of Bukhara Deer” came into effect in 2002 and was signed by Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan, the CMS Secretariat, the WWF and the International Council for Game and Wildlife Conservation (CIC) (CMS, 2016). The MoU provides an intergovernmental framework for governments, scientists and other stakeholders to monitor and coordinate ongoing conservation efforts (Vagg, 2015). In addition, an action plan has been established, aiming to, inter alia, restore the range and number of suitable habi-

tats for the subspecies (CMS, 2002). *C. e. bactrianus* is listed in the Red Data Book of Uzbekistan, where it has been assessed as “endangered” (Azimov *et al.*, 2009).

Distribution range and abundance

Historically, Bukhara deer inhabited all river valleys of the Amu Darya and Syr Darya basins, as well as the valleys of several minor rivers in Central Asia (Pereladova, 2013). Their range strongly contracted during the 19th and 20th centuries because of land conversion (for agriculture) and poaching (Brook *et al.*, 2017). Bukhara deer had disappeared from the Syr Darya basin by 1900 and the total population consisted of 350-500 individuals in the mid-1960s (Brook *et al.*, 2017). From the 1970s, special reserves were established for the protection of Bukhara deer in Central Asia, and populations were restored in parts of their former range. By 1989, there were about 900 deer distributed in 13 populations/groups, but populations contracted again to about 350 individuals after the breakup of the former Soviet Union due to the resurgence of poaching (Pereladova, 2013). Following restoration activities undertaken from the 2000s onwards, the population of Bukhara deer increased to a total of 1,900 individuals in Uzbekistan, Kazakhstan, Turkmenistan and Tajikistan by 2011 (Pereladova, 2013), and to 2,700 by 2015 (Pereladova pers. com. to Brook *et al.*, 2017) (figure 1).

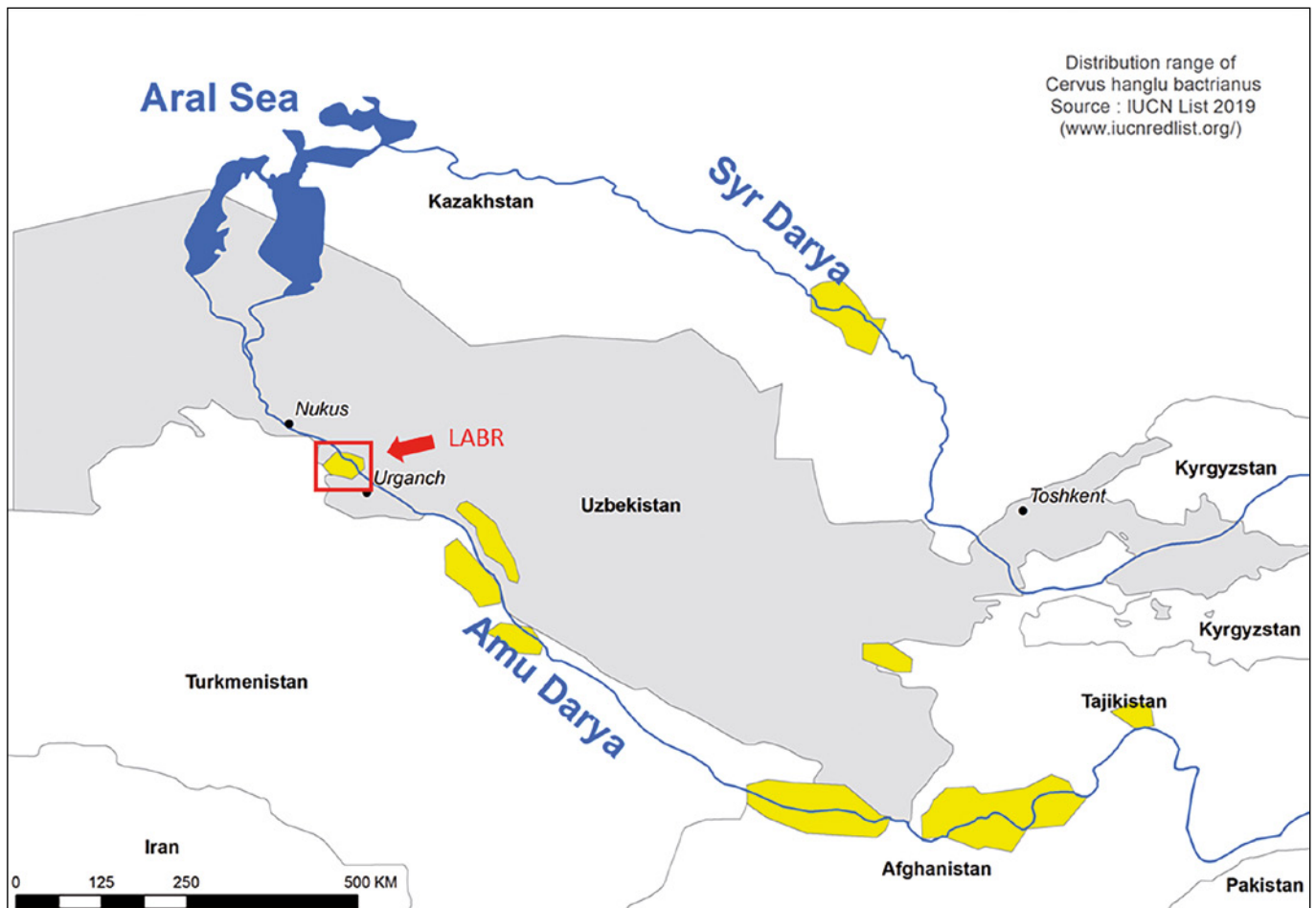


Figure 1.
 Current distribution of free range Bukhara deer population (Brook *et al.*, 2017).

