Review of the status of the Persian leopard

Panthera pardus tulliana in the Lesser Caucasus



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About the Persian Leopard Working Group (PeLeWG)

Conservation of the Persian leopard, its prey and habitats requires the mobilisation of global and national efforts. The Range-Wide Strategy for the Conservation of the Persian Leopard was first discussed and endorsed at the First Range State Meeting for the Persian Leopard (20-22 September 2022, Tbilisi, Georgia) and then adopted at the COP14 (14th Conference of the Parties of the Convention on Migratory Species CMS, 12-17 February 2024, Samarkand, Uzbekistan). Originally, this Strategy was developed within the CMS Central Asian Mammals Initiative (CAMI).

Implementation of this Strategy called for the formation of a professional, representative and motivated group of experts who would lead and coordinate the strategy implementation process on a technical level. This was an impetus to establish the Persian Leopard Working Group (PeLeWG, https://pelewg.net) in March 2023. It is an affiliated partner of the IUCN/SSC Cat Specialist Group (https://www.catsg.org) and has over 50 members. The group is managed by the Steering Committee of 15 members, including two Co-Chairs, all from the range countries.

Abstract

The Persian leopard *Panthera pardus tulliana* population remains critically small in the Lesser Caucasus, which covers Armenia, Nakhchivan (Azerbaijan), southern Georgia, and north-eastern Türkiye. By reviewing the most reliable evidence from 2010–2023, including camera-trap records and photographs, this report assesses the current status, patterns and trends of this big cat nearly two decades after major conservation investments in the region. The population is estimated at a minimum of 6–20 adult individuals recorded in Armenia and Nakhchivan, indicating a very small founder group with potential vulnerability to inbreeding depression. Although numbers and range appear to have increased since the early 2000s, reliable historical baselines are lacking. Once considered a key source population, the north-western Iranian reserves no longer function as such and may now act as a demographic sink. The main threats include habitat fragmentation and loss, political instability, prey depletion and limited prey richness in some areas, and illegal killing. While prey abundance, particularly of bezoar goats *Capra aegagrus*, is currently adequate, its enhancement is essential for long-term population growth. The Persian leopard metapopulation remains fragile, consisting of loosely connected individuals rather than stable sub-populations. Southern Nakhchivan acts as a source area, with dispersal into Armenia and Türkiye suggesting a slow recovery. Females show signs of breeding expansion into southern Armenia, while movement data reveal remarkable male dispersal distances of 200 km or more. To secure a safe future for Persian leopards in the Lesser Caucasus, this report highlights a need for sex-specific ecological research, telemetry-based movement studies, genetic research, enforced population monitoring, and transboundary collaboration under the Persian Leopard Working Group (PeLeWG). Long-term survival will depend on maintaining habitat connectivity through an integrated “land sharing–land sparing” approach that combines protected areas with community-managed landscapes.

1. Introduction

The Persian leopard (Fig. 1) is the last big cat surviving in Southwest Asia following the extinction of the Asiatic lion *P. leo leo* (= *P. l. persica*), the Caspian tiger *P. tigris tigris* (= *P. t. virgata*), with the Asiatic cheetah *Acinonyx jubatus venaticus* confined to a meagre number of animals in central Iran (Farhadinia et al. 2017, Kitchener et al. 2017). Leopards are well-known for their adaptability and tolerance to humans, but poaching, prey loss, and habitat degradation and fragmentation make the future of the Persian leopard precarious unless intensive and long-term conservation efforts are effectively applied.

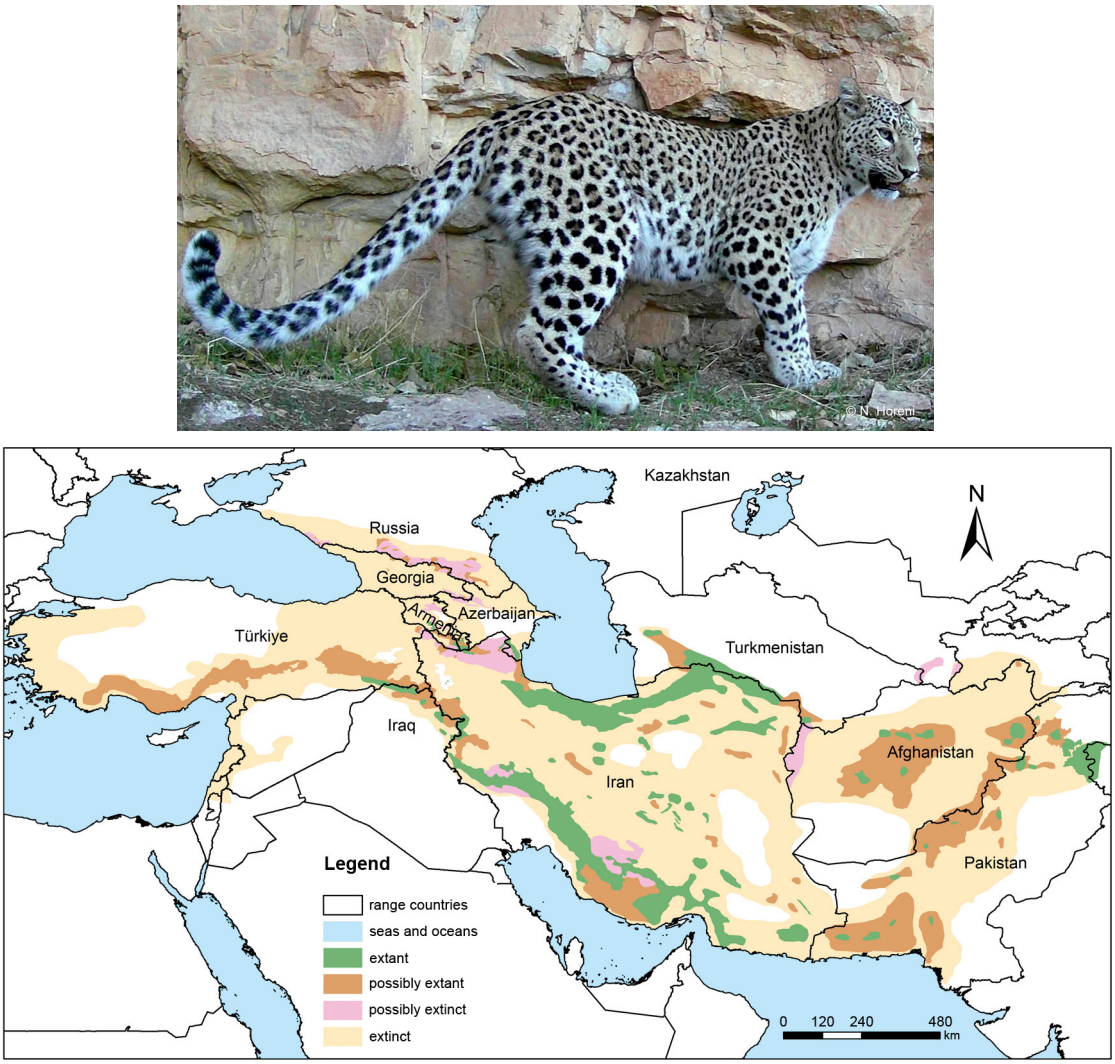


Fig. 1. The Persian leopard and its distribution area from the 2023 IUCN Red List of Threatened Species™ (Photo by N. Horeni; range map adapted from Ghoddousi & Khorozyan 2023).

Currently, the Persian leopard is distributed across 12 countries, but is resident in only nine of them (Afghanistan, Armenia, Azerbaijan, Iran, Iraq/Kurdistan, Pakistan, Russia, Türkiye and Turkmenistan) while in the other three it occurs occasionally (Georgia, Kazakhstan) or

its presence is uncertain (Uzbekistan) (Fig. 1). The total population is estimated at least 750–1,044 individuals, with the highest numbers hosted by Iran (528–732), followed by Turkmenistan (60–80) (Ghoddousi & Khorozyan 2023). The global population of the Persian leopard is divided into four subpopulations, and none of them contains more than 250 mature individuals. Considering this, and an apparent trend of population decline, which cannot be reliably quantified, the Persian leopard was classified on the latest IUCN Red List of Threatened Species™ as "Endangered" (Ghoddousi & Khorozyan 2023).

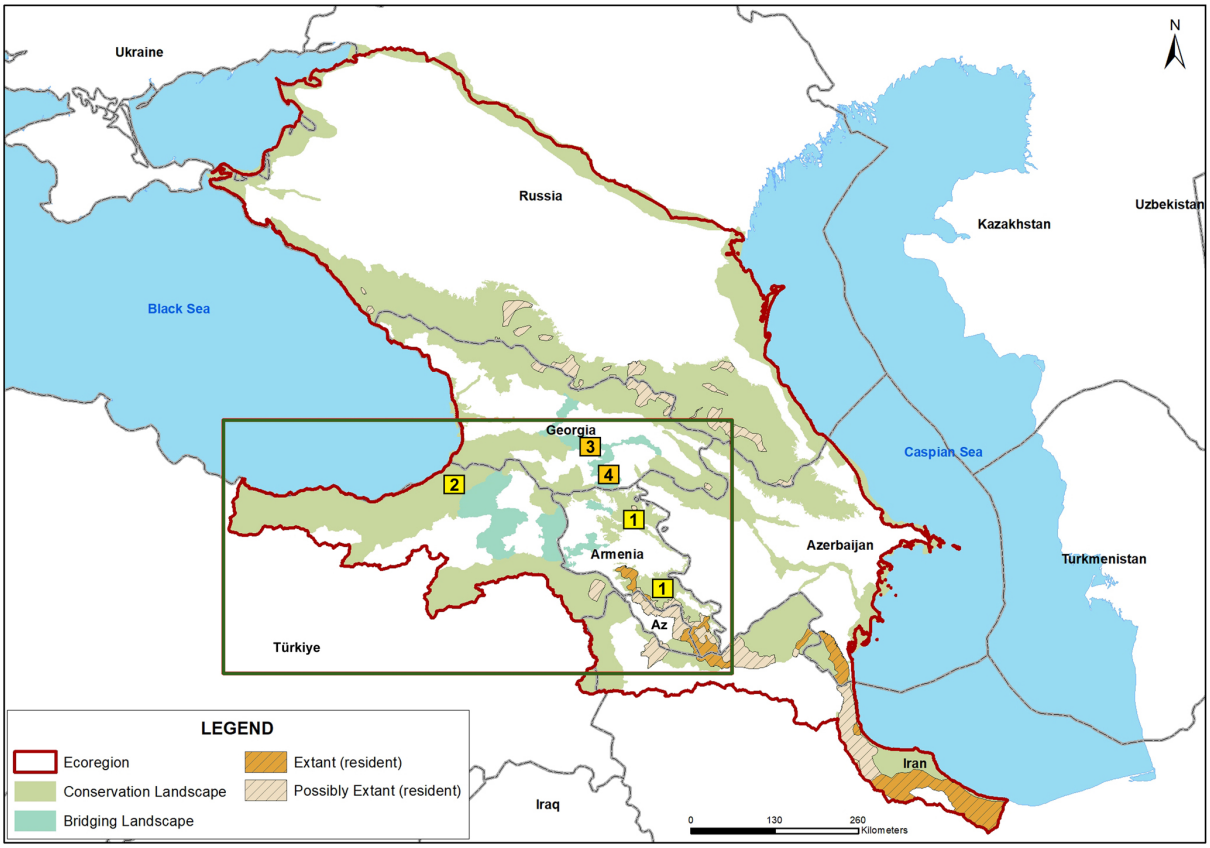


Fig. 2. Map of the Conservation Landscapes (1 – Eastern Lesser Caucasus, 2 – Western Lesser Caucasus), Bridging Landscapes (3 – Trialeti-Gombori, 4 – Algeti-Lori) and the Caucasus Ecoregion overlapping with the Persian leopard range. The Lesser Caucasus is shown in the rectangle. Only "Extant" and "Possibly extant" areas of the leopard range are included for reliability (Landscape maps from Zazanashvili et al. 2020; range map from Ghoddousi & Khorozyan 2023).

