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Perspective

Livestock grazing in protected areas and its effects on large mammals in the Hyrcanian forest, Iran

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ABSTRACT

Protected areas are the most important tool to safeguard large mammals from overexploitation, but their effectiveness is insufficiently studied in temperate ecosystems. The Hyrcanian forest is one of the oldest and most threatened temperate forests globally. Anthropogenic activities are widespread and negatively affect wildlife species in the Hyrcanian forest. We conducted surveys in ~22% of the Hyrcanian forest by walking 1204 km in 93 16-km^2 cells distributed randomly in 18 protected and non-protected study sites. We used Bayesian occupancy modeling to measure the effects of livestock grazing, logging and poaching on distribution of six large mammal species. Our results explicitly show that grazing had negative and significant impact on the occupancy of very patchily distributed Persian leopard ($\beta = -1.65$, Credibility Interval -2.85 to -0.65), Caspian red deer ($\beta = -1.36$, CI -2.34 to -0.45) and roe deer ($\beta = -1.61$, CI -2.96 to -0.58) while logging did so for red deer ($\beta = -0.82$, CI -1.69 to -0.03). Poaching could not be determined due to low detectability of poaching signs. Grazing intensity was high in protected areas (IUCN category V), no-hunting and non-protected areas and much lower in national parks (II) and wildlife refuges (IV). Representing 66% of total reserves in the Hyrcanian forest, category V protected areas urgently require priority actions in assessment of grazing capacities, allocation and enforcement of grazing quotas, and better coordination between governmental conservation and natural resource management organizations to avoid further depletion of the large mammal community in the Hyrcanian forest.

1. Introduction

Protected areas are the cornerstone of conservation, but many of them lose rare and ecologically sensitive large mammals at alarming rates due to insufficient size and poor protection from overexploitation and other threats (Watson et al., 2014; Maxwell et al., 2016). Albeit many studies reporting local species extirpations from logging, grazing and poaching in tropical regions, the effects of these threats on

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temperate ecosystems remain understudied (Brodie et al., 2015) since most temperate forests have already lost many large species.

Livestock grazing, logging and poaching are among the main drivers of biodiversity loss but their effects can be both synergistic and contrasting across different species (Brodie et al., 2015; Maxwell et al., 2016). For example, logging and grazing may improve food supply for predators but also provoke human-predator conflicts and poaching (Laurance et al., 2008).

Livestock grazing inflicts intense landscape degradation and has multiple effects on large mammal distributions (Karanth et al., 2011; Ripple et al., 2014, 2015). Livestock causes large-scale changes in vegetation structure and adversely affects native herbivores via trophic competition (Maxwell et al., 2016; Gordon et al., 2017). Logging simplifies the complexity of forest ecosystems and reduces habitat quality (Müller et al., 2016). In addition, logging and grazing contribute to road development which increases habitat accessibility to poachers, thus exerting substantial effects on the survival of large mammals (Laurance et al., 2008; Brodie et al., 2015; Maxwell et al., 2016).

The Hyrcanian forest (hereafter, HF) located in Iran and Azerbaijan is a Tertiary relict temperate forest of high conservation value due to the exceptional diversity of landscapes and species converging between Asia, Europe and Africa (Fig. 1). It is part of the Caucasus Biodiversity Hotspot and harbors a diverse community of large mammals, such as the Persian leopard (*Panthera pardus saxicolor* Pocock, 1927), brown bear (*Ursus arctos* Linnaeus, 1758), grey wolf (*Canis lupus* Linnaeus, 1758), Caspian red deer (*Cervus elaphus maral* Ogilby, 1840), roe deer (*Capreolus capreolus* Linnaeus, 1758) and wild boar (*Sus scrofa* Linnaeus, 1758) (Olson and Dinerstein, 1998; Firouz, 2005). The last Caspian tiger (*Panthera tigris virgata*) was killed in 1953 in the Hyrcanian forest (Firouz, 2005). Sixty percent of the HF is under legal protection and natural resource use is managed by the government (Zehzad et al., 2002; Firouz, 2005; Makhdoum, 2008; Dabiri et al., 2010; Müller et al., 2017).

