

RESEARCH ARTICLE

Local ecological knowledge provides novel evidence on threats and declines for the Caucasian grouse *Lyrurus mlokosiewiczzi* in Arasbaran Biosphere Reserve, Iran

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Abstract

1. The Caucasian grouse *Lyrurus mlokosiewiczzi*, one of the most poorly known species of grouse, is experiencing population declines associated with multiple threats. Evaluating species' population status in relation to different local human activities is important to inform conservation and identify suitable management methods, but determining status and threats for poorly known taxa may require assessment of non-standard sources of ecological information.
2. We investigated what novel insights can be provided by local ecological knowledge (LEK) about population status and threats to the Caucasian grouse, in relation to the comparative status of other co-occurring wildlife and to different local land-use activities, and how data on local awareness and attitudes can guide conservation planning for this species. We conducted an interview survey in rural communities in the Arasbaran Biosphere Reserve (ABR), Iran, and collected LEK from 95 respondents within villages situated close to the locations of surviving and extirpated grouse populations.
3. LEK is a useful tool for assessing the status of grouse populations: 41.1% of respondents recognized grouse and 30.5% had seen the species, and respondents within villages situated close to surviving grouse populations had greater awareness, sighting likelihood, and more recent sightings. More respondents considered that grouse and other galliforms had declined in comparison to other wildlife. Decline and disappearance of grouse populations is associated with alteration and disturbance of grouse habitat, with potential drivers including increased cattle grazing and local bans on harvesting fodder.
4. These findings provide a new baseline to guide the development of suitable grassland management strategies (e.g. grazing regimes) for this species, and highlight the importance of further assessment of the effects of habitat disturbance on grouse survival, including understanding local histories of human–environmental interaction. Current landscape management methods are not supported by local people within the ABR, with most respondents disagreeing

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with the strict conservation measures currently in place, and we recommend that a new management system should be developed for Caucasian grouse conservation, including targeted conservation education and involving local community participation and co-management.

KEYWORDS

Arasbaran biosphere reserve, Caucasian grouse, Iran, local ecological knowledge, population decline, threats

1 | INTRODUCTION

Although evidence-based conservation policy and planning is predominantly informed by ecological field data, occurrence records collected directly by trained scientists are sometimes insufficient to provide a robust baseline for understanding the status and conservation requirements of threatened species (Danielsen et al., 2014; Gilchrist et al., 2005; Jones et al., 2008). The local ecological knowledge (LEK) of Indigenous and rural communities is increasingly recognized as a valuable alternative source of information about threatened species and biodiversity change, and may represent the only information about many otherwise poorly known taxa. LEK can thus represent a supporting complementary tool for informing conservation of biodiversity, with growing interest in its role, scope and value (IPBES, 2019; Turvey et al., 2014; Zayonc & Coomes, 2022), and should be considered in official conservation management and planning (Joa et al., 2018). This approach has been formalized within the Aichi Targets by countries that ratified the Convention on Biological Diversity, which recognize their obligation to respect, preserve and maintain the knowledge of Indigenous and local communities, with Aichi Target 18 stating that Indigenous and local knowledge should be 'fully integrated and reflected in the implementation of the Convention' by 2020 (Cuyler et al., 2020). The importance of LEK for conservation management is also highlighted in Principle 22 of the Rio Declaration of Environment and Development, which prioritizes the knowledge and traditional practices of local communities in environmental management (Cicin-Sain & Knecht, 1995).

There is no universally accepted definition of LEK, but it constitutes the knowledge and perceptions of a particular group of people about local ecosystems and their interactions with the environment, with its use in wildlife management similar to 'expert opinion' in population assessment (Caro-Borrero et al., 2017). In particular, people in remote communities are often reliant on natural resources for food and thus have considerable knowledge about the current and past status of many animal and plant species in surrounding landscapes, and can potentially provide important information on various aspects of the population status, threats and/or last observations of rare or recently extinct species that can inform conservation planning and prioritization (Berkes et al., 2012; Turvey et al., 2015). LEK is recognized as a robust, cost-effective method for collecting data across wide geographical areas, notably

for rare or elusive species that are otherwise difficult to study (Pan et al., 2016). It is considered especially likely to provide conservation-relevant information about species that are relatively large-bodied and morphologically distinctive ('charismatic') and thus easily identifiable, and/or that are culturally or economically important (Jones et al., 2008; Turvey et al., 2014). While absolute numerical baselines on species' population parameters are very difficult or impossible to obtain from LEK, relative differences in respondent reporting between sites, years and/or across co-occurring species groupings can be used instead to evaluate comparative patterns of status and trends (Turvey et al., 2015, 2017, 2019). LEK data collection methods typically involve interviews through which researchers obtain information directly from interviewees, using either questionnaires containing predefined questions or informal conversations (Camino et al., 2020). As well as obtaining baseline data on the status of target species, this data collection process can also evaluate local awareness and attitudes about environmental issues, which can influence behaviour towards threatened biodiversity and support for management actions; this is of particular importance in areas where human and wildlife interests are potentially in conflict, and can identify important awareness-raising and community engagement needs (Christensen & Knezek, 2015; Zamani et al., 2020).