The southern part of the Lesser Caucasus Range (hereafter – Lesser Caucasus), shared by southern Armenia and south-western Azerbaijan (the exclave of Nakhchivan Republic), is part of the Persian leopard range where long-term conservation efforts have led to a well-documented increase in leopard numbers (Khorozyan et al. 2022). Since 2002, these efforts have consistently been led by the World Wide Fund for Nature (WWF) through its three implementing country offices in Armenia, Azerbaijan and Georgia, with support and funding

from its offices in Germany and Switzerland. The Lesser Caucasus belongs geographically to the Caucasus subpopulation and the Caucasus Ecoregion (Fig. 2). Leopard conservation and population monitoring have been implemented within the frameworks of the 10-year Strategy for the Conservation of the Leopard in the Caucasus Ecoregion (2007–2017, 2017–2027; Caucasus Leopard Working Group 2017) and its follow-up national Action Plans. The Ecoregional Conservation Plan for the Caucasus (Zazanashvili et al. 2020) and the Range-Wide Strategy for the Conservation of the Persian Leopard (2022) also provide a strong formal background for conservation actions. In parallel, small-scale efforts have been undertaken in Iran by the Department of Environment and several non-governmental organisations.

Although the Persian leopard population appears to be recovering in the Lesser Caucasus, there is no ground for complacency as leopard numbers are still too low to reach stability and viability. It is therefore critical that we learn from past experience, define current status, understand existing challenges, and formulate pathways for further actions that maintain and boost recovery. These are the main goals of this report.

This report is timely as the IUCN/SSC Cat Specialist Group and the Convention on Migratory Species (CMS) recently led the development of the Range-Wide Strategy for the Conservation of the Persian Leopard (2022), which was ratified by most of the range countries. The Persian Leopard Working Group (PeLeWG, https://pelewg.net) was established in March 2023 to support the range countries in implementing this Strategy. The outcomes of this report could therefore be used to improve the implementation of the Strategy. We also believe that this assessment provides useful guidelines for leopard conservation programmes and projects beyond Southwest Asia across the global leopard population in Asia and Africa.

This report consists of three main parts – **Status Review**, **Population Assessment**, and **Conclusions and Outlook**. The **Status Review** summarizes our general knowledge of Persian leopard ecology and status (historical and current), threats and challenges, prey resources, and the political and societal support of leopard conservation. The **Population Assessment** elucidates the Lesser Caucasus metapopulation as a network of core habitat patches interconnected by individual movements. We pay particular attention to patterns and differences between males and females because general analyses are male-biased due to the wide-ranging behaviour of males and the resulting dominance of males in data samples. It obscures the information about females, which is key to understand population vitality and viability. We also discuss functionality of core habitats as sources and sinks. We consider

transboundary movements of Persian leopards within the Lesser Caucasus – and between it and neighbouring areas – as a vital prerequisite for ensuring population connectivity and long-term viability at the regional scale. Finally, the **Conclusions and Outlook** provide a set of key lessons and recommendations for improving and adapting current leopard monitoring, research and conservation efforts in the region, and planning new activities for population recovery in compliance with the Range-Wide Strategy for the Conservation of the Persian Leopard (2022).

2. Status Review

Lesser Caucasus: description and structure

Geologically, the Lesser Caucasus is a system of mountain chains extending from north-eastern Türkiye and southern Georgia through most of Armenia and western Azerbaijan southward to Iran. It is ecologically connected with the Greater Caucasus Range by the Likhi Range in central Georgia and separated from it by the extended Colchic Lowland in western Georgia and the Kura-Arax Lowland in Azerbaijan. The Lesser Caucasus gradually transforms into the Anatolian Highland to the west, the Armenian Highland to the south, and the Karadagh (Qaradagh, Arasbaran) Range of the Iranian Highland to the south-east. The Lesser Caucasus can be considered broadly, with Mt. Aragats (4,090 m asl) as its highest peak, or narrowly as a single mountain chain, with its highest point on Mt. Gyamish (Gamiş, 3,724 m asl).

This report considers the boundaries of the Lesser Caucasus in their broadest context, reflecting the wide-ranging behaviour of Persian leopards, while remaining within their known range (Ghoddousi & Khorozyan 2023). We therefore delineate the Lesser Caucasus as inclusive of the "Extant" and "Possibly extant" polygons of the Persian leopard range, as assessed for the IUCN Red List of Threatened Species™ (Ghoddousi & Khorozyan 2023). This includes the Eastern Lesser Caucasus (Armenia, Azerbaijan) and the Western Lesser Caucasus (Georgia, Türkiye) Conservation Landscapes, and the Trialeti-Gombori and Algeti-Lori Bridging Landscapes (both in Georgia) (Zazanashvili et al. 2020). We do not consider this region in isolation and view it as a geographical entity naturally connected with neighbouring Conservation Landscapes and Bridging Landscapes. These two terms are defined by the 2020 Ecoregional Conservation Plan for the Caucasus (Zazanashvili et al. 2020) as follows: a Con-

servation Landscape is “a geographically defined large area, typically larger than 5,000 km^2, identified as a priority for conserving biodiversity and maintaining healthy ecological processes and environmental services”, and a Bridging Landscape is “a physico-geographical entity that physically connects the Conservation Landscapes”. The map of Conservation Landscapes and Bridging Landscapes is shown in Fig. 2.

Using this approach, we define the Lesser Caucasus as an area encompassing Armenia, western Azerbaijan (Nakhchivan Republic), southern Georgia and north-eastern Türkiye. The neighbouring countries and areas maintaining connectivity with the Lesser Caucasus include: a) Russia, northern Georgia and northern Azerbaijan (Greater Caucasus Range); b) south-eastern Azerbaijan (Talysh Range) and north-western Iran (Karadagh and Alborz Ranges); and c) the transboundary area of south-eastern Türkiye, north-eastern Iraq (Kurdistan Region) and western Iran sharing the Zagros Range (Fig. 2).

Status in the past

The leopard appeared in the Caucasus during the late Pliocene to the early Pleistocene (ca. 170,000–300,000 years ago) when the species migrated from Africa, its place of origin, to Asia through the Middle East (Uphyrkina et al. 2001). The northern boundary of the range lay in the Caucasus (Vereschagin 1959). Here, the Pleistocene-aged bones of leopards are known from South Ossetia and Azerbaijan (400,000–300,000 years ago), and the more recent Holocene fossils (10,000 BC) were excavated in the Russian Caucasus and Azerbaijan (Khorozyan & Abramov 2007). From the Stone and Bronze Ages (5,000–2,000 BC), the rock carvings of leopard hunting by prehistoric men were discovered in southern Armenia (Mezhlumyan 1985) and a leopard skull was found in north-western Azerbaijan (Gadjiev & Rakhmatulina 2000).

Phylogeographically, the Persian leopard population in the Lesser Caucasus and the Caucasus in general is an extension of the population in Iran, at least its north-western part. During the Pleistocene, the leopard migrated to the central parts of the Caucasus from the south (present-day Iran), along with the mouflon *Ovis gmelini* and the Indian crested porcupine *Hystrix indica*, and then dispersed over other suitable areas of the Caucasus (Vereschagin 1959). Therefore, the Lesser Caucasus population can be considered as the “crossroads” between Iran in the south, North Caucasus (Greater Caucasus Range in Georgia, Russia and

Azerbaijan) in the north and Türkiye in the west, securing the connectivity between these three spatial units. The leopard's status at regional scales was never studied in historical times, but major historical publications (Radde 1899, Dinnik 1914, Ognev 1935, Vereschagin 1959, Heptner & Sludsky 1972) describe the leopard as an extremely rare and secretive, but widespread, carnivore whose most reliable records used to come almost exclusively from hunting reports.

Before the late 1930s, it was the norm to conduct most intensive field surveys in areas where socio-economic interests were at stake, and particularly where natural resources were explored. Such areas included the Russian Caucasus and Georgia which were the outposts of the Russian Empire in the Caucasus, and eastern Azerbaijan that retained one of the main oil reserves. Armenia remained an undeveloped rural part of the Russian Empire and later the Soviet Union, resulting in leopard records in this country appearing only in the late 1930s before World War II (Khorozyan & Abramov 2007). Consequently, historical information about leopard distribution in the Caucasus is spatially biased towards the areas with higher human densities where higher leopard hunting and encounter rates made recording leopards more likely, and is therefore not related to leopard numbers themselves (Khorozyan & Abramov 2007). Despite this, we believe that this information is sufficiently reliable to indicate general trends and patterns of leopard distribution and status in the Caucasus, particularly in the Lesser Caucasus.

Leopard hunting in the Russian Caucasus, primarily in its western part, was rampant in 1880–1910 due to royal hunts. It accelerated a local extinction that could not be reversed, even by the establishment of Caucasian Reserve in 1924; however, some individuals survived in neighbouring areas along the Black Sea coast until the mid-1950s (Khorozyan & Abramov 2007). Leopard hunting rates soared from the 1920s to the mid-1970s all over the Caucasus when the Soviet Union (then a single country made up of Armenia, Azerbaijan, Georgia and Russia, *inter alia*) prioritised the recovery of the national economy after World Wars I and II, and the government incentivised people to kill carnivores and keep their populations down (Khorozyan & Abramov 2007). Even influential scientists (Radde 1899, Dinnik 1914, Ognev 1935, Vereschagin 1959, Heptner & Sludsky 1972) tended to support hunters indirectly by considering leopards and other carnivores as "vermin" rather than targets for conservation. The state paid bounties for delivering the furs of large carnivores (grey wolf *Canis lupus*, brown bear *Ursus arctos*, Eurasian lynx *Lynx lynx*, leopard) and small carnivores (red fox *Vul-*

pes vulpes, golden jackal *C. aureus*, jungle cat *Felis chaus*, European wildcat *F. silvestris*, Afro-Asiatic wildcat *F. lybica*, mustelids) to state-operated skin collection and purveyance centres. Scientific research was focused mostly on distribution mapping and its changes over time, often using such skin delivery records as the data source. It was a common practice to falsely consider the numbers of delivered skins to be directly proportional to species population sizes. Some information was incorrect, e.g. showing the northward expansion and growth of the leopard population in Armenia in 1958–1971 based on increasing numbers of leopard skins delivered (54 in 1967–1971 vs. 12 in 1958–1966, including 25 vs. 5 from the north; Gasparyan & Aghajanyan 1974). A later publication, however, admitted a misidentification of lynx skins as leopard ones, and reported that only 23 leopard skins were delivered during 1949–1978 (Aghajanyan 1986).

Although the 1970s marked the years when the Persian leopard was granted full official protection in the Caucasus countries, illegal hunting continued and its scale was underestimated because hunters stayed quiet to avoid official fines (Khorozyan & Abramov 2007). Such hunting cases were extremely rare, indicating a collapse of the leopard population in the Caucasus that nullified its viability and ecological functionality.

In the early 2000s, expert assessments indicated that the total number of Persian leopards could not exceed 30–65 mature individuals over the entire Caucasus Ecoregion of >580,000 km^2 (Lukarevsky et al. 2004, Khorozyan et al. 2005, Lukarevsky et al. 2007a). The leopard population in north-western Iran, the only region with confirmed reproduction during the 2010s, was expected to support leopard presence in neighbouring countries (Khorozyan & Abramov 2007, Lukarevsky et al. 2007a, Breitenmoser et al. 2010, Farhadinia et al. 2015a). This information was based on surveys of leopard signs (mostly faeces and tracks) and the analysis of anthropogenic mortality records, which could only be used to confirm leopard presence sporadically but said nothing about the distribution, numbers and status. Even areas of leopard absence remained obscure because surveys were designed opportunistically, and records of mortality sites are intrinsically biased towards certain areas which are more visited and better known. No systematically planned work existed. Even the first applications of camera-traps in the Caucasus, which produced the first-ever images of leopards in Georgia (2004), Armenia (2005, 2007) and Azerbaijan (2007) (Lortkipanidze et al. 2004, Khorozyan & Abramov 2007, Lukarevsky et al. 2007b) did not transform presence-absence surveys into more sophisticated research, but played a huge role in awareness and

fundraising for the present-day WWF Caucasus Leopard Conservation Programme. The application of occupancy and presence-absence modelling to sign surveys was the main approach, enabling the mapping of the leopard range, the description of its priority conservation areas, and the identification of the key determinants of leopard presence (Gavashelishvili & Lukarevskiy 2008, Khorozyan et al. 2010).