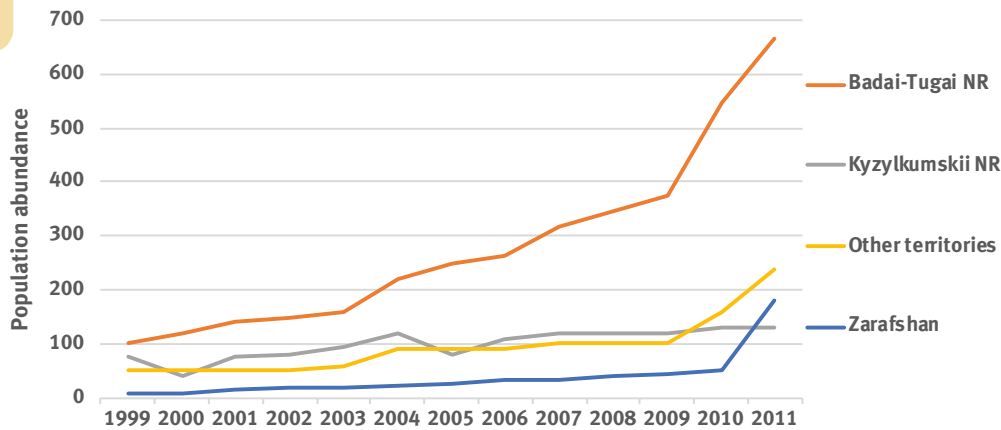


Figure 2. Estimation of population trends of Bukhara deer in Uzbekistan (Pereladova, 2013).

In Uzbekistan, the creation of national reserves and a reintroduction programme initiated in the 1970s made it possible to rebuild several populations. Bukhara deer are now found in the LABR (former Baday-Tugay State Nature Reserve), Kyzylkum and Zarafshan (syn: Veravshan) State Nature Reserves as well on other scattered areas. Some of these populations are shared with Turkmenistan or Tajikistan. According to the last published estimate (Pereladova, 2013), the Bukhara deer population in Uzbekistan was estimated at 1,200 individuals in 2011.

In LABR, the restoration of Bukhara deer population started in 1976 with a reintroduction of four individuals (one male and three females) from Romit State Nature Reserve in Tajikistan (Pers. Com.: Kayrbek Musrepov (science officer), Aziz Matkurbanov (LABR ranger) and Mukhabbat Kamalova (GIZ)). Nine additional individuals were introduced in 1979 (sex not specified). To our knowledge, there were no further introductions, and the current population originates from these 13 individuals. These individuals were provisionally kept in a holding pen (2.7 ha) located in LABR. We do not have information on the release process in LABR.

The authors did not have access to any publications or field reports on the methodology used to estimate deer population in LABR. From interviews conducted with the field teams, it appears that road counts made by car have been carried out annually, according to a standardized methodology (count implemented along about 40 km of tracks in a 100-metre strip on either side of the track, repeated three times, and averaged).

Hypothesis and object of the study

The first field observations (Gond *et al.*, 2019) and land-cover mapping (Cesaro *et al.*, 2019) showed that the vegetation in the Baday-Tugay core zone was deteriorating. On the other hand, the precise number of deer sheltered in this area was not known. The hypothesis that this degradation of the vegetation could be caused by an over-density of deer was therefore posed. To verify this hypothesis, an accurate count of the number of animals was programmed, the methodology and results of which are the subject of this article. The outputs of the study also will be used to complete the file to apply to the World Network of Biosphere Reserves recognized by the UNESCO MAB Programme.



Photos 9 & 10. Vegetation Units – Bare Soil (photo left); Water (photo right). Photos R. Peltier.

Methodology

Study area: Lower Amu Darya State Biosphere Reserve & Tugay habitat

LABR (712 km²) is located in central-western Uzbekistan near the border of Turkmenistan (Lon: [N42°30'-41°30'] – Lat: [E59°40' -60°50']), and stretches along the Amu Darya River course for about 125 km in an elongated, SE-NW oriented shape. The area has a continental and desertic climate, with cold influence of the Arctic and Siberian fronts and a large range in temperature (Nukus: -11 to 36°). Annual rainfall ranges from 100 to 150 mm and occurs from autumn to spring, while summer weather is dry and hot. Le Houérou (2005) classifies the vegetation in Mediterranean biomes and the phytogeographic entity as Aralo-Caspian. The history of the reserve dates back to 1971 with the creation of the Baday-Tugay State Reserve for deer conservation. This Reserve was extended in 2011 by the creation of LABR to protect the Tugay habitat.

The zonation of LABR includes a transition area (human activities), a buffer zone (restricted human activities) and a core area (nature protection). The core area consists of two separate large zones, the Northern core (Nazarkhan: 33 km²) and the Southern core (Baday-Tugay: 77 km²), with ends

spaced 25 km apart and a small central core (Jumurtau). Core areas are not inhabited. The boundaries of the Southern core correspond to those of the former Baday-Tugay State Reserve, within which deer were reintroduced in the early 1970s and where the current deer population is mainly confined today because of agricultural activities in the South of Baday-Tugay and of absence of vegetation (rocky steppe) and industrial activities (cement plant and quarry) in the North of Baday-Tugay (figure 3).