Several laws to protect plant biodiversity in Iran's forests have been implemented, such as the forest nationalization law (1963), the law banning livestock grazing inside core zones of protected areas and wildlife refuges (1982) and the law on livestock exclusion from all HF (1989). Since 1956, hunting inside protected areas is permitted only under special licenses (Firouz, 2005). Despite these legislative acts, human activities such as grazing, logging, poaching and wood collection are widespread and unorganized in the HF (Firouz, 2005; Makhdoum, 2008; Sagheb-Talebi et al., 2014; Ghoddousi et al., 2017a; Müller et al., 2017). Due to overexploitation, the forest cover of Iran has halved during the past five decades (Ghoddousi et al., 2017a). Nowadays, about 4 million livestock are roaming across the HF, leading to overgrazing (Sagheb-Talebi et al., 2014), deterioration of forest regeneration and forest recessions, especially in lowlands (Akhani et al., 2010). The Hyrcanian forest cannot supply sufficient fodder for livestock and its current economic use is unsustainable (Noack et al., 2010). In Golestan National Park, Iran's oldest reserve, the red deer population has declined by 89% since the 1970s due to poaching motivated by subsistence, leisure and hostility toward park staff and conservation laws (Ghoddousi et al., 2017b).

While understanding of the effects of human threats on the distribution of large mammals is among the top conservation priorities in this region, it largely remains overlooked by scientists and conservationists. The paucity of information and conservation guidance is particularly evident at large scales, which is critical considering the spatial requirements of populations of these species (Ripple et al., 2015). In this study, we combined intensive field surveys and Bayesian occupancy modeling to document the effects of overgrazing, logging and poaching on the distribution of six large mammal species throughout the HF. We also assessed the efficiency of protected area categories in preservation of large mammals. Further, we discuss the management actions required to address declines of large mammals in the Hyrcanian forest.