Iran had always been considered as the main source population for the Caucasus. However, Moqanaki et al. (2013) did not record fresh leopard signs using faecal DNA analysis, and their interviews suggested very little reliable proof of leopard presence in the majority of Iranian sites along the Iran-Azerbaijan-Armenia border. It implies that, in the mid-2000s, the Iranian Caucasus had unfavourable conditions for leopard existence, and it was unlikely that the assumed source population from north-western Iran would be able to support the natural recolonisation of the Caucasus. Since 2012, no leopards have been confirmed in Kantal National Park, which used to host the largest detected population of Persian leopards in north-western Iran (R. Masoud, pers. comm.). However, there were regular observations of Persian leopards in the two recently gazetted Agh Dagh and Kaghaz Konan Protected Areas, both of which are located at least 100 km away from the Iran-Azerbaijan border. In contrast, no records of leopard presence have been confirmed from the borderline protected areas of Iran since 2012.

This overview of the historical status of the leopard in the Caucasus, including the Lesser Caucasus, provides some insight into a possible bottleneck effect that this big cat faced during the 20th century due to intense human persecution. Local extinctions and the disruption of connectivity between ever-diminishing populations, especially between the Greater Caucasus Range and the Lesser Caucasus Range, could serve as a strong impetus for genetic deterioration and even inbreeding depression. These aspects deserve in-depth research using a comparison of historical and contemporary materials from the Caucasus.

Current status and ecology

The Persian leopard is one of the rarest mammals of the Lesser Caucasus, but acts as a flagship taxon symbolising biodiversity conservation, fundraising and awareness building in the region (Askerov et al. 2020). Due to its natural beauty, position atop the food chain, elusive nature and wide-ranging behaviour, it also serves as an umbrella for biodiversity and a

pillar for conservation at large landscape scales (Range-Wide Strategy for the Conservation of the Persian Leopard 2022). Despite these traits, local people may perceive leopards as a threat to domestic animals and humans, or as valuable trophies fetching money and prestige (Rosen & Mengüllüoğlu 2022, Soofi et al. 2022). Human pressures, direct and indirect, threaten Persian leopard existence and keep its population at a low level in the Lesser Caucasus. Threats are considered in more detail below.

As of 2022, the total population size of Persian leopards in the Caucasus Ecoregion was estimated as 60–97 adult individuals including 40–57 in the Iranian Caucasus, minimum 6–17 in Azerbaijan (including 3–11 in Nakhchivan and 3–6 in Talysh), minimum 3–9 in Armenia, 11 reintroduced and two wild leopards in the Russian Caucasus, two in eastern Türkiye and one in Georgia (Khorozyan et al. 2022, Ghoddousi & Khorozyan 2023). The number in the Iranian Caucasus was inferred from a strong linear relationship between the numbers of reliable records and the estimated numbers of individuals in other parts of the Persian leopard range. Evidence shows that this number is an overestimate (Moqanaki et al. 2013, R. Masoud, pers. comm.), and more field surveys, primarily camera-trapping, are required to assess the current leopard status in the Iranian Caucasus. According to these data, the Lesser Caucasus population consists of a minimum of 6–20 adult individuals recorded in Armenia and Nakhchivan. There is no reliable pre-2000 baseline number of adult individuals from the Caucasus Ecoregion and the Lesser Caucasus to compare these estimates with.

The main prey of the Persian leopard in the Lesser Caucasus is the bezoar goat *Capra aegagrus* (Khorozyan et al. 2022), followed by wild boar *Sus scrofa* and European roe deer *Capreolus capreolus*. The staple prey base of this predator consists of medium to large ungulates. Locally, the leopard's diet can be supplemented by the mouflon in the south of the Lesser Caucasus (southern Armenia, Nakhchivan), northern chamois *Rupicapra rupicapra* in the west (Georgia, Türkiye), and the red deer *Cervus elaphus* in the west and east (Georgia, Azerbaijan) (Weinberg et al. 2020). However, the last three species are unlikely to play a major role in the leopard diet due to their rarity (all of them), large body size and seasonal availability of suitable juveniles (red deer), and at least partial habitat separation from leopards (chamois, mouflon). Leopards also kill small prey, including the Indian crested porcupine, European hare *Lepus europaeus* (Khorozyan & Malkhasyan 2002, Khorozyan et al. 2008), badgers *Meles meles* and *M. canescens*, European wildcat, golden jackal, red fox and raccoon dog *Nyctereutes procyonoides* (Rozhnov et al. 2019, Pkhitikov et al. 2021, Weinberg et

al. 2021a). Apparently, leopards tend to kill small prey more frequently in areas with lower densities of large ungulate prey (Trepet et al. 2022) or high densities of competitors, but individual preferences are also possible. Leopard predation on domestic animals and dogs is extremely rare in the Lesser Caucasus.

Generally, leopards live in habitats rich in prey, but certain patterns unrelated to prey are also noticeable. In the Lesser Caucasus, these big cats prefer woodlands and arid grasslands with rocky outcrops and precipitous cliffs where the bezoar goat lives, and where there are numerous secluded places for hunting from ambush, resting and cub rearing (Khorozyan et al. 2022, Rosen and Mengüllüoğlu 2022). These difficult-to-access habitats are also least affected by humans and livestock. As leopards have high paw pressure and cannot successfully hunt and move in deep snow (Pikunov & Korkishko 1992), snow cover is an important limiting factor for leopards in the Lesser Caucasus. Leopards tend to reduce their movements in deep snow or move to areas with less snow (Trepet et al. 2022). This may be a reason why leopards prefer southern slopes at low to middle elevations, and stay on northern slopes only during snow-free seasons (Gavashelishvili & Lukarevskiy 2008, Khorozyan et al. 2010, Khorozyan et al. 2022).

Major threats

The survival of Persian leopards in the Lesser Caucasus faces the following threats (Khorozyan et al. 2022, Rosen & Mengüllüoğlu 2022):

- Fragmentation and loss of suitable habitats due to human activities
- Political instability, which reached its peak during the armed conflict between Armenia and Azerbaijan
- Prey depletion and limited number of wild ungulate prey species (richness) in some areas
- Illegal killing

Some other threats may also exist in neighbouring populations, e.g. changes in the distribution of pathogens due to global climate change (Naidenko et al. 2021).

***Fragmentation and loss of suitable habitats*.** Socio-economic activities – especially agriculture, mining and tourism – encroach on large areas of suitable habitats, increase human densities and presence, and create linear barriers such as roads and fences. Although leopards in general, and Persian leopards in particular, can tolerate human infrastructure and coexist with humans by separation in space use and time (i.e. crepuscular and nocturnal activity), they mainly try to avoid human-dominated areas (Chistopolova et al. 2021). At the same time, the leopard's wide-ranging behaviour involves exploring large tracts of natural habitats, which are shrinking and becoming increasingly isolated (Gavashelishvili & Lukarevskiy 2008, Khorozyan et al. 2010, Bleyhl et al. 2022). Persian leopards may suffer from high mortality on some high-traffic highways bisecting local populations, such as in eastern Iran (Safaei et al. 2012, Kazemi et al. 2016), but they frequently use dirt or even asphalted roads if their traffic intensity is low (Fig. 3). Barbed-wire border fences can limit leopard movements in some areas, e.g. the Iran-Turkmenistan border (Farhadinia et al. 2021a), but also can be crossed or jumped over elsewhere, e.g. on the Armenia-Iran border. The Armenia-Iran border is electrified, but it does not kill or shock – instead, it sends signals to the control unit indicating that somebody touched the fence, and border guards come immediately to inspect the site.



Fig. 3. A leopard spotted on 26 April 2024 on the road near Karchevan village in southern Armenia (Photo by a local villager, shared by A. Samvelyan).

As leopards move over long distances, the lack of habitat connectivity is a serious obstacle for population viability in the Lesser Caucasus. This impediment is applicable not only to widely roaming males that dominate the Caucasus leopard population, but also to spatially clustered females.

***Political instability*.** The armed conflict between Armenia and Azerbaijan, which has lasted since the breakdown of the Soviet Union in 1991 until 2023 and continues to smoulder, poses an imminent threat to leopard survival, both directly and indirectly. A direct

threat is the use of landmines along the Armenia-Nakhchivan border, which may kill or maim leopards (Fig. 4), and firearms that can be used for killing leopards and their prey. Camera-traps have recorded leopards that were likely maimed due to the conflict, and they appeared in good physical shape, implying that at least some are able to survive and hunt successfully. There is a unique series of images showing a maimed leopard succeeding to hunt bezoar goats from ambush in southern Armenia. However, records of such individuals usually taper off after 1–2 years of camera-trapping, which may suggest (but not confirm) their death or replacement by stronger, younger individuals moving in from outside the camera-trapped areas. Other leopards may be killed by landmines immediately and without our knowledge, thus increasing the uncertainty in leopard survival in the Lesser Caucasus. Mine clearance is an essential measure to be taken across the war-struck area. An indirect effect of the conflict is the intensive construction of bypass roads and other infrastructure away from the border, which may not limit leopard movements (and dirt roads and some asphalted roads with low traffic may even facilitate it; see above), but make leopard habitats more accessible to humans.



Fig. 4. Leopards with their legs partially amputated by landmines (Photos by WWF Armenia and WWF Azerbaijan).

Prey depletion and limited prey richness. In some areas, a depleted prey base also poses a threat to leopards. This is not only related to low abundance of prey, but also to the limited number of ungulate species available. As described in more detail below in "*Prey resources: status and trends*", the bezoar goat is the leopard's staple prey in the Lesser Caucasus and is currently recovering due to conservation efforts. In Khosrov Reserve of Armenia, this species makes up about 90% of the leopard diet, in part because roe deer are absent here and the availability of wild boars can be seasonally variable (Khorozyan & Malkhasyan 2002). Also, wild boar numbers can fluctuate widely due to diseases, as shown below, which

may aggravate the pressure of predation on bezoar goats and even potentially instigate livestock killing and human-leopard conflict.

Illegal killing. The rates of leopard poaching are very low in the Lesser Caucasus due to the visibility of WWF and other conservation projects, stringent punishment for leopard killing (Farhadinia et al. 2021a; see below in "*Political and societal support of leopard conservation"*), and very rare cases of damage to livestock and other domestic animals or attacks on humans. We recorded three documented cases of leopard killings in Armenia in 2002–2021, none in Nakhchivan in 2013–2021, and one in Georgia in 2003–2021 (Khorozyan et al. 2022). Only one case of presumed natural mortality was recorded in Nakhchivan in May 2021, and was most likely caused by heavy snowfall.

However, poaching rates are higher in the Talysh Range of south-eastern Azerbaijan (Spassov et al. 2019) where leopards regularly kill cattle that graze freely in the dense Hyrcanian Forest (six leopards killed in 2002–2021; Khorozyan et al. 2022). In February 2014, an adult leopard was killed in the Chubar Highlands of Gilan Province, north-western Iran, approximately 30 km away from Hirkan National Park, the main protected area of the Talysh (Maharramova et al. 2018). The most recent case in the Talysh occurred back in 2015, which may reflect a positive impact of public awareness raised by the WWF Caucasus Leopard Conservation Programme. Retaliatory or preventive illegal killing of leopards is widespread in the Hyrcanian Forest of Iran where cattle grazing in leopard habitats is a common practice, and prey density is low and patchy (Babrgir et al. 2017, Khorozyan et al. 2018, Soofi et al. 2018).