Iran is a signatory to the CBD and thus formally recognizes the importance of incorporating LEK into conservation management. LEK has previously been studied in Iran to understand sustainability of traditional methods of natural resource management by local communities, notably rangeland and silvopastoral management, and medicinal properties of plant species (Ashrafzadeh & Salem, 2017; Bouzarjomehri, 2018; Ghorbani et al., 2013; Valipour et al., 2014). However, the usefulness of LEK to establish conservation baselines and inform decision-making has not been investigated for many of the country's key biodiversity landscapes or conservation priority species.

Assessments of species threat status across Iran's fauna and flora have not yet been comprehensively conducted; among regionally assessed mammals, nearly 13% of species are threatened with extinction and a further 14% are near to qualifying for threatened status (Yusefi et al., 2019). Several threatened species in Iran represent global conservation priorities, but identification of targeted management activities is often hindered by limited data on their

status, distribution and specific threats. One such species is the Caucasian grouse or Caucasian black grouse *Lyrurus mlokosiewiczi*, which is assessed on the IUCN Red List of Threatened Species as Near Threatened (Baskaya, 2003; BirdLife International, 2016). This species is endemic to the Caucasus Ecoregion (Storch, 2007), occurring within montane habitats in Russia, Georgia, Armenia, Azerbaijan, northeastern Turkey and northwestern Iran (Baskaya, 2003). In Iran, it occurs only in the Arasbaran region, different areas of which are designated under different levels of protection as the Arasbaran Biosphere Reserve (ABR), Arasbaran Protected Area and Arasbaran National Park (BirdLife International, 2016). Its population size and distribution have declined over recent decades (Baskaya, 2003; BirdLife International, 2016; Habibzadeh et al., 2010), and its population in Iran has been estimated by different authorities as less than 500 birds (IUCN, 2016) or about 100 birds (Storch, 2007) based on habitat modelling and counts of lekking males. It is listed on level (I) of the Convention on International Trade in Endangered Species of Wild Fauna and Flora in Iran (Darvishi et al., 2015), and is fully protected by Iranian national wildlife conservation law. The penalty for illegal hunting is about USD 476 (1 USD = 42,000 Iranian Rial) (Department of Environment, 2010).

The Caucasian grouse has been the focus of little targeted ecological field research (Baskaya, 2003; Darvishi et al., 2015) because of its restricted range, the difficulty of access to its remote mountain habitat and its small population size (Habibzadeh et al., 2013). It is a morphologically distinctive bird and therefore easily identifiable, and is known to be hunted illegally across parts of its range (BirdLife International, 2016), thus suggesting that local people who coexist within the same landscapes might possess conservation-relevant LEK about the species.

The main aim of this study was therefore to investigate what novel insights LEK can provide about population status and threats to the Caucasian grouse in Iran, and how data derived from interviews with community members in the ABR can guide conservation planning for this species. In particular, we aimed to assess (1) the factors that explain variation in reported awareness and experience of grouse across the ABR landscape, to test whether respondents living closer to surviving grouse populations possess more LEK about the species and (2) whether there were any differences between human activities in villages near or far from surviving grouse populations that might explain spatial patterns of local grouse extinction or survival, to test whether activities such as specific livestock husbandry practices might influence the ability of local landscapes to support grouse. We also aimed to use LEK to determine the comparative status of grouse in relation to different co-occurring bird and mammal species within the ABR, and local awareness and attitudes towards wildlife conservation and existing environmental management.

2 | STUDY AREA

The Caucasus Iranian Highlands in northwestern Iran are adjacent to the borders with Armenia and Azerbaijan. This region includes mountainous landscapes with high alpine meadows, forests, semi-arid steppes, rangelands, and rivers and springs. Since 1976, UNESCO has registered 80,646 hectares of the region as a biosphere reserve, covering an altitudinal range of 450–2700m above sea level (a.s.l.) (Figure 1), and comprising a core zone of 9478 ha, a buffer zone of 62,451 ha and a transition zone of 8716 ha. Arasbaran contains more than 200 species of birds and at least 48 species