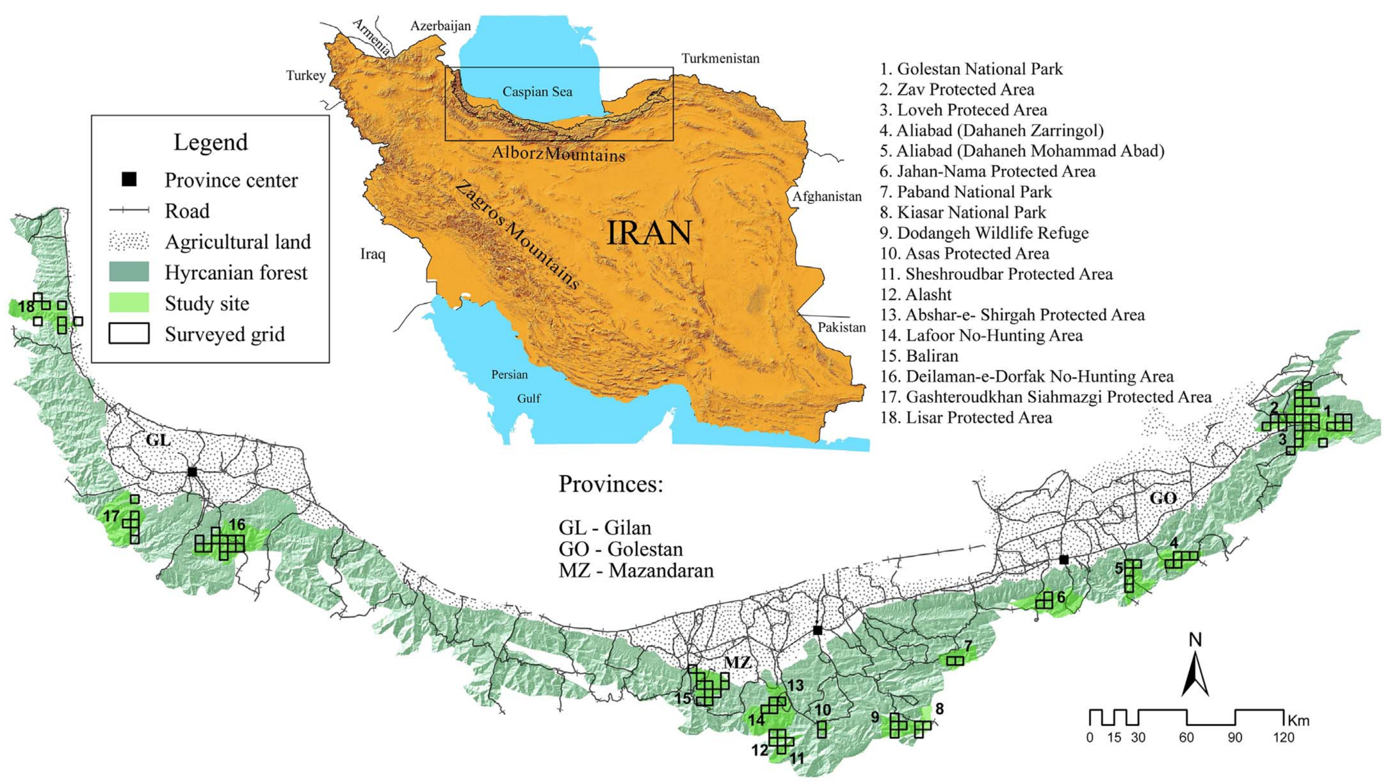

Fig. 1. The map of the study areas across the Hyrcanian forest, northern Iran.

2. Material and methods

2.1. Study area

The Hyrcanian forest forms a green arc along the Caspian Sea. It expands from the Talysh Mountains in Azerbaijan through the northern slopes of the Alborz Mountains to Gollidagh in eastern Iran with elevations ranging from −28 to 2800 m. The mean annual precipitation ranges from 530 to 1350 mm, occasionally reaching up to 2000 mm in the western parts. The mean air temperature of the warmest and coldest months varies from 28–35 °C to 1.5–4 °C, respectively. The lowland forests are dominated by *Zelcova carpinifolia*, *Gleditsia caspica* and *Pterocarya fraxinifolia* with regular presence of *Parrotia persica*. In montane areas, tree dominance shifts to *Quercus castaneifolia*, *Carpinus betulus*, *Fagus orientalis* and *Quercus macranthera* depending on temperature regimes. The forest understory is covered mainly by *Ruscus hyrcanus*, *Ilex spinigera*, *Buxus hyrcana* and ferns (Sagheb-Talebi et al., 2014).

2.2. Study design

We assessed the impact of anthropogenic threats on the Persian leopard, brown bear, grey wolf, Caspian red deer, roe deer, and wild boar. We selected 18 study areas, covering 4015.60 km^2 and including three national parks (NP), eight protected areas (PA), one wildlife refuge (WR), two no-hunting areas (NHA) and four non-protected areas (NPA) throughout the HF (Fig. 1). We placed a regular grid of 4 × 4 km cells over the study areas using the Hawth's Tools in ArcGIS 10.2 (ESRI Co., USA). Cell size was based on an approximate average home range size of all target species (Yackulic et al., 2011; Kiffner et al., 2013). For surveys, we randomly selected ∼45% of the total number of cells in each study area.

The single-season occupancy framework assumes that the occupancy state of the species does not change in a site within a season (MacKenzie et al., 2006) and we assumed that our survey periods were short enough to comply with this assumption. We considered surveyed cells as sites and the entire period of surveys as a season. During three survey periods (August–October 2015, February–April 2016 and August–October 2016), we surveyed most cells by a team of 2–3 people led by an experienced ranger or a local guide who could unambiguously identify signs of target species and anthropogenic threats. We walked along random trails of 2–13 km inside each selected cell and recorded the presence of fresh signs (tracks, scratches, scrapes, feeding and resting places, and wallows) and direct observations (sightings and sounds) of species at 200 m intervals (Karanth et al., 2011). Concurrently, we recorded the occurrence of anthropogenic threats such as the signs of poaching (encounters with poachers, gun shells, gunshots), logging (cut trees, logging activities), and livestock grazing (cattle, sheep, goats and domestic dogs). Each survey team took photographs of animal and threat signs for final identification. To minimize the observer bias, we rotated team members between study areas and sites (MacKenzie et al., 2006).

2.3. Analysis

We used the presence (1) and absence (0) data on each species across cells as the response variables. The intensities of logging, poaching and livestock grazing represented the predictors. These intensities were quantified as the proportions of the number of 200-m trail segments with signs to sampling effort (km of trails walked per cell and survey). Additionally, we considered sampling effort as a predictor of detection probability (MacKenzie et al., 2006). We calculated Spearman's *rho* for rank correlation among predictors and used posthoc tests in R packages ‘nparcomp’ to compare grazing intensities among the study areas with different protection levels. We took the IUCN categories of study areas from Protected Planet (www.protectedplanet.net). For each species, we quantified the effects of threats on their occupancy probability ψ while simultaneously accounting for imperfect detection and sampling efforts. Specifically, ψ of each species in cell i was described as:

$$\mathrm{logit}(\psi_i) = \alpha_\psi + \beta_{\mathrm{livestock}}\, x_{\mathrm{livestock},i} + \beta_{logging}\, x_{\mathrm{logging},i} + \beta_{\mathrm{poaching}} x_{\mathrm{poaching},i}$$