All of the core areas are covered with natural or degraded vegetation. Natural vegetation is composed of Tugay, a form of riparian forest or woodland associated with fluvial and floodplain areas in arid climates (Gintzburger *et al.*, 2003). This floodplain ecosystem, which is endemic to Central Asia, has been strongly degraded due to land conversion, forest fires, and groundwater lowering resulting from intensive irrigation and dam construction. Within the Amu Darya basin, about 90% of Tugay ecosystems have been lost since the 1930s (Kuz'mina and Treshkin, 2012; Marmazinskaya, 2012). LABR thus hosts one of the last relict riparian Tugay fragments, which highlights the strategic importance of the Reserve for the conservation of natural habitats and species of Uzbekistan.

The remains of the Tugay forests located along the Amu Darya River are fragmented and suffer extreme pressure

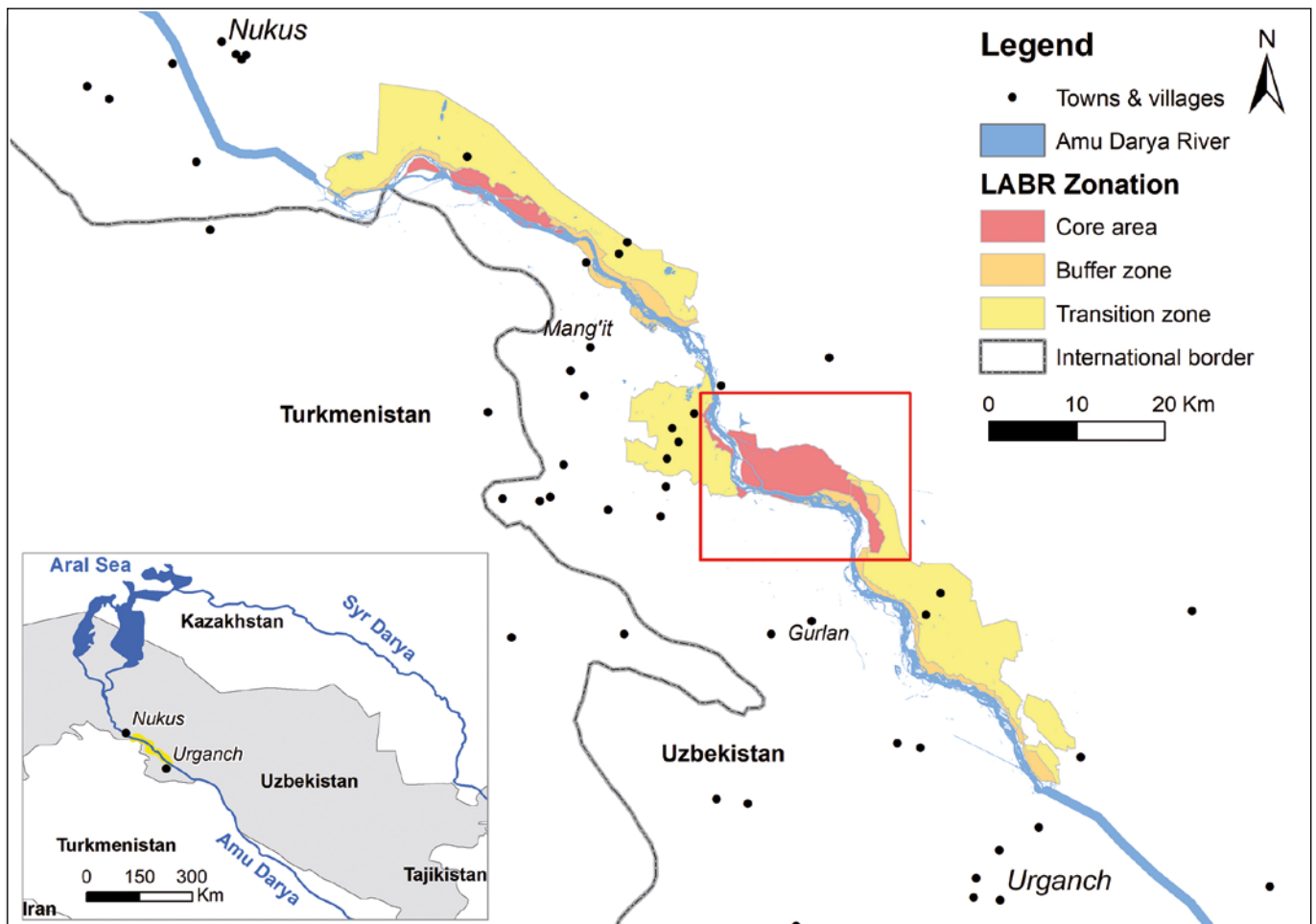


Figure 3.

The study area is delimited by the red square on the LABR zonation map (zone limits are being changed).