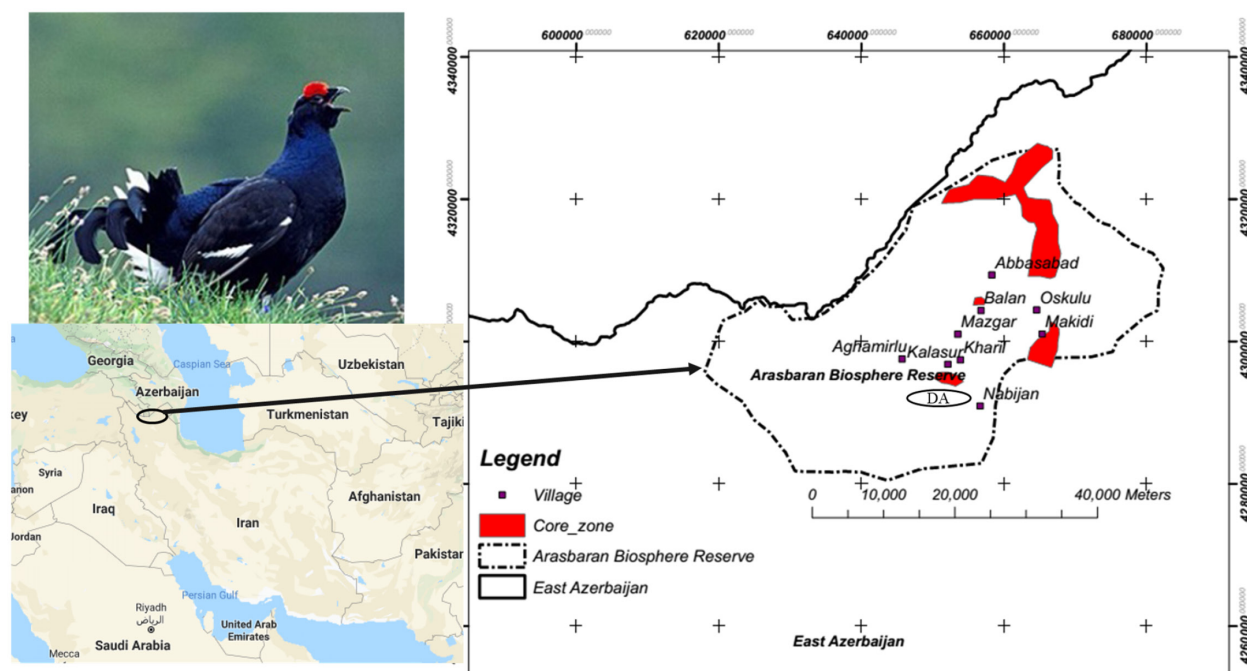


FIGURE 1 Location of study area (bounded by dashed line) and distribution of Caucasian grouse *Lyrurus mlokosiewiczi* in northwestern Iran (highlighted in red). Grouse photo from Cauca <https://www.pinterest.com/pin/pheasants-galliformes--16466354871618147/>

of mammals (Darvishi et al., 2015). The grouse only occurs in the reserve's core zone, in upland habitats above 1800m a.s.l., mostly on southern slopes at forest edges and along the upper altitudinal timberline (Darvishi et al., 2015). The core zone contains four villages with a total population of 120 people, with 59 villages (total population: 4345) in the buffer zone and 16 villages (total population: 3446) in the transition zone (Amini Parsa et al., 2016). The main subsistence activities of these communities are agriculture, gardening, apiculture and livestock production, with hunting and grazing prohibited within the core zone. Several nomadic groups also live in the reserve and seasonally inhabit the core zone (Department of Environment, 2010). The grouse thus occurs within a human-occupied landscape in the ABR, with rural communities who make use of locally occurring natural resources living relatively close to surviving grouse populations, and thus potentially possessing LEK about grouse population status, distribution, trends and threats.

3 | METHODS

We established the past and present known distribution of the Caucasian grouse within the ABR using data from all existing published field surveys, periodic population monitoring by the Department of Environment, and unpublished reports and interviews by ornithologists, foresters, previous hunters and local people (e.g. BirdLife International, 2016; Braunisch et al., 2019). We then conducted fieldwork in spring and summer 2020 within all of the villages inside the ABR situated close to the known locations of surviving grouse populations (Kalasur, Kharil and Nabijan), or to the locations of grouse populations known to have been extirpated within living memory (Abbasabad, Aghamirlu, Balan, Makidi, Mazgar and Oskulu) (Figure 1). The mean distance of the first set of villages from the known locations of surviving grouse populations was 3.85 km, and the mean distance of the second set of villages from the known former locations of extirpated grouse populations was 2.55 km.

We mostly conducted interviews with household heads, who were selected through opportunistic encounters by walking through each village (Pan et al., 2016; Zhang et al., 2020), and also with informants considered to be knowledgeable about local environmental conditions who were selected through snowball sampling (Newing et al., 2011), including shepherds and herdsmen, local hunters, foresters, and village councillors and elders. Respondents were aged 18 years or above, and were mostly male ($n = 90$, 95% of respondents), because males were encountered more regularly in villages and were more willing to be interviewed due to cultural and/or religious reasons. We conducted semi-structured interviews comprising open-ended questions in the local Azeri language in a flexible, informal face-to-face format (Ziembicki et al., 2013). We trialled interview protocols and content during a pilot survey conducted in April 2020. We only conducted interviews after informed consent was obtained from each prospective respondent; the purpose of the survey was explained briefly, and respondents were informed that their participation was voluntary and that all personal information

they provided was confidential. A permit to conduct research was obtained from the relevant wildlife authority prior to fieldwork, and all interviews in this study were conducted with prior informed consent of the interviewees. We confirm that all authors have abided by all necessary ethical standards during this research project. Interviews took 30–40 min to complete.