Human-leopard conflicts are expected to increase over time as the leopard population in the Lesser Caucasus recovers and expands. We therefore need to be well-prepared to identify potential conflict sites, map and describe conflict hotspots, and plan conflict mitigation measures in cooperation with governments, conservation organisations, and local stakeholders before such conflicts become commonplace (Soofi et al. 2022). A comprehensive programme of education and awareness-raising must be a fundamental part of promoting human-leopard coexistence. Potential mitigation measures, such as protective collars, shepherds, guarding dogs and compensation schemes, can be tested in the conflict-prone Talysh Range first and then, if successful, replicated in the Lesser Caucasus.

Lack of females: "cherchez la femme" in action

A majority of the Persian leopard population in the Lesser Caucasus consists of males, which are capable of long-distance dispersal and can reach distant, even unsuitable, places. In contrast, females are detected only in southern Nakhchivan and southern Armenia on both sides of the transboundary Zangezur Range and its branches, as shown by camera-trap pictures and videos of females. These are fewer than those of males and strongly clustered in space (Khorozyan et al. 2022; Fig. 5). Outside Nakhchivan, there are a few more recent records of females in southern Armenia. First, a female named BURLA crossed the Zangezur Range to its eastern side in southern Armenia with two cubs and was photographed in Zangezur Sanctuary by a local driver in November 2021 (Khorozyan et al. 2022). Then, in April–November 2024, BURLA's dispersing daughter MISTY was camera-trapped twice on the Meghri Range, in Arevik National Park in the extreme south of Armenia, at a nearly 30 km straight distance from the Nakhchivan border. And, lastly, MISTY with a cub was camera-trapped in Arevik National Park in November 2024 and January 2025. This provides strong evidence of the recent beginning of female dispersal out of Nakhchivan.

Outside Nakhchivan and southern Armenia, female leopards are currently present only in the four areas adjoining the Lesser Caucasus: (1) the central part of the Russian Greater Caucasus (among the reintroduced leopards only); (2) the Talysh Range in south-eastern Azerbaijan; (3) Iraqi Kurdistan; and (4) the western Alborz and Zagros Ranges in Iran (Ghoddousi et al. 2022, Khorozyan et al. 2022). No females have been identified among the wild-born leopards in the Greater Caucasus, as well as in the Turkish Lesser Caucasus. There is no current information about the exact locations of females reintroduced in the Greater Caucasus, but from seven females released here in 2016–2023, only two were confirmed dead, while there are signs of survival of four other females and no data on another one. According to telemetry data, they survived the first post-release year and demonstrated success in hunting and avoidance of human infrastructure (Rozhnov et al. 2022). Two females released in 2018 and 2022 were recorded in March 2024 in the Republic of Kabardino-Balkaria, with one observed likely to be in oestrus (https://sev-in.ru/node/3692).

The absence of females among detected leopards in the Lesser Caucasus outside Nakhchivan and southern Armenia can be explained by their behaviour. Female leopards select safe habitats with sufficient prey resources and dense cover optimal for raising cubs and

protecting them from males and competitors (Parker et al. 2023, Khorozyan 2025). The habitats of Nakhchivan are supposed to be the most suitable for females, leading them to stay and not move away to resettle other areas. However, populations of bezoar goats and other ungulate prey are abundant in many areas outside Nakhchivan where female leopards are not found. Also, female leopards and other felids are well-known for their philopatry, i.e. a tendency to stay in the vicinity of the mother's home range (de Oliveira et al. 2022). Given that Nakhchivan was the first location where female leopards were detected across the Lesser Caucasus, we assume that it harboured the first reproduction of leopards across the region. Therefore, female offspring follow the philopatric pattern and tend to stay closer to their natal area. On the other hand, recent camera-trap captures of females in southern Armenia suggest that the female density in Nakhchivan has stabilized and females have to move out to establish their home ranges. Fattebert et al. (2015) found that a leopard population recovering from over-harvest demonstrated an inverse density-dependence of female dispersal distance, i.e. females dispersed over longer distances when population density decreased, and vice versa. We believe that philopatry can explain the limited occurrence of female leopards outside Nakhchivan and southern Armenia.

As of 2025, there were six females camera-trapped in the Lesser Caucasus: four adults (named KILID, BANU, RUMUS and GAMZA) and one sub-adult in Nakhchivan, and one adult (MISTY) in southern Armenia. KILID was documented to breed as of spring 2024. The first mating footage of her was obtained in December 2022, followed by footage in September 2023 showing her with two cubs. A young female, most likely one of these two cubs of KILID's, was recorded in May 2024. BURLA was a "super-mom of the Caucasus" who gave birth to six cubs across three litters over four years (Fig. 6), and was last camera-trapped in September 2022, possibly indicating that she died. The grown-up daughters of BURLA have been camera-trapped multiple times since then. One of them, MISTY (born in 2021), moved to Armenia and was camera-trapped alone in April-November 2024 and with a cub in November 2024 and January 2025 on the Meghri Range in the extreme south of Armenia. RUMUS, also born in 2021, is another daughter of BURLA. BANU was camera-trapped with a male, and was recently recorded with three cubs.

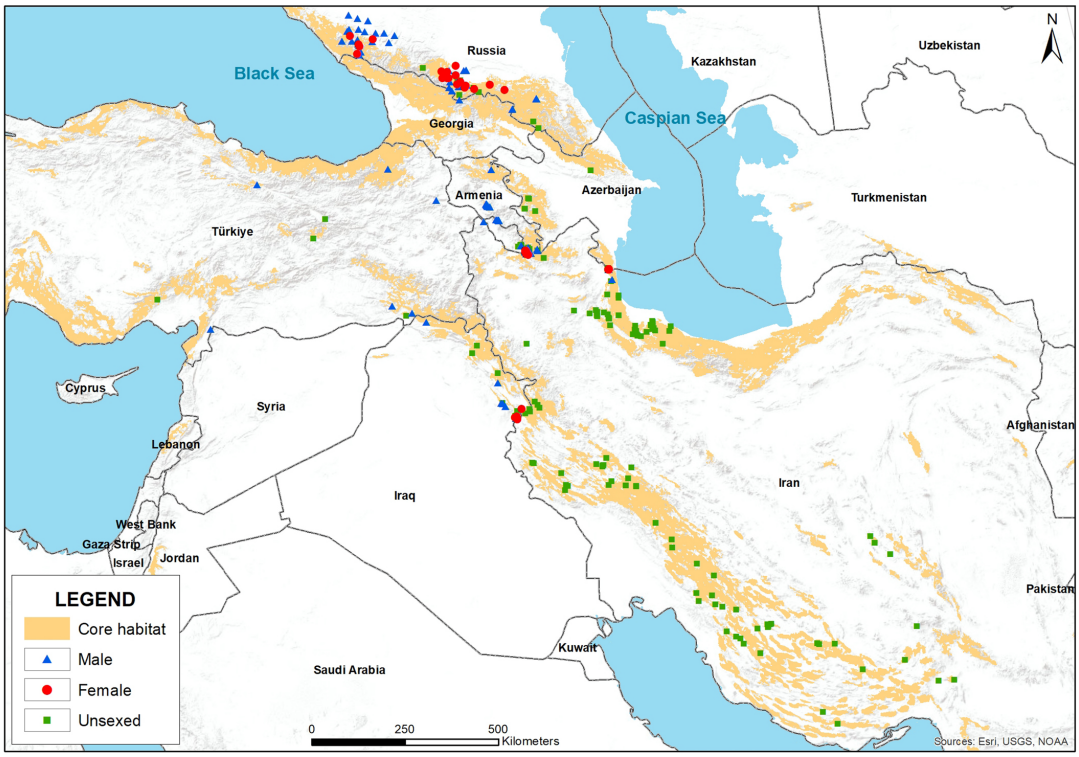


Fig. 5. The distribution of sexed (n = 278 for males and n = 107 for females) and unsexed (n = 462) wild and reintroduced Persian leopard records from our database (category C1 – hard facts, 2010-2023) over core habitat patches (Habitat map from Bleyhl et al. 2022).



Fig. 6. BURLA the "super-mom" female with three cubs in southern Nakhchivan (Photo by WWF Azerbaijan).

Prey resources: status and trends

As the leopard's main prey (Table 1) in the Lesser Caucasus is the bezoar goat, the information on abundance and densities of this ungulate species is of paramount importance to defining and applying targeted actions to secure a plentiful prey base for the recovery and viability of the leopard population in the region. The monitoring and surveys of the bezoar

goat are included in the Caucasus ecoregional leopard conservation strategies, national leopard Action Plans, and the Range-Wide Strategy for the Conservation of the Persian Leopard (2022), hence its population assessments are more detailed and frequent than those for other ungulate prey species.

Table 1. Information on abundance and local densities of the leopard's main prey species in the Lesser Caucasus parts of Armenia, western Azerbaijan (Nakhchivan), southern Georgia and north-eastern Türkiye in 2000–2020. See text for more details. "NA" stands for not available, and "–" means the absence of the species.

Species	Armenia	Nakhchivan	Georgia	Türkiye
Bezoar goat	≥ 2,500 12.9 ind/km^2	≥ 1,200 4.5–13 ind/km^2	Occasional visits from Türkiye	NA
Wild boar	6.9 ind/km^2	NA	NA	NA
Roe deer	0.4 ind/km^2	NA	NA	NA
Red deer	few individuals	< 125	≤ 650	NA
Mouflon	200–250 0.8 ind/km^2	≥ 400 3–3.6 ind/km^2	–	–
Chamois	–	–	500–600	–

In the Lesser Caucasus, the current distribution of bezoar goats is confined to the precipitous and rocky mountains of southern Armenia, Nakhchivan Republic and the western part of "mainland" Azerbaijan (Shahdagh and Murovdagh Ranges, Karabagh Highland), and the Kaçkar Range in north-eastern Türkiye (Gadjiev & Rakhmatulina 2000, Khorozyan et al. 2009, Talibov et al. 2009, Weinberg et al. 2020, Weinberg et al. 2021b). The numbers were estimated as at least 1,200 individuals in Nakhchivan, mostly in Zangezur National Park and Ordubad Sanctuary, and no less than 2,500 in southern Armenia (Weinberg et al. 2020). Earlier estimates were lower, such as 1,000 in Nakhchivan and up to 1,500 in Armenia (Khorozyan et al. 2009, Talibov et al. 2009). The densities were 10–13 individuals/km^2 in the Zangezur and Negramdagh Ranges, and 4.5 individuals/km^2 in Darydagh, all in southern Nakhchivan, and were apparently lower in the northern parts (Weinberg et al. 2021b). In Armenia, the density was estimated as 12.9 individuals/km^2 in the Meghri Range (Khorozyan et al. 2008). These densities should not be extrapolated at larger scales, such as country-wide, because they were estimated in predefined high-density areas and upscaling would produce an over-

estimate. There is a consensus that bezoar goat populations in southern Armenia and Nakhchivan increased as a result of long-term conservation efforts such as WWF activities and other projects in both countries, as well as due to the hunting ban in Nakhchivan imposed in 2001 (Weinberg et al. 2021b, Khorozyan et al. 2022). Bezoar goat numbers and densities in north-eastern Türkiye are unknown (Weinberg et al. 2020).