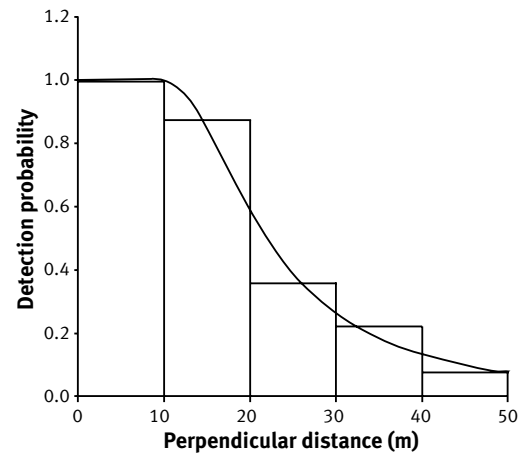
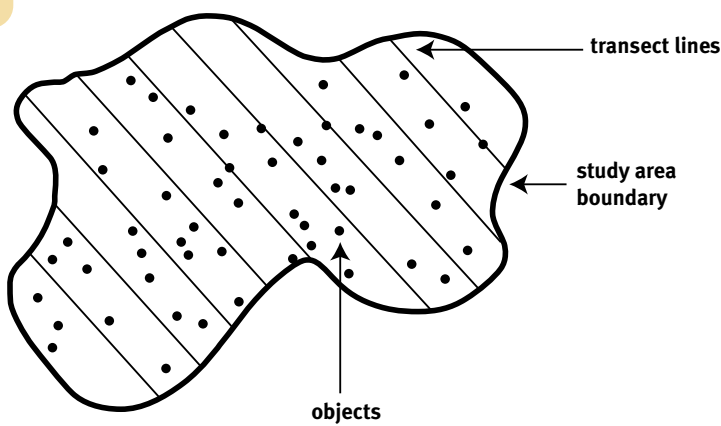


Figure 4. Principles of the distance sampling method (Buckland *et al.*, 2015).

from expanding intensive irrigated agriculture. Woody Tugay contains different species of poplars (*Populus pruinosa*, *P. diversifolia*). The understory is generally composed of *Tamarix* sp., *Phragmites communis* and *Typha* sp. associated with a plant community with dominant xero-halophytes (*Karelinia caspia*, *Limonium otoplepis*, etc.) and true halophytes species (*Aeluropus littoralis*, *Climacoptera turcomanica*, etc.). Woody vegetation structure is organized with a fragmented canopy at 10-12 m and an understory at 2-4 m. The vegetation units of the map of LABR produced by CIRAD (Cesaro *et al.*, 2019; Gond *et al.*, 2019) are illustrated in photos 1 to 10.

Deer census methodology

Distance sampling method

The deer population was estimated using the distance sampling foot count method (Buckland *et al.*, 2005, 2015). Distance sampling is a widely used methodology for estimating animal density or abundance. This method is based on the sampling of objects (in this case animals) detected along a linear path called the transect line or transect (figure 4, left).

This method takes into account the fact that individuals are not equally detectable by the observer. A key underlying concept is that the probability of detecting an animal decreases as its distance from the observer increases. In other words, the probability of observing an animal 50 m from the transect is lower than the probability of observing an animal 20 m from the transect. Much of distance sampling methodology consists of modelling the probability of detecting an animal given its distance from the transect and thus estimating the proportion of animals not detected (figure 4, right).

While walking straight along transect lines, observers take note of animals detected on either side of the transect (species and number) as well as the following two parameters (figure 5):

- the radial distance (r) between the observer and the animal at the time of detection;
- the angle of view (θ) between the walking line and the observer-animal line.

In this study, radial distances were measured using a laser rangefinder (Bushnell) and angles using a direct-sight compass (Suunto KB14) (figure 5).

Deer survey in LABR

The extent of the survey area was defined not on the basis of administrative boundaries, but by considering the extent of natural vegetation present in the core area of LABR and in its immediate vicinity where rangers knew deer were present. On this basis, the study area was 88 km².

The survey design consisted of 12 parallel straight lines spaced 1,400 m apart, oriented north and south. A 13th transect oriented NW-SE was designed on the Jumurtau zone (figure 6). The total transect length was 65 km (average length: 5 km, max: 7.6 km).

The survey took place between 24 and 29 October 2019. Each transect was covered once and observations took place in the morning,

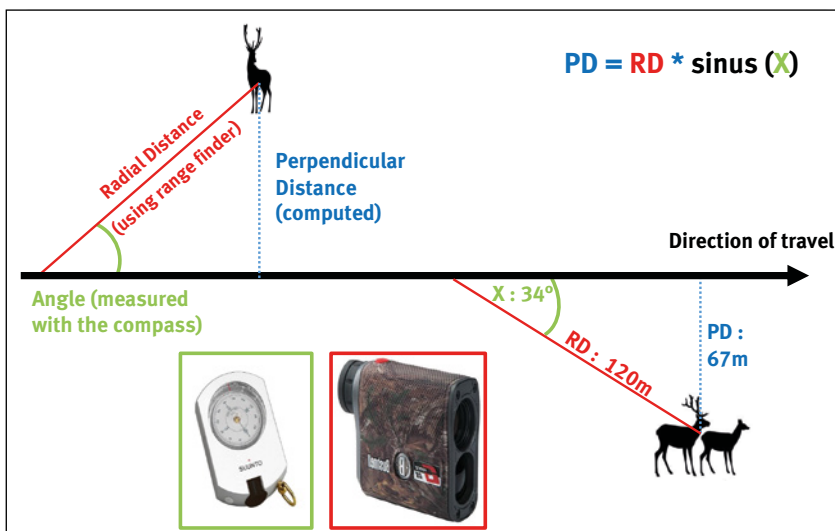


Figure 5. Principles of data collection.