To assess ψ by the observed presence-absence data for each species, we modeled the probability of true occurrence z of each species in cell i as a random variable derived from the Bernoulli distribution with probability ψ:

$$z_i \sim Bernoulli(\psi)$$

Occupancy models treat the observed presence (or absence) of a species at survey j as an outcome of a detection process, i.e. a random Bernoulli variable defined by z and the sign detection probability p:

$$y_{ij} \sim Bernoulli(z_i \times p_{ij})$$

The quantification of detection probability p allows including possible impacts of bias arising from variability in sampling effort:

$$\mathrm{logit}(p_{ij}) = \alpha_p + \beta_{\mathrm{effort}} y_{ij}$$

We used the Bayesian occupancy modeling in R2JAGAS package of R (Plummer, 2003; Su and Yajima, 2015; R Core Team, 2016; see models in Appendix 1). Apart from adaptability to low sample sizes, the Bayesian framework offers flexibility in regard to missing observations (Kéry, 2010; Dorazio and Rodríguez, 2012). Threat effects on species occupancy were assessed from the posterior distributions of the intercept α and slope β. The direction of threat effects was determined from positive or negative estimates of β. The significance of difference of threat effects from 0 (no effect) was assessed from the overlap of the credibility interval (CI) with 0. The CI ranges between 2.5 and 97.5 percentile of the posterior distribution. We ran three chains with 100,000 iterations to assess the posterior distribution of the coefficients from the estimation of their prior distribution. We chose a vague prior from the uniform distribution with the boundary estimates of α and β from −10 to 10 (Kéry, 2010). The first 20,000 iterations were discarded. Chains were thinned to every 40th value of the iteration to avoid autocorrelation. Convergence of three chains was assured by Gelman et al. (2014) statistics and achieving a minimum effective posterior sample size of 100 (Kéry, 2010).

3. Results

We walked 1204 km of trails during 147 field days and recorded 2876 signs of six mammal species (Appendix 1). Overall, we surveyed 93 cells, of which 45 cells were surveyed three times, 21 twice and 27 once for logistical reasons (Table 1). The intensities of grazing and logging were most correlated (r = 0.59), followed by logging and poaching (0.39), and grazing and poaching (0.37).

Signs of both roe deer and red deer were absent in Zav PA, Lisar PA and Lafoor NHA (Fig. 1). The roe deer was absent in Alasht. The Persian leopard was absent in Paband NP and Lisar PA. The grey wolf and red deer were absent in Abshar-e-Shirgah PA. Wild boar and brown bear were present in all sites. Grazing had the highest intensity (0.92, CI 0.78 to 1.05), logging had intermediate (0.52, CI 0.42 to 0.62) and poaching had the lowest (0.14, CI 0.11 to 0.18).

The leopard had a moderate detection probability (p = 0.70, CI 0.61 to 0.77), but fragmented distribution (ψ = 0.88, CI 0.27 to 0.99). Leopard occupancy was negatively affected by grazing (β = −1.65, CI −2.85 to −0.65) (Fig. 2). The grey wolf had the lowest detection probability regardless of effort (p = 0.25, CI 0.18 to 0.34), but it was present in all study areas (ψ = 1, CI 0.81 to 1). The brown bear was present in all study areas (ψ = 0.99, CI 0.51 to 1) and had a moderate detection probability (p = 0.62, CI 0.54 to 0.71), which increased with effort (β = 0.38, CI 0.04 to 0.75; Fig. 2). The red deer had very

Table 1
The distribution of anthropogenic threats in study areas throughout the Hyrcanian forest. Abbreviations: IUCN – International Union for Nature Conservation, NHA – no-hunting area, NP – national park, NPA – non-protected area, NR – not reported, PA – protected area, WR – wildlife refuge.