The wild boar is the second most important prey for leopards in the region, after the bezoar goat (Lukarevsky et al. 2007b, Khorozyan et al. 2022). It has been considered a common species not in need of conservation actions. For this reason, information about its status is limited throughout the Lesser Caucasus (Weinberg et al. 2020). In the Meghri Range, wild boar density was estimated as 6.9 individuals/km^2 (Khorozyan et al. 2008). In Georgia and Armenia, where pig farming is common, wild boar populations are sometimes decimated by African swine fever transmitted by domestic pigs, making some key protected areas in the forests of Armenia experience strong population declines (Khorozyan et al. 2022). Such depressions in wild boar abundance may put additional pressure on leopards, and possibly also wolves. These predators may increase predation on bezoar goats or even intensify attacks on livestock and thus provoke human-leopard conflicts and retaliatory killing. Concurrent spatio-temporal trends in wild boar dynamics and changes in wild boar contribution to leopard diets, and the ability of wild boar populations to recover from swine fever outbreaks, require in-depth research.

Like the wild boar, the roe deer is a common species not prioritised in research (Weinberg et al. 2020). Its density in the Meghri Range was estimated as 0.4 individuals/km^2 (Khorozyan et al. 2008). Roe deer distribution should be the focus of studies, particularly to understand the reasons for its absence in Khosrov Reserve and local rarity in some other places.

The mouflon is primarily distributed in Iran. In the Lesser Caucasus, its range is limited to a narrow strip along the Armenia-Nakhchivan state border from the Iranian border in the south northwards to the Urts Range. The population is possibly split into two disjunct populations (Weinberg et al. 2020). In contrast to other ungulates, mouflons live on smooth slopes covered by open meadows and grasslands, and are therefore strongly and negatively affected by overgrazing (especially by domestic sheep) and poaching (Bleyhl et al. 2019). The population in Armenia is about 200–250 individuals with a decreasing trend, and in Na-

khchivan at least 400 and increasing (Khorozyan et al. 2009, Weinberg et al. 2020). Specifically, the Nakhchivan population consists of 150 individuals in the Negramdagh Range (density 3.0 individuals/km^2) and up to 120 in the Darydagh (3.6 individuals/km^2) (Weinberg et al. 2021b). In Armenia, the density is only 0.8 individuals/km^2 in the area of junction between the Zangezur and Bargushat Ranges, and further decreases in winter when mouflons move to the warmer Nakhchivan side (Khorozyan et al. 2009). Higher mouflon numbers in Nakhchivan are the result of conservation efforts, as well as much wider areas of suitable hilly habitats with warmer climate than on the Armenian side, which is rugged and colder.

In the Lesser Caucasus, the northern chamois is present only in the Adjara-Imereti Range where its numbers are estimated as 500–600 individuals (Weinberg et al. 2020). Red deer went extinct in the Lesser Caucasus of Azerbaijan by the end of the 19th century, but its reintroduction in the 1960s resulted in a population of up to 125 individuals in Goygol Reserve, which then slumped in the 1990s due to the armed conflict between Armenia and Azerbaijan. An isolated population of up to 650 red deer survives in Borjomi-Kharagauli Protected Areas in the Georgian part of the Lesser Caucasus (Weinberg et al. 2020). The red deer reintroduction project is underway in Dilijan National Park of north-eastern Armenia.

Although some information about prey numbers and densities is available from the Lesser Caucasus (Table 1), there is no knowledge of how much prey is essential to secure leopard viability in the region.

The leopard's diet in the Lesser Caucasus was studied only in Khosrov Reserve of Armenia (Khorozyan & Malkhasyan 2002), and research on how leopard prey preferences change over space and time in the region in relation to changing prey availability is an imperative. For example, we need to understand how leopards change their diets when wild boars become rare due to diseases or other causes, or how leopards diversify their diets in areas where prey resources are dominated by bezoar goats.

Political and societal support of leopard conservation

Rarity and imminent vulnerability to extinction have led to the Persian leopard being officially protected in all the range countries of Southwest Asia. In the Caucasus, it is categorised as "Critically Endangered" in Armenia, Azerbaijan's Nakhchivan Republic, Georgia and Russia (Red Data Book of the Republic of Nakhchivan 2006, Red List of Georgia 2006, Khoro-

zyan 2010, Red Data Book of the Russian Federation 2021), “Endangered” in Iran and some republics of the Russian Caucasus (Yarovenko 2009, Karami et al. 2012), “Near Threatened” in Azerbaijan (Askerov 2013), and “Strictly Protected” in Türkiye (D. Mengüllüoğlu, pers. comm.). Illegal leopard killing in these countries is punishable by heavy fines and imprisonment (Farhadinia et al. 2021a, Farhadinia et al. 2022a).

The general public in the Lesser Caucasus countries is aware and supportive of leopard conservation, with fundraising and awareness-raising campaigns commonly receiving wide coverage in mass media (e.g., 2024/2025 Christmas and New Year campaigns and the currently running campaigns of WWF Armenia, see https://www.facebook.com/wwfarmenia/posts). Local rural people are also generally positive and supportive due to high visibility of WWF conservation projects on the ground and their close cooperation with local stakeholders. This may also explain why information about leopard killings has not generally been posted on social media, and particularly on Facebook which is the most popular platform in the region.

However, we believe that one of the main reasons for such support of leopard conservation is the lack of conflicts related to livestock losses or fear caused by leopards. Leopard attacks on domestic livestock and pets are very rare and random in the Lesser Caucasus, which may be related to low numbers of leopards and/or sufficiency of their wild prey base. Attacks on humans are extremely rare, particularly in comparison with attacks by wolves and even more so brown bears, but further research is required to get reliable quantitative data on such attacks.

The issue of human-leopard conflict is expected to emerge as the leopard population recovers and individuals, especially males, become more likely to clash with people in rural environments such as village outskirts and pasture lands. It is therefore essential to anticipate this and incorporate mitigation strategies into all leopard conservation projects in the Lesser Caucasus.

3. Population Assessment

3.1. Metapopulation structure

3.1.1. Introduction

The threats described above fragment the Persian leopard population into separate clusters. Linear barriers, especially high-traffic roads, as well as intensive land use and occasional illegal killing, lead to population fragmentation at landscape levels, significantly hampering connectivity between clusters. Reduced connectivity is more alarming for females which are less mobile than males (see above). Given the small size of leopard population in the Caucasus, and in the Lesser Caucasus in particular, each cluster may consist of only one or a few individuals, making them extremely vulnerable to illegal killing. Removal of just one primary breeder can disrupt and dissolve the whole cluster. Therefore, it is reasonable and practical to consider the Persian leopard population in the Lesser Caucasus as a "metapopulation", i.e. a network of connected clusters (subpopulations) that act as either sources or sinks (Fattebert et al. 2013, Dolrenry et al. 2014). Metapopulation analysis is beneficial because it (1) considers the dynamics of clusters and their connectivity, especially in wide-ranging species such as carnivores, and (2) has strong implications for biodiversity and habitat conservation at large landscape levels. However, since local clusters consist only of individuals and not true subpopulations, the Lesser Caucasus metapopulation should be considered in the context of landscape-scale fragmentation rather than as a cohesive population.

3.1.2. Methods

To assess the Persian leopard metapopulation structure in the Lesser Caucasus, we collated the most reliable georeferenced records from the region from 2010 until the end of 2023. We used only the most reliable records belonging to category C1 (hard facts; Molinari-Jobin et al. 2012), which include undeniable and verifiable information such as camera-trap images/videos and photographs (Bleyhl et al. 2022). Our database included C1 records from the latest range-wide status assessment of populations in the Caucasus Ecoregion (Khorozyan et al. 2022) and the western range (Ghoddousi et al. 2022), and was updated by incorporating the newest records. The data from the South Caucasus (Armenia, Azerbaijan, Georgia) were represented mostly by camera-trap records compiled by the WWF Caucasus Programme Office in cooperation with Humboldt University of Berlin in open-source Camelot v.

1.6.16 (Pötzschner 2024). Other reliable evidence, such as photographs taken by local people on their mobile phones, was also included. Data on leopards reintroduced in the Russian Greater Caucasus were a sub-sample posted on the portal "Mammals of Russia" (https://rusmam.ru/atlas/map). We analysed only independent captures, defined as those from different locations, of different individuals recognised from spot patterns, or taken at the same location but more than 20 minutes apart (Ghoddousi et al. 2023). The Russian data were considered independent if they came from different locations and dates.

We plotted records of all leopards including males, females and unsexed individuals (Fig. 5), and separately recognised individuals, on GIS maps and overlaid them with shapefiles of core habitats and suitable habitats mapped by Bleyhl et al. (2022) at a 1-km resolution. Individuals were recognised based on unique spot patterns on either flank and sex-specific characteristics. Core habitats are defined as "continuous cells with a habitat suitability above the 25th percentile of values at our presence locations…. and a cumulative area of at least 250 km^2 (i.e. the minimum area for breeding populations in Iran…)" (Bleyhl et al. 2022). We drew potential corridors as the vectors stretching through the cells with Habitat Suitability Index (HSI) > 0.7 (Hirzel et al. 2001). This threshold is effective at predicting species presence vs. absence (Hirzel & Guisan 2002).

For the analysis, we used only records from spatially distinct locations (i.e. that originated from different places) to avoid biases caused by same-site repeated sampling (pseudoreplication). We used the chi-square (χ^2) test to compare frequencies of records in core vs. none-core habitats, and Mann-Whitney and Kruskal-Wallis tests to compare HSI between male, female and individual records at the conservative significance level of $p = 0.005$ (Benjamin et al. 2018). Standard error (SE) was a measure of estimate variation throughout the text. All mapping was done at WWF Armenia in ArcGIS 10.8.

3.1.3. Results and discussion

The data collected for this report (total n = 847) are described in Table 2. A majority of transboundary movements were recorded between Armenia and Nakhchivan (one male and one female) and between Armenia and Türkiye (two males). Elsewhere, records of individual movements across borders were very few (Talysh-Iranian Caucasus, Georgia-Russia) or none (Iraqi Kurdistan). However, we think that this was an indication of insufficient simultaneous

survey efforts on both sides of the borders, or correlated with the distance to the border, rather than a sign of actual limited movements (Table 2). This information provides ample space for future research of transboundary leopard movements at large scales in the Lesser Caucasus and its adjacent regions, with validation of independent leopard movement data obtained from GPS tracking of Persian leopards in north-east Iran (Farhadinia et al. 2018, Farhadinia et al. 2019) and the Russian Greater Caucasus (Rozhnov et al. 2020, Hernandez-Blanco et al. 2021, Trepet et al. 2022).

Table 2. Description of the sample of C1 records collected in 2010–2023 for this report. M and F denote males and females, respectively, and UNK is unknown sex. Arrows indicate transboundary movements between countries.

Country	Area	Total No. records	No. M records	No. F records	No. individuals recognised (shared by countries)
Armenia, AM	Lesser Caucasus	121	111	1	6 M, 1 F (1 M, 1 F ↔ AZ; 2 M ↔ TR)
Azerbaijan, AZ	Nakhchivan	438	98	70	2 M, 3 F (1 M, 1 F ↔ AM)
	Talysh	63	4	12	3 M, 2 F, 1 UNK (1 M ↔ IR)
	Other areas	4	0	0	0
Georgia, GE	Greater Caucasus	2	2	0	1 M (1 M ↔ RU)
Iran, IR	North-west (Caucasus)	46	1	0	1 M (1 M ↔ AZ)
	West (Zagros)	59	0	0	0
Iraq, IQ	Kurdistan	33	17	5	7 M, 2 F (0)
Russia, RU	Greater Caucasus	70	38	19	1 M, 2 F (1 M ↔ GE)
Türkiye, TR	East and south-east	11	7	0	2 M (2 M ↔ AM)
Total		**847**	**278**	**107**	**18 M, 9 F, 1 UNK**

The spatially distinct records were 129 for males and 56 for females. Female records were located much more frequently in core habitats (83.9%) than male records (69.0%), but this difference was insignificant ($\chi^2 = 4.474$, $p = 0.034$). HSI in male and female locations also

did not differ (Mann-Whitney U = 3184.5, p = 0.201). This result implies that the difference in male and female occurrence is more likely to be based on other factors than habitats and their suitability. However, the placement of camera-traps was not random but biased towards sites of higher detection probabilities, thus introducing uncertainty into our preliminary results. Incorporation of an array of relevant factors, especially those correlated with threats such as various human activities, is a recommended approach to understanding patterns and differences in distribution of male and female leopards in the region, preferably with the use of telemetry rather than bias-prone camera-trapping (see above). A comparison of grid cells with and without breeding females could be the first step. Including threat factors would be especially relevant for males (Khorozyan et al. 2022) because they roam widely, more frequently occur outside core habitats, have higher chances of encountering humans, and lead more nocturnal lives as an adaptation (see below in *"Temporal behavioural patterns"*).