After collecting demographic information about each respondent, we asked questions about their knowledge of grouse, including biological and ecological characteristics and local distribution; their perceptions of local grouse status, and factors affecting this status; and human activities within the local landscape, including knowledge and experience about hunting, attitudes towards conservation, and past exposure to conservation awareness-raising activities. We determined respondent awareness of grouse by asking whether they recognized local names for the species (*Mesha khuruzu* and *Ghara khuruz*). We also asked comparable questions about a series of other locally occurring mammal and bird species (brown bear, *Ursus arctos*; wolf, *Canis lupus*; leopard, *Panthera pardus*; wild cat, *Felis lybica*; roe deer, *Capreolus capreolus*; wild goat, *Capra aegagrus*; wild boar, *Sus scrofa*; grey partridge, *Perdix perdix*), to provide comparative data on local perceptions of the status of other biodiversity, and to reduce the interview focus on grouse in case of any sensitivity about answering questions on this species or on local activities that might adversely affect grouse.

We investigated the relationships between respondent awareness and experience of surviving or extirpated grouse populations, and their socio-demographic characteristics and environmental interactions, within a quantitative framework. We contextualized our results with additional narrative information on respondents' perceptions of grouse ecology, local behavioural and environmental changes, and experience of local environmental management, which might provide further conservation-relevant insights (Newing et al., 2011). This combined approach aimed to assess the insights that LEK can provide for understanding Caucasian grouse conservation status, threats and management needs.

Specifically, we investigated the following questions using multivariate generalized linear models with a binomial error structure with logit link function:

1. *What factors explain variation in reported awareness and experience of grouse across a landscape with spatial variation in local grouse persistence?* Full additive generalized linear models were constructed for two different binary response variables (whether respondents know grouse, and whether they have seen grouse), and including the following fixed effects: whether village is situated close to surviving grouse population, respondent age, respondent gender, years of respondent education, whether or not respondent is retired, respondent's household size, respondent's total family income and whether respondent has always lived in their village.
2. *Are there differences between human activities in villages near or far from surviving grouse populations that might explain spatial patterns of local grouse extinction or survival?* A full additive generalized

linear model was constructed for the binary response variable 'village is situated close to surviving grouse population', and including the following fixed effects: respondent age, respondent gender, years of respondent education, whether or not respondent is retired, respondent's household size, respondent's total family income, whether respondent reported that their village received many visitors, number of cattle owned by respondent, number of sheep owned by respondent and whether respondent grazes their livestock in the forest.

These fixed effects were selected because age, gender, education level, income and employment/retirement status are all known to correlate (directly or indirectly) with variation in people's interactions with and awareness of nature (e.g. Allendorf & Yang, 2017; Ogunbode & Arnold, 2012; Turvey et al., 2010, 2017; Xiao & Hong, 2010); household size and number of visitors represent metrics of local human density and associated possible direct disturbance of grouse populations/habitats; and indices of cow and sheep numbers and husbandry practices (forest grazing) represent metrics of possible disturbance and habitat modification by livestock. We did not include whether respondents reported that they hunted as a further model predictor, because it is assumed that this sensitive and regionally illegal behaviour is likely to be underreported in the study region (cf. Nuno & John, 2015), and will thus not represent a consistently measured parameter across our respondent sample. We applied a hypothesis testing approach for generalized linear models using stepwise model selection, removing the non-significant predictor variable with the highest p value at each step, and model checking to assess subsequent significance of changes in deviance resulting from removal of terms (Crawley, 2007). We also used chi-squared tests to investigate differences in respondents' perceptions of population change between grouse and other locally occurring species. We analysed all data in R version 3.2.3 (R Core Team, 2015).

4 | RESULTS

4.1 | Respondent sample

In total, 95 people were interviewed, although not everyone provided information on all questions. Mean respondent age was 55 years (range: 20–90 years; SD = 15 years), with 65% of respondents aged ≥ 50 years. Mean household size was 5.2 individuals (range: 2–8 individuals; SD = 1.27 individuals). Educational level was low; most respondents had no formal education or had only finished elementary school (68%), and only 14% and 7% had attended high school or had an academic degree, respectively. Only 12% of respondents reported that they had not lived in their village for their entire lives. The main livelihood of 70% of respondents was animal husbandry, with 57% of respondents owning cows (mean: six cows per household) and 23% owning sheep (mean: 46 sheep per household). Of these livestock owners ($n = 70$), 73% reported grazing their livestock in the local forest. In addition, 32% of respondents

practiced additional farming activities and identified as farmers. On average, 77% of respondents' total annual income was provided by animal husbandry.

4.2 | LEK about Caucasian grouse

In total, 41% of respondents reported that they knew what a Caucasian grouse was. These respondents generally provided accurate information about the species, including that the male is black with a red comb and the female is grey, that it is slightly larger than a chicken or grey partridge and smaller than a turkey, and that it typically feeds on seeds, insects and other items. In total, 31% of respondents reported that they had seen the species. Generalized linear models showed that respondents were more likely to know about grouse and have seen grouse if their village was situated near to a surviving grouse population ('*know grouse*': live near grouse = 21/27, not live near grouse = 18/68; generalized linear models, est. = 2.591, SE = 0.584, $z = 4.439$, $p < 0.0001$; '*seen grouse*': live near grouse = 18/27, not live near grouse = 11/68; generalized linear models, est. = 2.474, SE = 0.556, $z = 4.450$, $p < 0.0001$). Knowledge of grouse was also positively correlated with total family income, with wealthier families more likely to know about grouse (est. = 0.004, SE = 0.002, $z = 2.666$, $p = 0.008$). A higher proportion of sightings were reported from the past decade by respondents living near to surviving populations (live near grouse: mean last-sighting time = 9.6 years earlier, SD = 12.9 years; not live near grouse: mean last-sighting time = 17.3 years earlier, SD = 14.8; Figure 2).