Area	Size (km^2)	No. cells	IUCN category	Proportion of grid cells with presence of anthropogenic threats		
				Grazing	Logging	Poaching
Golestan NP	874.02	14	II	0.37	0	0.12
Zav (A & B) PA	143.23	8	NR	1	0.57	0.70
Loveh PA	33.49	3	NR	0.89	0.78	0.33
Aliabad (Dahane Zarringol) NPA	121.67	5	–	0.89	0.78	0.11
Aliabad (Dahaneh Mohamm Adabad) NPA	82.94	5	–	1	0.80	0.20
JahanNama PA	317.47	3	V	0.89	0.22	0
Paband NP	181.45	2	NR	1	0.50	0.50
Kiasar NP	92.65	2	–	1	0.50	0.50
Dodangeh WR	169.04	5	IV	0.60	0.53	0.53
Asas PA	29.97	2	V	1	1	1
Sheshroudbar PA	79.22	2	NR	1	0	0.50
Abshar-e-Shirgah PA	36.39	1	V	1	0.50	0.50
Lafoor NHA	363.52	3	–	1	1	1
Alasht NPA	129.11	3	–	1	0	0.33
Baliran NPA	206.00	10	–	0.96	0.93	0.52
Deilaman-e-Dorfak NHA	448.86	10	–	0.64	0.64	0.57
Gashteroudkhan-Siahmazgy PA	395.14	8	V	1	0.17	0.50
Lisar PA	311.42	7	V	1	0.79	0.63
Total	4015.60	93	–	0.90	0.54	0.47

fragmented distribution ($\psi = 0.71$, CI 0.13 to 0.97), but a moderate detection probability ($p = 0.78$, CI 0.70 to 0.86). Red deer occupancy strongly decreased with grazing ($\beta = -1.36$, CI -2.34 to -0.45) and logging ($\beta = -0.82$, CI -1.69 to -0.03) (Fig. 2). Compared to other studied species, roe deer had the most limited and highly fragmented distribution ($\psi = 0.67$, CI 0.10 to 0.97), with low detection probability ($p = 0.55$, CI 0.43 to 0.67). Roe deer occupancy was negatively affected by grazing ($\beta = -1.61$, CI -2.96 to -0.58). Wild boar was the most widespread and highly detectable species ($\psi = 1$, CI 0.80 to 1; $p = 0.95$, CI 0.91 to 0.98) and its detection probability significantly increased with effort ($\beta = 1.47$, CI 0.55 to 2.55) (for detailed models and data see Appendix 2). Grazing intensity was significantly higher in PA vs. NP (F-value = 6.18, $p < 0.001$), NPA vs. NP (F-value = 5.70, $p < 0.0018$), and NHA vs. NP (F-value = -2.99, $p = 0.04$) (Fig. 3).

4. Discussion

Our results show that livestock grazing strongly and negatively affects the distribution of the Persian leopard, Caspian red deer and roe deer in the HF. These species are threatened either globally or nationally, and have very patchy distributions in this region. The two deer species and the leopard appear to be locally extinct in some study areas. The fact that most of these areas are officially protected and located within the distribution areas of these species raises a serious concern regarding the effectiveness of conservation efforts in the HF. Our study region is believed to be the stronghold for survival of the globally endangered Persian leopard in the Middle East (Kiabi et al., 2002; Farhadinia et al., 2015), but our results suggest a high degree of fragmentation of its population. Additionally, our results suggest that the red deer is under persistent pressure from logging which may facilitate access of poachers to core zones and lead to increased poaching (Laurance et al., 2008; Brodie et al., 2015). We did not find significant effects of poaching on red deer or other species, possibly due to low detectability of poaching signs (Brodie et al., 2015; Rauset et al., 2016). In contrast, fine-scale studies demonstrate drastic declines of red deer due to poaching, e.g. in Golestan National Park by 89% from 2096