Our database documented 28 individuals between 2010 and 2023 (18 males, 9 females, and 1 unsexed, Table 2), but only 17 (60.7%) of them (12 males, 5 females) had at least two spatially distinct recaptures, which would allow us to present their (transboundary) shortcut movements. The mean number of such recaptures per individual was 7.7 ± 2.1 for males (range 2–22) and 8.6 ± 2.7 for females (range 2–17). The remaining 11 individuals were captured only once or several times in the same, or very close, places, implying that quite large areas of leopard presence are inadequately covered by camera-traps due to the limited numbers of these devices.

An analysis of individuals with the highest numbers of recaptures (n = 22 for male NEO, 18 for male BASAT, 17 for male BOGHAKAR, 17 for female BURLA, and 12 for female BANU) has shown that all 86 records were located in core habitats. There was no difference in HSI between locations of these male and female individuals (Mann-Whitney U = 548.5, p = 0.010), supporting a similarity between HSI of male and female locations in general. However, there was a significant difference between individuals (Kruskal-Wallis $\chi^2 = 24.3$, $p < 0.001$). Interestingly, it demonstrated that locations of each of these individuals had much higher HSI than NEO's locations in Khosrov Reserve, Armenia (Mann-Whitney U varied from 33 to 80, p from < 0.001 to 0.002 in all pairwise comparisons).

We mapped the locations of known individuals, except for two individuals from the Talysh Range with recaptures which almost completely overlapped, and overlaid them with HSI > 0.7. This approach allowed us to identify suitable habitats and display mountain ranges that are highly likely to be movement routes. Such a micro-scale analysis of leopard spacing is practically very useful for conservation purposes in the Lesser Caucasus given every square kilometre and every living individual is of immense value. Further research on the extent to which these suitable habitats and corridors are influenced by favourable factors (e.g. protected areas, prey-rich hotspots and secluded places with minimum human influence) and threats (e.g. high-traffic roads, poaching hotspots) will allow us to identify high priority areas and gaps for conservation and population monitoring.

In addition to extrapolating potential movement routes from fine-scale occurrence data, our micro-scale analysis revealed the following phenomena:

- Mutually exclusive occurrence of two males in Khosrov Reserve and Arpa Protected Landscape, Armenia (Fig. 7). The male NEO was detected in certain areas at particular times while the other male BORAN was camera-trapped in other areas, but then appeared to swap areas. Possibly, these males used the same home ranges, but displayed temporal separation. Such overlaps in home ranges of male leopards, and felids in general, are possible when prey resources are sufficient and males do not have to compete for food (Macdonald et al. 2010), but they tend to avoid mutual contacts, possibly to maximise their chances for mating. The same pattern of temporal separation between two males was found in Bafq Protected Area of central Iran (Farhadinia et al. 2021b).

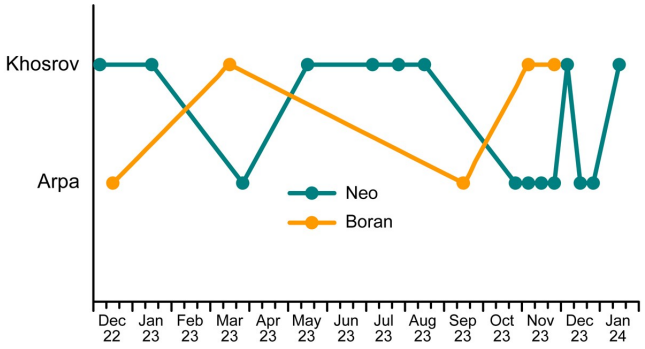


Fig. 7. Mutually exclusive occurrence of the males NEO and BORAN in Khosrov Reserve and Arpa Protected Landscape, Armenia revealed from camera-trap captures (dots on the graph). The lines are given for illustrative purposes only. Each month consists of early (1-10th days), middle (11-20th) and late (21-30(31)th) sections.

- Importantly, the male ARMAN was camera-trapped in northern Armenia, a unique record from the area where even historical data are rare, but then he was captured in north-eastern Türkiye and is still being recorded there. Based on habitat suitability, he most likely made a detour through southern Georgia, covering a ca. 275 km straight distance. This displacement is longer than several others recorded, including a 170 km shortcut Neo took from southern Nakhchivan to Khosrov Reserve (Askerov et al. 2019); 21.7–27.7 km for two reintroduced males in the Western Greater Caucasus, Russia (Trepet et al. 2022); 9.8–81.6 km for five GPS-tracked males in north-eastern Iran (Farhadinia et al. 2018); over 50 km in central Iran (Farhadinia et al. 2021b); and 112 km in southern Iran (Pars Wildlife Guardians Foundation, unpublished report 2021). It is considered among the longest confirmed displacements of leopards in the world (Fattebert et al. 2013); noteworthy as this individual is still alive (D. Mengüllüoğlu, pers. comm., 21 January 2025).
- Use of unsuitable habitats by males. The male BORAN was recorded in a riparian wetland of the Arax River located at the intersection between Türkiye, Armenia and Nakhchivan; these local habitats are generally classified as unsuitable. Although this was a single record which cannot indicate patterns, it shows that males, particularly dispersers, may leave core habitats during their movements. There are several similar cases of occurrence and residence of leopards on shores and islands of Lake Urmia, north-western Iran. As shown above, male records were more frequently located outside of core habitats than those of females, albeit this difference was insignificant.

It is still premature to define the exact source and sink patches of the leopard metapopulation in the region, although some patterns are becoming clearer. Certainly, southern Nakhchivan is a current source where local females breed and produce new individuals that disperse further into Armenia and Türkiye. However, we should not rely too much on the breeding of a few prolific females. The founder group size is very small and consists of interrelated individuals, making the whole population prone to inbreeding and genetic depression. Wide-ranging movements expose males to high human-caused mortality upon encounters, as evidenced by the dominance of males among leopard killings in the Caucasus. Therefore, it is reasonable to assume that the Lesser Caucasus metapopulation consists not of stable sources and sinks, but of latent clusters which can transform between a source, a sink

and a temporary stepping stone in different periods of time depending on imminent threats and the availability and the status of females.

The reintroduction of female leopards appears to be a strong and obvious solution to boost the recovery of the leopard in the Lesser Caucasus. We suggest tracing how female dispersal away from the natal area increases during the next five years (during which two generations of female cubs should be born and become mature) of leopard monitoring in the Lesser Caucasus. In case no dispersal is detected that could help recolonise other parts of the southern Lesser Caucasus, female reintroduction is an option to be considered. In any case, it is essential to monitor the genetic status of females taking into account that the founder population is small and inbreeding depression is expected to be a real problem for the long-term survival of the whole population.

Another source of uncertainty in the status of the leopard is an increasing number of anecdotal records reported by local people and rangers in recent years, especially in Iran, that are not properly documented. It is unclear whether the rise in records reflects actual leopard dispersal from other areas or simply higher rates of reporting, especially via social media, due to better awareness rather than a true increase in leopard numbers. It is unlikely that these records reflect a real increase in population size as the Persian leopard is highly threatened range-wide, although high-density hotspots also exist in some protected areas and ambient lands in north-eastern Iran (Farhadinia et al. 2019). No high-density leopard populations are known in the Lesser Caucasus and neighbouring regions. High visibility of Persian leopard records should therefore be treated with caution because a real increase in carnivore population size is a very slow process that takes decades. The Lesser Caucasus provides a good example of this slow process given that despite 20+ years of dedicated conservation efforts, we still have a recovering, but unstable and not yet viable, population teetering on the brink of extinction.

Connectivity of the Persian leopard population between the Lesser Caucasus and neighbouring populations in the Greater Caucasus (Azerbaijan, Georgia, Russia), Talysh Range (Azerbaijan), Karadagh and Alborz Ranges (Iran), and the Zagros Range (Iran, Iraq, south-eastern Türkiye) appears to be patchy and consists of a network of stepping stones rather than continuous core habitats (Fig. 5). The role of connectivity in leopard recovery potential is crucial but not yet studied. The reasons for this patchiness are both geographical (naturally isolated mountain ranges separated by human-dominated lowlands) and anthro-

pogenic (persecution and other current threats). The paucity of leopard records from these potential corridors may not only reflect real rarity, but also lack of survey efforts which would provide essential information about the presence/absence. Non-detection despite presence is very plausible in these areas, and the distinction between non-detection and true absence is possible only with the implementation of properly designed field surveys, in addition to expertly designed questionnaire surveys among knowledgeable people such as hunters and rangers. Range-wide monitoring of the Persian leopard population across 25×25 km grid cells is going to be a primary source of such information and an unprecedented effort in Southwest Asia, particularly by combining scientific surveys and citizen science. The PeLeWG is striving to raise funds for such a range-wide monitoring effort and transform it into a long-term self-sustaining initiative.

3.2. Temporal behavioural patterns

3.2.1. Introduction

It is scientifically proven that mammals become more nocturnal when living close to people (Benítez-López 2018, Gaynor et al. 2018), and this trend is particularly striking in carnivores (Burton et al. 2024). This is because the expansion of human activities leaves less spaces for wildlife to survive, and the only way to co-exist with humans is to exploit the time generally not used by humans – the night. To test the nocturnality of leopards in the Lesser Caucasus, we analysed the largest temporal activity dataset of leopard camera-trap records from Nakhchivan.

3.2.2. Methods

We collected 24-hour temporal activity data of leopard camera-trap captures from Nakhchivan, and compared them between years (2019–2022) and seasons (2018–2023) for all captures, sexes and individuals (2018–2023). We retrieved these data from the Camelot database (see above). We defined winter as December–February, spring as March–May, summer as June–August and autumn as September–November. More information about sampling is given above in *"Metapopulation structure"*. The sample sizes are shown in Table 3.

Table 3. Sample sizes of the temporal data of Persian leopard camera-trap captures collected during 2018–2023 in Nakhchivan (total n = 438), and full-year data during 2019-2022. These data are part of the total sample described in Table 2.

Category	Sub-category	Sample size (n)
Year with full data (n = 433)	2019	49
	2020	137
	2021	122
	2022	125
Season (n = 438)	Winter	108
	Spring	129
	Summer	123
	Autumn	78
Sex (n = 168)	Males, M	98
	Females, F	70
Individual (n = 163)	BURLA, F	30
	KILID, F	13
	BANU, F	23
	BASAT, M	58
	BOGHAKAR, M	39

3.2.3. Results and discussion

The graphs showing the distributions of time data are illustrated in Fig. 8. The curves show that leopards are mostly crepuscular and nocturnal, being active mostly between 18:00 h and 8:00 h. The proportions of diurnal images during 8:00–18:00 h were similar between years (18.4–28.6%, mean 23.3 ± 2.1%), i.e. about a quarter of all captures. Also, leopards were more diurnal during autumn (33.3% of all images) and winter (37.0%) than during spring (16.3%) and summer (9.8%). This could be caused by thermoregulation (avoidance of hot weather) or following the activity patterns of bezoar goats; these two factors are correlated as goats also become more crepuscular during the hot season. Additionally, leopards could become more nocturnal in spring and summer to avoid shepherds and shepherd dogs, who could also shift the activity of bezoar goats to the darker times of the day.