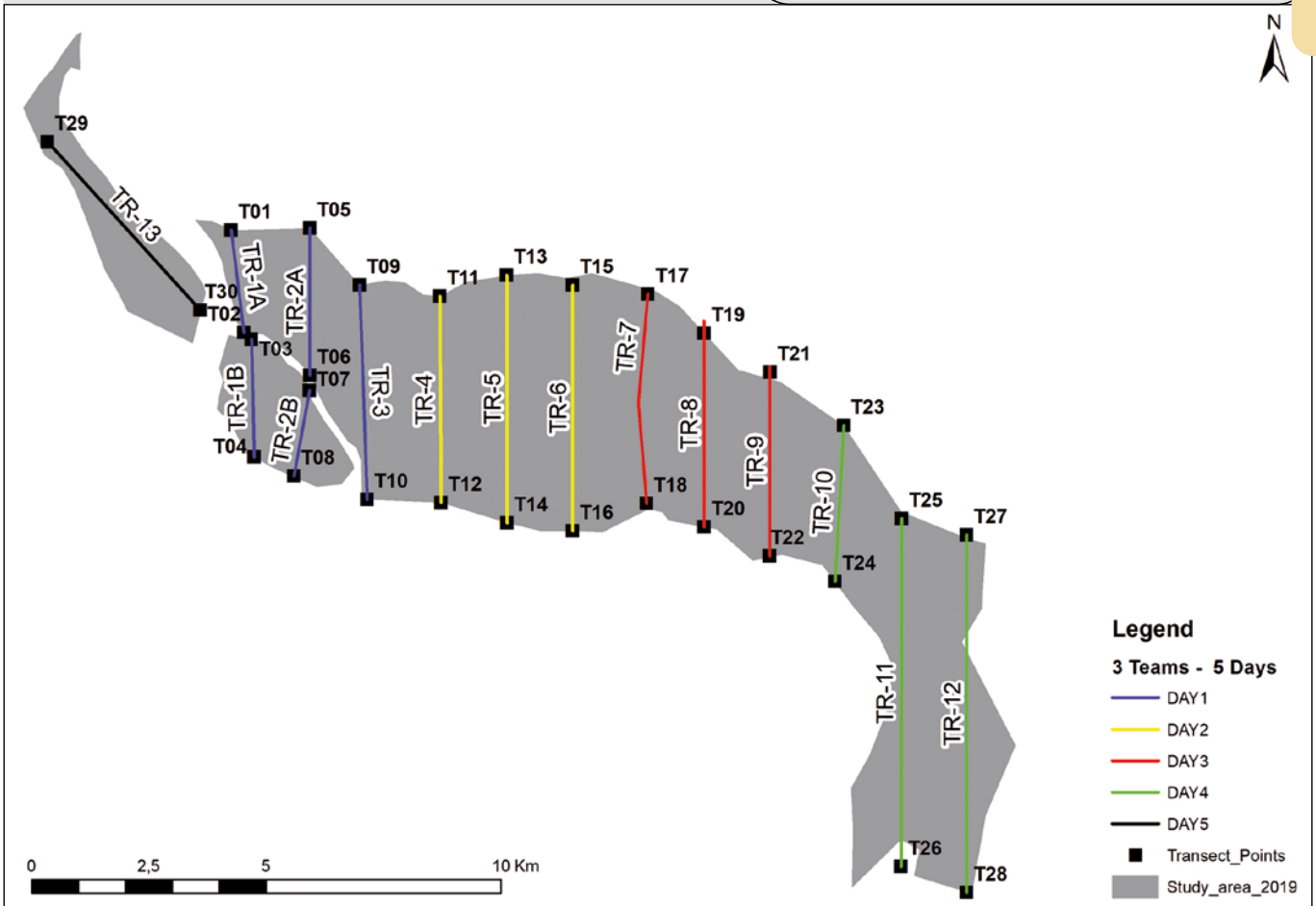


Figure 6.
 Survey design of LABR distance sampling foot count.

starting between 7:30 and 8:00 (sunrise during the survey period occurred from 7:10 to 7:20). The average duration of the morning observations was 2h20.

Census teams consisted of three persons (one team leader and two observers) walking in line and separated by 3 to 5 m from the next team member. Before the count, the teams were trained to manipulate their instruments (compass, GPS, rangefinder) and fill in the datasheet (photo 11). The team leader was in charge of navigation (using a GPS) and of data recording as recommended by Jachmann (2001). Both observers spotted, identified and counted in all directions (using compass, rangefinder and binoculars) as precisely as possible the animals encountered.

Data analysis

During the count, 127 observations of individuals or herds were made and a total of 336 individuals were observed (average group size: 2.5 individuals, maximum: 10 indiv.). Data were analysed using DISTANCE 7.3 software (Thomas *et al.*, 2010). A size-bias regression was applied by regressing cluster size against estimated $g(x)$. A right truncation was applied to exact distance measurements by discarding the largest 5 percent of distances. Several contacts were probably missed at zero distance from the transect line, particularly in the dense thickets of transects n°11 and 12. However, no correction was applied to the model to account for $g(0) < 1$.

The estimated Effective Strip Width (ESW) was 216 meters and the sampling rate was therefore 31% of the study area (2 x 216 m/1,400 m). The detection function was modelled using a half-normal model with cosine adjustment of order 2.



Photo 11.
 Illustration of field data collection.
 Photo D. Cornelis.