All respondents with knowledge of the species stated that grouse usually live at the timberline and in the areas between forest and rangeland (locally called *qajar*). Most people who reported grouse sightings (67%) had seen the species at the timberline. Some respondents (11%) also reported that birds enter rangelands after July when nomads and local people have left these areas, with reasons mentioned including that the birds preferred cold areas, and that they sheltered in the forest to avoid being hunted. One respondent stated that '*when the weather is foggy, it comes out of the forest and you can see it in rangelands easily*'. When asked about grouse habitat, 39% of respondents considered that the species' preferred habitat and area of occurrence had not been impacted by human activities, and only 2% considered that its habitat had been negatively affected.

4.3 | Grouse declines: Reasons and comparative patterns

Nearly all respondents either thought that grouse had declined in recent years (49%), or they were not sure about the species' past population trend (47%), with almost no-one considering that the population was stable or had increased (Figure 3). In total, 34% of respondents believed that a decline started when conservation measures were introduced in the region. These regulations prohibited the

FIGURE 2 Last-sighting dates for Caucasian grouse reported by respondents living near and far from surviving grouse populations. Figure legend: Dark grey, sightings by respondents living near to surviving populations; pale grey, sightings by respondents living far from surviving populations

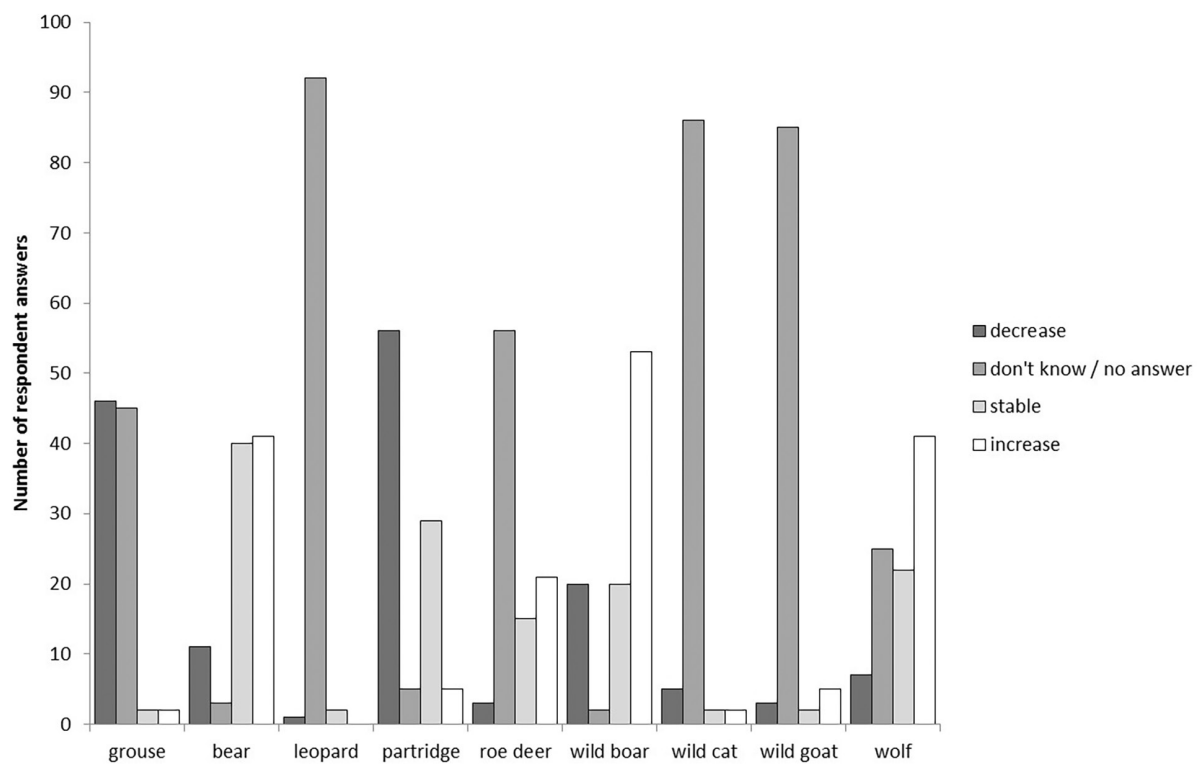
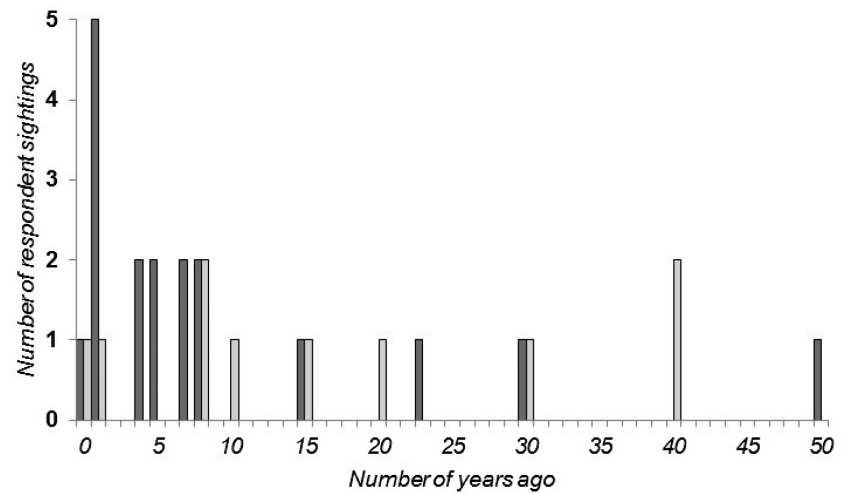