However, what is interesting is that females were found to be much more diurnal (54.3% of records from 8:00-18:00, see above) than males (29.6%). This was confirmed also in individuals (46.7% for BURLA, 61.5% for KILID and 65.2% for BANU vs. 25.9% for BASAT and

35.9% for BOGHAKAR). It may suggest that the crepuscular and nocturnal activity of the total sample is biased toward males who are captured more frequently due to their wide-ranging movements (Table 2). The diurnal activity of females may indicate that they feel safe enough to be active during daytime. However, we should not rule out the possibility that female diurnality may stem also from genetic selection and learning, particularly in relation to prey activity and human pressures. Additionally, females may stay away from males to avoid infanticide and harassment. In contrast, males have to remain cautious and be active mostly during the darker hours due to their long-distance movements and resulting higher chances of encountering humans. A similar pattern of mostly diurnal activity of females, but cathemeral activity of males, was found among Persian leopards in well-protected Tandoureh National Park, north-eastern Iran (Rouse et al. 2021).

It would be useful to see how the diurnality of females varies between years and seasons, or depends on the reproductive status of females, but such an analysis may be restricted by small sample sizes. It is even more important to explore how female diurnality is related to activity patterns of bezoar goats, especially during different seasons.

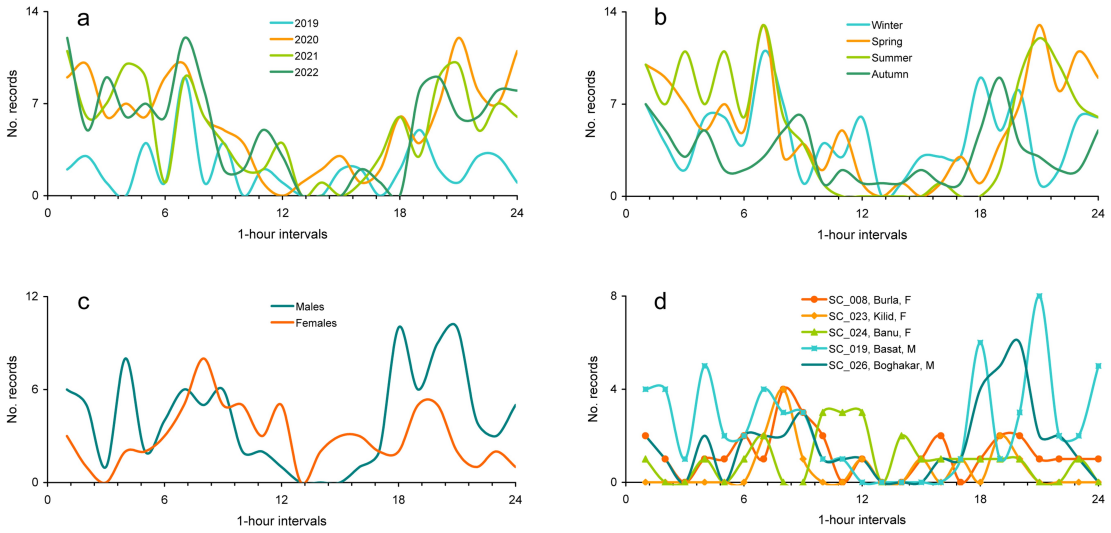


Fig. 8. Activity patterns of camera-trapped leopards in Nakhchivan according to a) years, b) seasons, c) sexes and d) individuals.

3.3. Genetic status and viability

Small wildlife populations, including leopards, are exposed to a high risk of extinction from inbreeding depression, which is caused by mating between closely related individuals and can result in adverse effects such as lower survival and morphological anomalies. As

discussed above, the leopard population in the Lesser Caucasus has been recovering from a small founder group in Nakhchivan composed of interrelated males and females. Hence, the issue of inbreeding depression is very topical in the region, and its effects are very likely to manifest themselves as the population continues to grow and expand. This is a serious concern given the lack of genetic data on this leopard population, and the worst-case scenarios should be considered in conservation planning.

The disruption of population connectivity inhibits individuals, especially males, from successful dispersal and, as a result, they stay close to their parents and mate with relatives causing an overall increase in inbreeding (Naude et al. 2020). The cases of mother-son mating were repeatedly recorded in Arabian leopards *P. p. nimr* in Israel (Ilany 1990), and a single small and isolated Amur leopard *P. p. orientalis* population in the Russian Far East is also well-documented to have low genetic diversity (Sugimoto et al. 2014, Cho et al. 2022). The Israeli population was extremely small due to persecution, and it eventually vanished because a single female's cubs were recurrently killed by non-siring males to trigger a new oestrus and mating (Ilany 1990). The Amur leopard population is genetically impoverished and has some morphological characteristics of inbreeding (white paws, shortened or kinked tails, and a shortened skull), but its population rebounded by 2021 due to high birth rates, increasing the population by almost four times from 24–32 to 98–111 individuals (Marchenkova et al. 2023).

A series of genetic analyses was conducted on Persian leopards in Iran with the use of two mitochondrial genes of NADH-5 and cytochrome b (Farhadinia et al. 2015b, Farhadinia et al. 2020) and six highly polymorphic microsatellite loci (Farhadinia 2017). Mitochondrial genome sequencing revealed low haplotype diversity across three closely related NADH-5 and two closely related cytochrome b haplotypes. One dominant haplotype was shared by leopards from Iran, Turkmenistan and the Caucasus, supporting a common maternal genealogy (Rozhnov et al. 2011, Farhadinia et al. 2015b). Low diversity of mitochondrial genome could possibly be caused by selective pressure on genes responsible for hypoxia and cold temperatures at higher elevations (Farhadinia et al. 2015b, Farhadinia et al. 2020). On the other hand, Persian leopards from Iran exhibited moderately high diversity of microsatellites compared to other leopard subspecies globally. This result supported the lack of population subdivision and indicated no evidence for recent population expansion. However, a low number of microsatellite loci analysed and a very small sample from the Caucasus (two mus-

cle and skin samples not far from the Talysh Range; Farhadinia et al. 2015b) make these results suggestive rather than conclusive.

Historical bottlenecks have likely led to low genetic diversity in Persian leopards in the Caucasus as the regional population was decimated in the early to mid-20th century due to government-supported hunting of large carnivores which were branded as "vermin" (see *"Status in the past"*; Khorozyan & Abramov 2007). Overall, the Persian leopard population in this region declined overwhelmingly due to human pressures, such as killing, prey reduction and habitat loss/fragmentation (Ghoddousi & Khorozyan 2023).

From a practical perspective, the genetic viability of Persian leopards should be considered within the broader context of population fragmentation and connectivity. The one-migrant-per-generation rule, which is widely accepted by conservationists, states that the immigration of one fertile individual over the course of a generation significantly reduces the rates of genetic diversity loss in the recipient population (Wang 2004). A study of puma *Puma concolor*, a big cat similar in morphology and ecology to the leopard, has shown that even one prolific male immigrating over a 15-year period (i.e. three generations; Saremi et al. 2019) can substantially reinforce the viability of a small and isolated puma population (Gustafson et al. 2017). For fluctuating populations, the number of migrants per generation required to reduce genetic loss is much higher than one (Vucetich and Waite 2000).

Validity of this rule depends on the genetic quality of the recipient population. Given the genetically depauperate condition of the Caucasus leopard population resulting from its small Nakhchivan-based founder group, the number of migrants required to maintain viability of the Caucasus population, at least in the Lesser Caucasus, is a minimum of 2–3 per 7.42 years (generation time of the leopard; Ghoddousi & Khorozyan 2023). The potential for female immigration is even lower. Since 2013, all mating males in Nakhchivan originally came from the outside, most likely from Iran, but the Iranian part of the Caucasus Ecoregion can no longer be considered a viable source (see *"Status in the past"* and *"Current status and ecology"* above; Moqanaki et al. 2013, R. Masoud, pers. comm.). The closest viable population in the Alborz and Zagros Ranges of Iran are separated from the Caucasus by vast plains dominated by agricultural lands and other anthropogenic landscapes, making leopard immigration unpredictable and risky at best.

The source-sink dynamics of the Caucasus leopard population in the Iran–Lesser Caucasus–Talysh Range–Greater Caucasus can also be considered in the context of the "land sharing–land sparing" paradigm. This is because the Persian leopard status and conservation depend much on the presence and effectiveness of protected areas (Mohammadi et al. 2021). However, no single protected area in the region is large enough considering that Persian leopards have one of the largest home ranges among leopards, with ca. 100 km^2 for adult males (Farhadinia et al. 2018). Therefore, local leopards have to move through unprotected human-dominated landscapes to satisfy their spatial needs.

4. Conclusions and Outlook

Conclusions

The conclusions of this report can be summarised as follows:

- The Persian leopard population of the Lesser Caucasus (Armenia, Nakhchivan Republic of Azerbaijan, southern Georgia and north-eastern Türkiye) comprises a minimum of 6–20 adult individuals, but only four known breeding females recorded in Armenia and Nakhchivan. This implies a very small founder group which may expose the local population to inbreeding depression. The population appears to be increasing in numbers and distribution area compared to the early 2000s, but direct comparisons are impossible because of the lack of reliable baselines.
- Although the border reserves of north-western Iran were considered a source for the Lesser Caucasus, we believe that they are unlikely to act as such anymore as there have been no known leopard records there in the past 12 years. This may even mean the Iranian border reserves are now sinks for the Lesser Caucasus.
- The main threats to Persian leopard survival in the Lesser Caucasus are (1) fragmentation and loss of suitable habitats, especially for females, (2) political instability, (3) prey depletion and limited prey richness in some areas, and (4) illegal killing. Illegal killing, which is currently very low, may intensify over time with an increase in the leopard population and more frequent cases of human-leopard conflicts.

- Abundance of prey, primarily bezoar goats, appears to be sufficient for the current number of leopards throughout the Lesser Caucasus. However, the growth of prey populations should be secured to support an increasing number of leopards.
- The metapopulation structure of the Lesser Caucasus population is volatile and its interlinked clusters are represented by individuals and not sub-populations. Southern Nakhchivan acts as a source where local females breed and their sub-adult offspring disperse further to Armenia and Türkiye. There is encouraging evidence of females entering (with and without cubs), and breeding in, southern Armenia, possibly indicating that female density is about to approach stabilisation in Nakhchivan.
- Females appear to lead more diurnal lives than males in Nakhchivan. Their diurnality may be caused by safety of their habitats, behavioural adaptations to prey activity or infanticide avoidance. Males are more nocturnal, possibly because they move more actively than females and have higher chances to clash with people.
- Mapping and analysis of camera-trap recaptures of male and female individuals has allowed the exploration of potential movement routes of local Persian leopards. Generally, they are detected in their core habitats, but males are more likely to leave them and occur in unusual habitats such as wetlands. Co-occurring males may exhibit temporal separation, which is the use of the same areas at different times, possibly to maximize their chances for mating. Local males can cover long distances (up to 200 km and beyond in shortcuts), e.g. from Nakhchivan to south-western Armenia and from northern Armenia to north-eastern Türkiye, which are among the longest detected displacements of leopards in the world.
- Small population size may impoverish the genetic status and eventually cause inbreeding depression in leopards, which is already proved in Israel and the Russian Far East, and projected for the Lesser Caucasus. The immigration of at least 2–3 new and unrelated breeding individuals every seven years is required to substantially reinforce genetic diversity and boost viability of the Lesser Caucasus population. The number of effective immigrants needs to be high because the recipient population is inbred due to the small Nakhchivan-based founder group of interrelated males and females. There is great uncertainty on where these immigrants can come from. The effect of inbreeding depression, however, will depend much on the background genetic quality of the population,

male immigration rates, and demographic performance, including reproduction and survival rates.