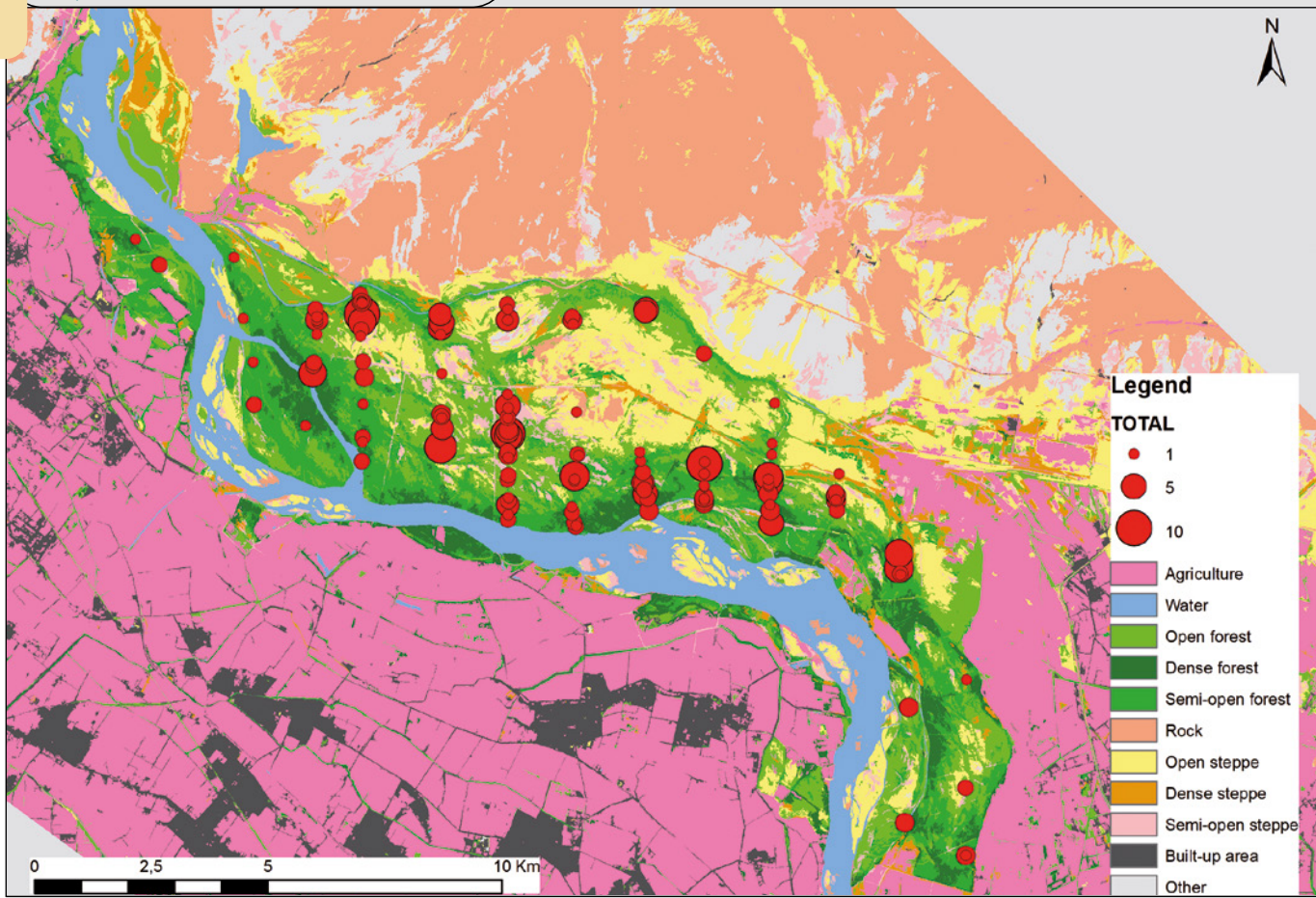


Figure 7.

Spatial distribution of deer observations during the 10/2019 survey, reported on the map of land occupation made by A. Jolivot (Cesaro *et al.*, 2019).

Additional field observations: Vegetation dynamics

During fieldwork in the Southern core area of LABR (Baday-Tugay), where the bulk of the deer population ranges, the mission team was very surprised by the intensity and extent of damage caused by deer to natural vegetation, especially to forest regeneration. No specific sampling of the damage was undertaken during the mission. However, the proportion of trees severely affected, dead or dying was roughly estimated.

of trees affected but with a good chance of survival at 15%. In the Southern core area of LABR, a very high proportion of the seedlings or suckers are being eaten (photo 13) and the forest is thus no longer being regenerated.

Such a situation strongly contrasts with vegetation dynamics in the Northern core area of LABR where deer are currently absent and where forest regrowth is clearly visible (photos 14 & 15).

Results

The analysis returns a density estimate of 24 Bukhara deer per square kilometre in a range between 15 and 38 (respectively minimum and maximum 95% confidence interval) (Cornelis *et al.*, 2021). This figure carried over to the total surface area (88 km²) gives a total population estimate of 2,112 deer [1,320 – 3,344, 95% CI]. An overlay of the vegetation map and the location of deer observations show a clear preference for forest areas, and an avoidance of steppe areas, at least at the time and period of year when the study was conducted (figure 7). The encounter rates are 1.95 obs./km and 5.17 animal/km.