FIGURE 3 Perceived population trends of Caucasian grouse and other co-occurring galliform and mammal species in Arasbaran biosphere reserve (ABR) reported by local respondents

collection of forage, meaning that vegetation density had increased within grouse habitat. In particular, this vegetation change was considered to have reduced the amount of seed available for grouse to feed on, and to have made it harder for young birds to move around. Most respondents (88%) considered that hunting was not responsible for grouse decline, because they suggested that the species had also been hunted in the past but this activity had not previously impacted the population. A few respondents (5%) also considered that grouse decline was caused by predators, such as common weasel *Mustela nivalis* and golden jackal *Canis aureus*, eating eggs and chicks. Overall, 58% of respondents did not think that current conservation regulations were effective at protecting the species.

Comparison of respondents' opinions on the status of grouse in comparison to their opinions on the status of other locally occurring mammal and bird species reveals statistically significant between-species differences in perceived population trends. Significantly, more respondents considered that grouse had declined (46/95) in comparison to bear (11/95; chi-squared = 28.9, $p < 0.0001$), leopard (1/95; chi-squared = 54.7, $p < 0.0001$), roe deer (3/95; chi-squared = 48.5, $p < 0.0001$), wild boar (20/95; chi-squared = 14.5, $p = 0.0001$), wild cat (5/95; chi-squared = 42.8, $p < 0.0001$), wild goat (3/95; chi-squared = 48.5, $p < 0.0001$) and wolf (7/95; chi-squared = 37.7, $p < 0.0001$) (df = 1 for all tests). These data suggest that wild boar, bear and wolf in particular might have increased in

recent years (Figure 3). However, there was no significant difference in the proportion of respondents who considered that grouse had declined compared to those who considered that grey partridge, the other galliform bird included in the survey, had declined (partridge (56/95; chi-squared = 1.7, $p = 0.190$)).

4.4 | Threats

Overall, 85% of respondents reported that wild animals were not hunted by local people (Table 1). The main reported reasons for lack of hunting were conservation and local awareness of the importance of wildlife, and declines in many animal populations. For example, one respondent stated that '*our sense of humanity does not permit us to hunt wildlife*'. When specifically asked about grouse, only 18% of respondents reported having heard of grouse ever being hunted (by both local people and outsiders), and only 2% of respondents, both older men (≥ 68 years old) from Kharil, reported that grouse were still hunted by local people for food. The most common reason given for not hunting grouse was that they were rare and/or had declined (reported by 40% of respondents). In addition, 22% of respondents said that people did not hunt grouse because of conservation or increased knowledge about the species, and 12% said it was because no hunters were locally present. Most respondents (83%) were aware that the species was protected by Iranian wildlife conservation law and there was a penalty for illegal grouse hunting, although none of the respondents knew what the penalty was; some respondents considered that hunting different wild animal species had separate penalties. One respondent stated that '*hunting has decreased now because of a decrease in the number of birds. It is not possible to hunt. There used to be a lot of hunting. I hunted myself. Now, because its population has decreased, it is a pity*'. Respondents all knew that because the region was a protected area, all wild animals were protected and hunting was prohibited.

Generalized linear models showed that grouse populations were more likely to survive close to a village if its respondents had a lower number of cattle (est. = -0.238 , SE = 0.082 , $z = -2.899$, $p = 0.004$) and a higher number of sheep (est. = 0.060 , SE = 0.017 , $z = 3.414$, $p < 0.001$).