Recommendations for leopard research and monitoring

This report puts forward a number of new avenues for applied research and monitoring, which will produce the practical information much needed for conservation efforts. What is clearly illustrated in this report is that such **research should consider differences of male and female leopards** as much as it is possible, especially in space use, ecology and behaviour. The avenues include, but are not limited to:

Distribution, ecology and mitigation of threats:

- GPS tracking of leopards in the Lesser Caucasus for modelling movement routes, barriers and core areas, and validation with independent GPS records from north-eastern Iran and the Russian Greater Caucasus. Such research is expensive (at least, in the beginning), demanding stable long-term funding and resources, and reliant on transboundary cooperation between Armenia, Azerbaijan and Türkiye across whose boundaries leopards regularly move. However, it is vital to understand: (1) why and how leopards select particular routes for movements; (2) how we can better manage and protect these routes, especially those used by sub-adult individuals for dispersal; (3) how related and unrelated individuals move and avoid inbreeding; (4) what the seasonal and individual prey kill rates and prey selectivity patterns are; and (5) health, genetic profiles and pathogen loads of the immobilised and collared leopards, as well as dead/confiscated leopards and their prey to discern disease transmission pathways. The topics listed below also can be studied within GPS tracking projects, or independently by camera-trapping and other related techniques in the same areas and periods, depending on available agendas and resources.
- Identifying high priority areas and gaps in leopard movements by studying favourable factors (e.g. protected areas, prey-rich hotspots and secluded places with minimum human influence) and threats (e.g. prey-lean areas, high-traffic roads, poaching hotspots) within micro-scale suitable habitats and corridors.
- Assessing differences between individuals and sexes in space use, behaviour (e.g. activity patterns) and ecology in response to prey, habitat conservation and threats.

- Recording occurrence and dynamics of human-leopard conflicts in relation to increasing leopard numbers, broadening distribution area, population structure, prey availability and hidden ("shoot, shovel and shut-up") poaching.
- Analysing leopard diet and its changes (especially in the context of livestock consumption) in space and time in relation to the availability of key prey species, primarily bezoar goats and wild boars, particularly in areas where prey richness is low.
- Exploring dietary preferences of individuals and sexes, and their changes over time, particularly in solitary females and females with cubs.
- Applying scientifically designed human-leopard conflict mitigation techniques in the Talysh Range and other conflict-prone areas.

<u>Genetic status</u>

- Assessing genetic drift, inbreeding, fine-scale sex/age population structure, individual genetic profiles (including the founder group) and reduced gene flow in the small leopard population of the Lesser Caucasus and neighbouring areas of Southwest Asia. This work can be done with the same field-collected faecal samples that are used for the dietary analysis, as well as with tissue samples from dead individuals and saliva from kills, and in cooperation with GPS tracking studies if possible.
- Investigating sex-related differences in the diet and validating the reliability of visual identification of leopard faeces through genetic studies. We envisage using a centralised lab to store samples from the entire range of Persian leopards to develop and analyse relevant genetic markers. The PeLeWG could provide a facilitatory role, while a reliable academic partner would take the lead in participatory research together with partners from the range countries, following the CITES guidelines.
- Building genealogical trees, especially for females and the founder group, and mapping individual movements and occurrence to see where unrelated males go and what their chances are of mating with unrelated females, sisters and mothers. This work should also be conducted in close cooperation with GPS tracking studies, if possible.
- Modelling genetic and demographic scenarios to assess the risk of genetic deterioration.

Monitoring

- Integrating the WWF Caucasus Leopard Conservation Programme into the range-wide leopard monitoring programme which is to be established and managed by the PeLeWG.

Recommendations for leopard conservation

Habitat fragmentation and resulting loss of connectivity is one of the main threats to Persian leopard viability in the Lesser Caucasus. Therefore, its conservation in the region is absolutely impossible without considering land-use practices. None of its protected areas is large enough to maintain viable leopard populations within them, and the incorporation of both protected and non-protected lands is essential to ensure habitat connectivity for safe movements of leopards, primarily females. Males, especially dispersing sub-adults, may leave core habitats and are much more likely to visit human-dominated areas. Such visits may lead to deadly conflicts (for leopards) in the worst case and to peaceful co-existence in an ideal scenario. Therefore, local people and authorities should be well prepared to offer the best-quality habitats for females and to accept the presence of males in their vicinities.

Wildlife conservation revolves around the two traditional paradigms of “land sparing” (allocation of wild areas with minimum human interference for protected areas) and “land sharing” (conservation in agricultural landscapes) (Löfroth et al. 2024). However, these approaches alone cannot provide a viable solution in many regions as land sparing is practical only for vast countries with low human densities (Russia, USA, Canada, Australia) and land sharing creates potential conflicts in relation to human safety and local livelihoods.

The best way to secure the connectivity of Persian leopard habitats in the long run is a combination of land sparing and land sharing (Mohammadi et al. 2021). Most leopards, particularly those residing in protected areas, spend some time on unprotected lands among local communities (Farhadinia et al. 2018). Protected areas, even if they are relatively small like in the Lesser Caucasus, can play an “anchoring” role for such roaming individuals. Therefore, a combined approach of land sparing and land sharing should be applied to ensure the viability and resilience of Persian leopards living in the mosaics of wild montane landscapes interspersed with human-dominated lands. This means that protected areas are key for securing leopard survival and, ideally, maintaining high local densities. In addition, lands outside protected areas should be managed by local communities as Community Conserved

Areas or other forms of Other Effective Area-based Conservation Measures (OECM, Farhadinia et al. 2022b) to reduce conflicts with livestock owners and foster sustainable livelihoods that support coexistence with wildlife. Integrating different land management regimes into leopard conservation could enhance existing efforts in various ways, contributing to a viable leopard population across the Lesser Caucasus and beyond.

There are a number of ambitious, large-scale and long-term projects in the Lesser Caucasus focused on promoting the network of protected areas and combining biodiversity conservation and monitoring with local livelihoods on unprotected lands. These projects have been managed by WWF, Eco-Corridors Fund for the Caucasus (ECF), Caucasus Nature Fund (CNF), Swiss Agency for Development and Cooperation (SDC), German Agency for International Cooperation (GIZ) and other organisations. Many projects led by WWF, ECF and CNF use the leopard as a flagship of landscape connectivity and large-scale biodiversity conservation, while the others focus more on human perspectives; all are invaluable to secure corridors for wildlife in general. Such initiatives that foster coexistence between conservation and local livelihoods are essential for securing habitat connectivity for leopards and other large mammals given that the Lesser Caucasus has high human densities and limited wild area coverage.

Major limitations, gaps and possible solutions

The main challenges facing Persian leopard research, monitoring and conservation in the Lesser Caucasus include:

- **Lack of professionals** who are specialised in wildlife management and could replenish and expand current teams in the South Caucasus, particularly within the Lesser Caucasus Range (Armenia, Azerbaijan). The solution is to focus on cooperation with national and international universities, academic institutions and non-governmental organizations (NGOs), which would require sustainable funding for scholarships, grants and other financial support mechanisms. The ongoing cooperation between WWF Caucasus Programme Office, WWF Germany and Humboldt University of Berlin has been fruitful in advancing scientific research and cooperation, but remains insufficient for developing national capacities in wildlife research, monitoring and management. A greater effort is required to boost cooperation within the region and beyond to initiate and, most im-

portantly, maintain high levels of activity. A promising example is the successful cooperation between WWF Armenia and the Scientific Centre of Zoology and Hydroecology, Yerevan aiming to reduce a research-conservation gap by involving national specialists.

- **Insufficient funding** to support high-quality leopard monitoring and conservation, and expand them in line with the increasing leopard population. The number of 5×5 km monitoring and survey grid cells should be sufficient to answer key questions about the population, while remaining realistic given current resource availability. These grid cells are clearly defined and standardised (Ghoddousi et al. 2023), but even so, simultaneous monitoring is often not feasible, especially in winter, due to limited funding for hiring additional personnel. The number of grids being surveyed significantly increased between 2019 and 2024 (Ghoddousi et al. 2019, Ghoddousi et al. 2023; Table 4). Yet more funds are required to buy additional camera-traps to cover wider areas, replace worn-out or lost devices, and implement more activities within the WWF Caucasus Leopard Conservation Programme. Obviously, the implementation of new research avenues such as GPS tracking and other recommendations listed above requires greater and more stable funding than is currently available. Current fundraising opportunities offer a positive outlook, but at an insufficient scale, and accessing support from the corporate sector is possibly among the most sought-after solutions. Reliance on WWF alone makes leopard conservation in the South Caucasus unsustainable in the long run. Mobilising governmental, academic and other national organisations should therefore be a priority to ensure that lasting solutions can be implemented.
- **Political instability** which makes it impossible or risky to conduct leopard surveys in some borderline areas. At the same time, transboundary conservation has successfully been implemented using the Persian leopard as a regional flagship and incorporating global professional networks such as the PeLeWG.
- **Lack of region-wide scientific research and related institutional capacities** to integrate information from each country, conduct comparative analyses, and produce results applicable to the entire Lesser Caucasus region. The PeLeWG is responsible for doing this at the range-wide scale. Current research is mostly focused on (sub)national populations or else the whole population in Southwest Asia, neither of which can be properly extrapolated to the Lesser Caucasus. There is an urgent need to GPS track leopards, espe-

cially females, in the region, but this requires greater financial, technical, human and time resources.

Table 4. The numbers of 5×5 km monitoring and survey grid cells used for leopard monitoring in the South Caucasus, and their changes between 2019 (Ghoddousi et al. 2019) and 2024 (Ghoddousi et al. 2023). Monitoring cells have been used for monitoring constantly due to regular camera-trap captures of leopards. Survey cells are for occasional camera-trapping, unless leopard captures transform them into the monitoring cells.

Country	Region	Cells	2019	2024
Armenia	Southern part	Monitoring	9	39
		Survey	38	105
Azerbaijan	Nakhchivan	Monitoring	6	24
		Survey	9	9
	Talysh	Monitoring	2	5
		Survey	6	4
Georgia	Greater Caucasus, Vashlovani	Monitoring	0	2
		Survey	0	55

- **Insufficient cooperation between stakeholders** including protected areas, Community Conserved Areas, academia, NGOs and governments. Generally, cooperation lasts only the duration of projects and fades out after project completion. There is no formal framework specifying the roles, duties and responsibilities of stakeholders in wildlife conservation of the South Caucasus, including the Lesser Caucasus.

Opportunities for research, monitoring and conservation

We see this report as a catalyst for securing a more secure future for leopards in the Lesser Caucasus and beyond. As research, monitoring and conservation form interconnected elements of a single triangle, we address them together when proposing new actions and ideas.

The following encouraging conditions already in place in the Lesser Caucasus provide a firm basis for new opportunities:

- **Stronger understanding** of the role of research in planning and implementing conservation programmes.
- **Deeper and continuous integration** of national academic science in global research and conservation networks. Of particular importance is the fruitful international cooperation between the national WWF offices and the IUCN SSC Cat Specialist Group (http://catsg.org), WWF Germany (https://www.wwf.de), Conservation Biogeography Lab of Humboldt University of Berlin (https://pages.cms.hu-berlin.de/biogeo/website), Persian Leopard Working Group (PeLeWG, https://pelewg.net), Eco-Corridors Fund for the Caucasus (https://www.ecfcaucasus.org), Caucasus Nature Fund (https://www.caucasus-naturefund.org), and other donors and partners. National cooperation, such as between WWF Armenia and the Scientific Centre of Zoology and Hydroecology (https://sczhe.sci.am), is also progressing.
- **Existence of framework documents** such as:
    - Ecoregional Conservation Plan for the Caucasus (Zazanashvili et al. 2020)
    - Range-Wide Strategy for the Conservation of the Persian Leopard (2022)
    - Strategy for the Conservation of the Leopard in the Caucasus Ecoregion, 2017–2027 (Caucasus Leopard Working Group 2017)
    - Constituent leopard Action Plans
    - Roadmap for Planning and Implementing Research and Monitoring of Large Mammals by WWF in the South Caucasus (Khorozyan 2024)
    - Guidelines for the Systematic Monitoring of Leopard and its Prey in the South Caucasus (Ghoddousi et al. 2023)
    - Guidelines on the Application of the Camelot Software within the WWF Caucasus Programme Office (Pötzschner 2024).

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