The proportion of trees severely affected, dead or dying (photo 12) was roughly estimated at 10%, and the proportion

Discussion

The distance sampling foot count in LABR implemented in October 2019 returned an estimate of 2,112 Bukhara red deer [1,320 – 3,344, 95% CI]. Producing accurate population estimates using this method requires a minimum of 60 to 80 contacts per survey (Buckland *et al.*, 2005, 2015). In this study, the number of contacts (127 observations) was well over the minimum required to model detection functions and to obtain reliable estimates. Results show that the sampling designs (transects spaced 1,400 m apart, 2 x 216 m bandwidth) made it possible to cover 31% of the study area, which is a fairly good sampling rate. In this study, sparsely distributed herds occurring in small clusters (2.5 individuals on average) provided

favourable conditions for a line transects design. Habitats of the Southern core area also provided suitable visibility conditions for deer observations, except the dense thickets located in the south-western section (transects n°11 & 12) where a undefined number of observations were missed. In this section, the assumption of a 100% detection of the animals present at zero distance from the transect line was not respected. Consequently, our study likely underestimated the population size by a few percentage points.

Since the line transect survey method differs from those previously implemented, the 2019 estimate should not be compared with the results of those methods, or aggregated to them. Although no access to technical reports was possible during the mission, we were told on site that road counts are implemented annually in LABR. If implemented in a standardized way, this index method may be useful to detect trends in population size, but it is not appropriate to estimate absolute figures of abundance because many animals are missed.

Results show that the deer reintroduction experiment undertaken for 33 years has been a conservation success: from an initial pool of 13 animals, over 2,000 range in LABR today. However, this success hides a severe problem: the population is confined to an area of 88 km² (about 12% of LABR area) with a density of about 24 individuals/km². This figure is very high and differs in order of magnitude from those observed elsewhere in the red deer distribution range. The Southern core area of LABR (previously Baday-Tugay Reserve) is surrounded by cultivated, semi-desert or built-up areas, leaving no opportunity for the deer population to expand their range or migrate.

In LABR, the deer population currently is unregulated. The size of the area is not large enough to host predators, with the exception of jackals. Although jackals were shown to prey on young fawns, their contribution to deer regulation appears clearly insufficient. Regulated hunting is also prohibited due to

the conservation status of Bukhara deer in Uzbekistan.

This situation has ecological consequences for the deer population itself and for the Tugay ecosystem. In a context of high density, the deer population of LABR is exposed to population crashes due to climatic events and disease outbreaks. The latter risk is also likely to be amplified by strong inbreeding due to the reintroduction of a very limited number of individuals. High deer densities have very probably ecological consequences for the Tugay forest in the Southern core area of LABR, where an absence of forest regeneration due to over-browsing is observed, even though these observations must be verified by systematic inventories of vegetation, on a scientifically verifiable basis. Although forest regeneration can be compromised by other factors (ex: changes in the rainfall regime or in underground water levels), the contrast in forest regeneration dynamics observed in the Northern part of the reserve, Nazarkhan forest (where deer are absent) lets suppose the role played by deer in the forest degradation process in the core area of the Southern part of the reserve, as can be observed on the multi-year landcover monitoring maps, esta-



Photos 12 & 13.

Debarking and browsing of shoots on a poplar strain, typical of the Southern core area of LABR. Photos R. Peltier.



Photos 14 & 15.

State of natural regeneration in the Northern core area of LABR (Nazarkhan). Photos R. Peltier.

blished by Cesaro *et al.* (2019), over the period 1988-2018.

A high-density context also has strong socio-economic implications for rural populations and local authorities. Two recent studies of the socio-economic interactions between local populations (Huet, 2019; Couetil, 2020) report that many farms adjacent to LABR (e.g., Tallyk and Jumurtau villages) face severe damage caused by deer feeding on crop fields and vegetables (photo 16). Farmers therefore try to deter deer intrusions on their own with the means they have available (surveillance platforms, barriers, corn fields to feed deer, etc.). Furthermore, a total absence of regulation also generates opportunity costs for LABR and local authorities because no sustainable use of deer is made (in terms of meat, velvet, or trophies).

Conclusions and recommendations

Although the ecological carrying capacity of Central Asian riparian forest ecosystems may be higher than elsewhere in the red deer distribution range, the worrying absence of Tugay forest regeneration is symptomatic of a strong ecological imbalance. It is very important that inventories of the vegetation be carried out over the next few years to scientifically verify these observations. The Bukhara deer population should also be considered in terms of social carrying capacity (i.e., the density threshold beyond which the species generates coexistence problems with humans). As a basis for comparison, deer populations ranging in Western Europe are generally maintained below a threshold of 1.5 to 3 individuals/km² in order to limit human-wildlife conflict (damage to production forests, crops, etc.).



Photo 16.

On the border between the reserve (left) and the cultivated area (right), the farmers have installed guard posts, spaced a hundred metres apart, where they spend the night to scare the herds of deer that come to damage their crops and their pastures.

Photo R. Peltier.

Table I.

Carrying capacity of Bukhara deer in LABR core area (according to N. Marmazynskaya).