TABLE 1 Reported levels of wildlife hunting and grouse hunting in Arasbaran biosphere reserve (ABR), including reported reasons for not hunting grouse

1. Is wildlife hunted?	Yes	15%
	No	85%
2. Are grouse hunted?	I have hunted grouse	2%
	I have heard of people hunting grouse	18%
	No hunting	80%
3. Reason for no grouse hunting	Grouse rarity and decline	40%
	Conservation or increased knowledge	22%
	Lack of hunters	12%
	No response	26%

4.5 | Publicity and education

Overall, 95% of respondents stated that they had not been provided with any education about wildlife conservation issues from any organization in the past 3 years, or did not know whether they had been. When asked for reasons why wildlife should be protected, respondents mentioned the need to reduce extinction risk, the beauty of nature and environmental sustainability. When asked about specific measures that could help conserve grouse and other wild animals, the most common suggestion (made by 23% of respondents) was control of the timing of harvest of forage from grouse habitat for non-commercial animal feed. Specific suggested approaches included stripping and periodic harvesting to decrease forage and shrub density. In general, respondents believed that a balanced solution should be found between harvesting and conservation. In this suggested solution, forage could be harvested while still conserving grouse. Many respondents also highlighted their desire to receive education about the importance of wildlife and environmental conservation. One respondent reported that '*they just prohibit us. I do not think this is the right method for conservation. Before conservation, in spite of harvesting we saw many birds in those areas, but recently, few birds are seen there despite there being no harvesting. It is better to educate and increase support for conservation in the local culture, and find a middle ground for conservation and harvesting*'.

5 | DISCUSSION

In this study, we show that rural respondents living near surviving populations of the poorly known, Near Threatened Caucasian grouse report greater awareness and experience of the species compared to respondents living in nearby regions where the species has been extirpated, within statistical models that also take variation in respondents' demographic characteristics into account. The information that these respondents provided about grouse appearance, dimorphism and dietary ecology is also consistent with independent ornithological understanding of the species. Our study thus demonstrates that communities within the ABR possess LEK about Caucasian grouse, and we highlight this useful conservation tool for a species occurring in remote montane landscapes that can be difficult to survey directly. Our respondents also provided considerable insights into local grouse population trends, habitat use and responses to human activities, which together establish a new baseline of site-specific information about several key parameters that can inform targeted conservation planning.

Our respondents suggest that Caucasian grouse and grey partridge have both declined in the study area during recent years, in contrast to local perceptions about the population status of other regionally occurring species such as bear, wolf and wild boar. These across-species comparative differences suggest that reported results are likely to reflect genuine ecological patterns, rather than local cultural attitudes about the general state of environmental resources (Turvey et al., 2015). Further evidence for grouse declines

is provided by the relatively long time periods since most respondents had last seen the species. These findings raise concerns about the local status of galliform populations in general within the ABR, and indicate in particular that Iran's surviving Caucasian grouse population requires both further study and targeted conservation attention.

Several anthropogenic factors have been associated with Caucasian grouse declines across other parts of their range, including both hunting and habitat modification (Baskaya, 2003; BirdLife International, 2016; Darvishi et al., 2015; Storch, 2000). Our results suggest that hunting of grouse has not been a widespread and serious concern within the ABR, and has further decreased as a local activity as the region's grouse population has declined. However, we note that as we did not conduct detailed questioning about levels of hunting offtake due to the sensitivity of this activity, we were unable to quantify levels or patterns of past or present grouse hunting; we therefore cannot yet predict a sustainable regional offtake threshold for the species, and so we recommend caution in assuming that hunting has not contributed to population declines. Population viability analysis should be conducted to better understand the likely vulnerability or resilience of Caucasian grouse to direct offtake within the ABR, as has been modelled for threatened grouse species in other systems (Bro et al., 2000; Hardy et al., 2018; Lu & Sun, 2011).

Conversely, statistical correlations between the local status (survival or extirpation) of grouse populations, and local community environmental interactions and respondent opinions about local environmental changes, suggest that alteration and disturbance of grouse habitat within the ABR is associated with decline and disappearance of grouse populations. Habitat disturbance might also account for the reported decline of grey partridge across the same landscape (Ewald et al., 2010; Kuijper et al., 2009). However, these two information sources provide different, potentially conflicting suggestions as to the type of habitat disturbance that has caused the problem. A local ban on harvesting fodder was put in place when the protected area was established, and respondents considered that vegetation regrowth following this ban was responsible for grouse decline, suggesting a possible perverse outcome of a well-intentioned conservation action that requires further investigation. Alternatively, grouse population survival is statistically associated with lower densities of cows and higher densities of sheep grazing within the local landscape.

Interestingly, both of these suggested extinction drivers are potentially inconsistent with studies on other threatened *Lyrurus* grouse populations. Livestock grazing is known to have an overall negative effect on grouse populations worldwide (Dettenmaier et al., 2017); and taller vegetation associated with reduced sheep grazing has been shown to provide better feeding and chick-rearing opportunities, more successful breeding, and increasing population densities for black grouse (*L. tetrix*) in northern England, associated with increased vegetative food availability and increased invertebrate abundance relative to habitats where grazing was high (Calladine et al., 2002). Taller vegetation resulting from reduced harvesting of forage might therefore be expected to support grouse populations. Conversely, fields grazed by cattle in other landscapes have

been shown to contain twice as many sawfly larvae, a major constituent of the diet of newly hatched black grouse chicks, leading to better black grouse breeding (QMS, 2010), suggesting that livestock grazing might also promote *Lyrurus* grouse populations in some circumstances. It is also possible that the patterns in our data might represent correlation rather than causation, as Caucasian grouse are now restricted within the ABR to rugged highland landscapes in the vicinity of Kalasur, Kharil and Nabijan villages, where it might be naturally harder for people to graze larger livestock; reduced cattle grazing might therefore not be directly responsible for local grouse survival.

The relationship between habitat modification and Caucasian grouse persistence or disappearance is therefore likely to be complex, and possibly influenced by both direct and indirect effects of grazing and direct harvesting of vegetation by local communities for animal feed. The specific dynamics of anthropogenic modification of vegetation, such as timing of harvest, are critical for most grassland birds; understanding the population-level effects of habitat change on Caucasian grouse therefore requires further information on precise timing, frequency, duration and spatial pattern of both grazing and harvesting, and on grazer densities across priority grouse landscapes (Dettenmaier et al., 2017). It is also important to identify the specific local land-use activities that are particularly threatening to grouse, and that can therefore potentially be modified to support human–grouse coexistence. Such modification should take into account the dependence of marginalized subsistence communities upon agricultural landscapes within the ABR, and avoid a significant major negative impact on local human livelihoods; these communities already face financial penalties if they hunt birds and graze livestock. However, our findings highlight the importance and urgency of further assessment of the effects of habitat disturbance on Caucasian grouse survival within the ABR. Research has documented the loss of important grouse habitat from this region using remote sensing data (Darvishi et al., 2015); we recommend that additional investigation should be conducted using multiple approaches, including further community-based data collection to understand local histories of human–environmental interaction, alongside field-based analysis of vegetation structure and change at local scales.

Finally, our results also demonstrate the importance of education to promote awareness and positive conservation values in local people about grouse and other wildlife. Feedback from respondents suggests that some of the reported decrease in grouse hunting is associated with positive conservation attitudes in local communities, although we note that this decrease is also associated with conservation enforcement and the increasingly rare status of the grouse population. Our statistical analyses also demonstrate that wealthier families are more likely to know about grouse, which might represent an indirect relationship with education, as wealthier families in rural communities within this region typically attend school for longer (Shafiei et al., 2019). However, almost no respondents had received any education about environmental issues from any stakeholder organization within the past 3 years. We therefore encourage the development of targeted conservation education campaigns for

rural communities within the ABR, including to explain the potential effects of different conservation and land-use practices on grouse and other species (Nelson et al., 2012), to support Caucasian grouse conservation and promote protection and sustainable use of wider biodiversity. Conservation education activities could also make use of local television programmes, the Internet and social media to provide information on relevant environmental issues (Fien et al., 2001; Ghanbari et al., 2019; Zhang et al., 2020).

We were not able to investigate all potential threats to Caucasian grouse in this study, such as possible predation by sheepdogs (Storch, 2000). This alpine species and its habitat are also likely to become progressively impacted by climate change (Habibzadeh et al., 2021). We acknowledge that we cannot directly assess the accuracy of local perceptions of grouse population dynamics and threats, as there is no comprehensive independent ecological monitoring baseline for understanding grouse population change and associated environmental change in this region to cross-validate our data, as has been conducted in studies of other social-ecological systems (Cuyler et al., 2020; Zayonc & Coomes, 2022); indeed, this knowledge gap is the reason why we undertook this study. We also recognize that our interview data are not necessarily comprehensive. For example, female respondents were undersampled in our study, but may have differing LEK about Caucasian grouse and differing awareness and attitudes about conservation, as demonstrated in other community-based studies in Iran (Plieninger et al., 2020). Data about illegal hunting of grouse or other wildlife obtained through direct interviews may also be limited due to respondent reticence or dishonesty, with specialist interview techniques for dealing with sensitive topics likely to be required to establish more reliable baselines (Nuno & John, 2015). However, our findings provide an important new framework to understand potential threats to the Caucasian grouse, across a conservation priority landscape where the suggested impacts of different anthropogenic activities on local grouse populations were previously poorly understood, and we highlight how these findings also identify further applied research needed to understand the effects on grouse survival of vegetation structure and changes in land management. Our results further reveal that current conservation methods are not supported by local people within the ABR, with most respondents disagreeing with the strict conservation measures currently in place.

The Caucasian grouse is urgently in need of further targeted research using ecological field methods within the ABR and more widely across its range, to establish robust observational baselines on its local status, habitat requirements, trends and interactions with human-modified landscapes. Such research is essential to evaluate the species' global status, and to assess whether similar declines are also occurring elsewhere, potentially necessitating a revision of its Red List status. However, engaging with local communities in the ABR to understand their LEK and conservation awareness is an important process for co-producing knowledge and identifying culturally sensitive conservation initiatives. Providing these urgently needed spaces of interaction is likely to be central to successful protection of Caucasian grouse in the ABR, in conjunction with further

conservation research. We recommend that a new management system should be developed for Caucasian grouse conservation, involving participation and co-management by local communities, and rigorous evaluation of sustainable resource use within the wider social-ecological system.

AUTHOR CONTRIBUTIONS

Sajad Ghanbari and Samuel T. Turvey conceived the ideas and designed the methodology; Sajad Ghanbari collected the data; Sajad Ghanbari and Samuel T. Turvey analysed the data; Sajad Ghanbari and Samuel T. Turvey led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose.

DATA AVAILABILITY STATEMENT

Data can be accessed at: <https://zenodo.org/record/6959991#.Yurv5xQzblU>.

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