	Area	Carrying capacity	Annual Growth
Southern Core	88 km ²	590 deer	106 deer
Northern Core	33 km ²	220 deer	40 deer

Without a relocation strategy, maintaining a population of 2,000 deer (24/km²) in the Southern core area of LABR is very probably not compatible with either the objective of conserving the Tugay forest ecosystem or the peaceful coexistence of deer with riverine populations of LABR. According to a local deer ecologist (N. Marmazynskaya), the ecological carrying capacity of Tugay ecosystems would be around a minimum of 15 ha per deer. Put differently, the Southern core of LABR could sustainably host around 6.7 individuals/km², or 590 individuals, based on an available habitat area of 88 km² (table I). Maintaining the population at this constant level would require removing around 106 animals per year from the area. Note this estimation is based on the average annual population growth rate of 18% observed in the Southern core area between 1999 and 2011.

There are several possible options (not mutually exclusive) to relieve the current pressure on the Southern core area.

Translocation towards the Northern core area of LABR

According to local carrying figures from N. Marmazynskaya, the Northern core of LABR could sustainably host around 220 individuals, based on an available habitat area of 33 km². Maintaining the population at this constant level would require removing around 40 animals per year from the area. We recommend translocating 60-80 deer towards the Northern core of LABR. On this basis, and assuming an average annual growth of 18% without population regulation, the maximum carrying capacity could be reached in 6-8 years.

Translocation towards other areas

Assessing the potential for translocating part of the deer population elsewhere in Uzbekistan or in Central Asia was outside the scope of this study. A previous assessment undertaken at the scale of Uzbekistan showed that several areas were potentially suitable for restocking deer (Marmazinskaya, 2012).

The potential for restocking other areas in Central Asia should also be urgently considered under the CMS MoU on Conservation and Restoration of

Tugay forests were studied and several massifs suitable for the Bukhara deer identified in the upper current of the Amu Darya River in the course of the project “Conservation of Tugay forests and strengthening the protected areas system in the Amu Darya Delta in Karakalpakstan”, financed by UNDP-GEF and the Government of the Karakalpakstan Republic. It is recommended that reintroduction begins to the south-east of the Aral Sea (the Amu Darya Delta and adjacent areas of the former bottom of the Aral Sea), the Akpetki Archipelago (Karabail) and the former Zholdyrbas bay. Some of the Tugay massifs at the southern margin of the Aral Sea proposed for reintroduction were included in the Nizhne-Amudaryinsky State Biosphere Reserve that was established in 2011. In Uzbekistan, promising areas for deer release are the Dalverzinskoye game management reserve (middle current of the Syr Darya River, 21,000 ha) and the Karakir sanctuary (Kyzylkum desert – extensive reed beds around lakes; groves of saxaul, Calligonum, and saltworts in the desert portion of the reserve, 30,000 ha). Positive experience of the Romit Nature Reserve allows further introduction work in mountainous areas. This can be implemented in the Surkhansky Nature Reserve - the Vandob area.

Extract from Marmazinskaya, 2012

Bukhara Deer signed by Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan, the CMS Secretariat, WWF and CIC (CMS, 2016).

As mentioned above, this MoU provides an intergovernmental framework for governments, scientists and other stakeholders to monitor and coordinate ongoing conservation efforts (Vagg, 2015). In addition, an action plan has been established, aiming to, inter alia, restore the range and number of suitable habitats for the subspecies (CMS, 2002).

Regulation of the LABR deer population

In the Southern core of LABR, reducing the deer population to an ecologically and socially tolerable density implies removing 70% of the population (i.e., 1,500 animals). Part of the stock (to be defined) probably could be moved to restock other protected areas in Uzbekistan and Central Asia.

Whatever this translocation potential, regulated hunting is necessary to control natural population growth within LABR and the remaining stocked areas because not enough predators are living within the reserve. In Uzbekistan, hunting of species listed on the Red Data Book of Uzbekistan is permitted with species dispensation from the Council of Ministers (Mallon, 2013). This option should be investigated as a way to address the urgency of regulating the deer population in the absence of an appropriate legal framework. Advocacy efforts also should be developed to facilitate the adaptation of the legal framework for a review of the conservation status of Bukhara deer and allow adaptive management through hunting run by state services and/or sport hunting. A mechanism to compensate for losses incurred by the populations living in the vicinity of LABR could be put in place through the sale of by-products (meat, antler, etc.).

The method used to count deer in the Baday-Tugay area gives an estimate almost equal to the previous total estimates

in Central Asia; at the regional level, it is necessary to protect this species, but at the local level, their density is certainly too high.

Access to experience data

The dataset generated during the experience is available on Cirad dataverse:

Cornelis D., Gond V., Cesaro J.-D., Peltier R., 2021. Databases of the publication entitled: Estimation of red deer population and its impact on Tugay forest ecosystem in the Lower Amu Darya State Biosphere Reserve, Uzbekistan. CIRAD Dataverse, V1. <http://dx.doi.org/10.18167/DVN1/THSVXS>

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Cornelis et al. – Contribution des auteurs

Rôle du contributeur	Noms des auteurs
Conceptualisation	D. Cornelis, R. Peltier
Gestion des données	D. Cornelis, V. Gond
Analyse formelle	J.-D. Cesaro, D. Cornelis
Acquisition du financement	R. Peltier, J.-D. Cesaro
Enquête et investigation	E. Kan, D. Cornelis, V. Gond, R. Peltier
Méthodologie	D. Cornelis
Gestion de projet	J.-D. Cesaro, R. Peltier, E. Kan
Ressources	E. Kan
Logiciels	D. Cornelis, V. Gond
Supervision	R. Peltier, D. Cornelis, E. Kan
Validation	D. Cornelis
Visualisation	R. Peltier, V. Gond
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