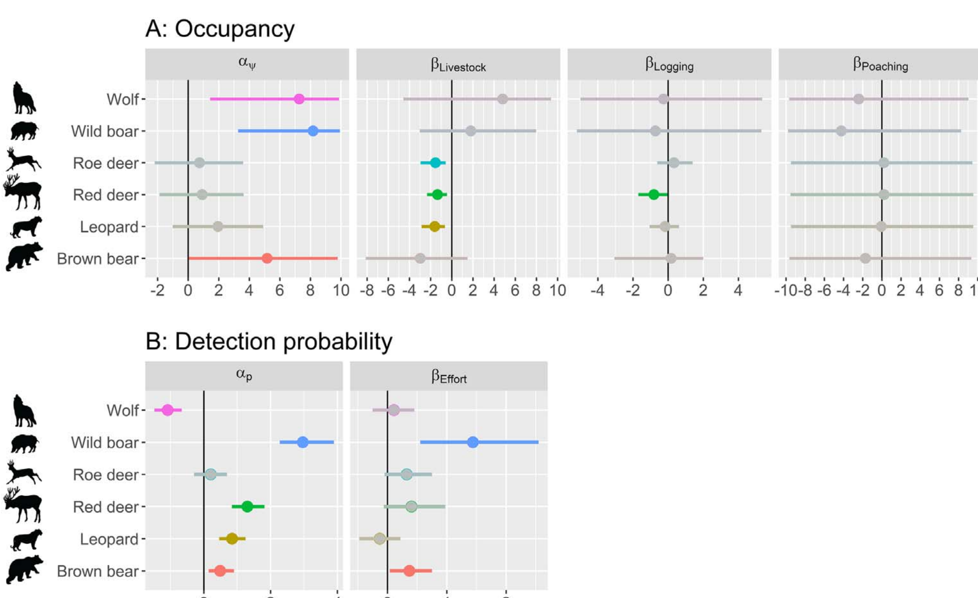

Fig. 2. The alpha (intercept) and beta (slope) coefficients of Bayesian single-season occupancy models and their 95% credibility intervals estimated for six large mammal species in the Hyrcanian forest. The credibility intervals intersecting with zero are shaded.

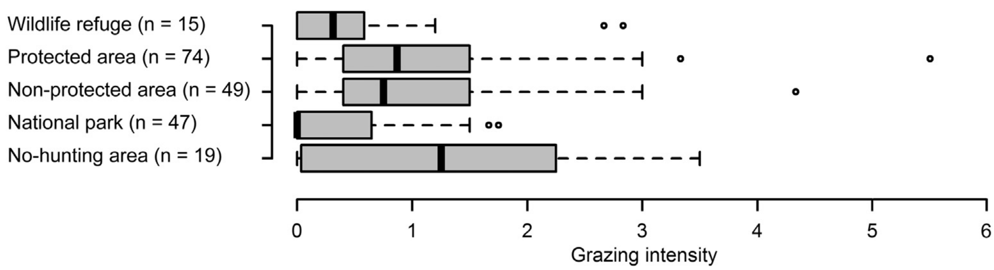

Fig. 3. Comparison of livestock grazing intensities across 18 study areas in the Hyrcanian forest. The numbers of grid cells surveyed in study areas are indicated in the parentheses. Circles indicate the outliers of the grazing intensity from individual field surveys.

individuals in 1976–1977 to 194–257 individuals in 2015–2016 (Kiabi et al., 2004; Ghoddousi et al., 2017b; Soofi et al., 2017). Possibly, the count of poaching signs is an inappropriate metric of poaching pressure because poachers tend to act in areas where animals are available, resulting in a positive correlation between poaching and prey populations (Brodie et al., 2015). Moreover, poaching can go undetected in forests due to dense vegetation, litter and secretive trails (Laurance et al., 2008).

We demonstrate that livestock grazing is the main threat affecting large mammal distribution in the HF. Therefore, it should be effectively managed through the assessment of the carrying capacity of pastures, allocation of grazing quotas and their enforcement. Local people still strongly depend on forest for pastures during the snow-free seasons. Since 1982, grazing has been permitted in 80% of the territories of protected areas (IUCN category V) and wildlife refuges (IUCN category IV), putting these reserves under serious pressure of overgrazing. We confirmed high levels of grazing in protected areas, but not in the wildlife refuge. Category V protected areas represent about 66% of the total coverage of reserves in the HF compared to only 0.01% of wildlife refuges and 0.10% of national parks. Herders hold official permits with specified sizes of pastures and grazing periods, but often overuse pasture lands and penetrate deep into the core zones under non-existing land allotments and inefficient governmental control. Such large-scale encroachment makes large mammals retreat into non-protected lands and clash with rural people (Farhadinia et al., 2015; Khorozyan et al., 2015).

Grazing control is impossible without the enforcement of better coordination between the Iranian governmental organizations responsible for conservation (Department of Environment, DoE) and natural resource management (Forest, Rangeland and Watersheds Organization, FRWO). Traditionally, DoE is responsible for the control of non-compliance activities inside reserves, but the enforcement of logging and grazing control inside and outside reserves is under the credentials of FRWO (Makhdoum, 2008; Dabiri et al., 2010; Kolahi et al., 2012). However, interests and management strategies of the two agencies often collide in protected areas and wildlife refuges. There is no clear separation of responsibilities of DoE and FRWO in these areas, where grazing is occurring on 80% of lands and prohibited in core zones covering only 20% (Makhdoum, 2008). The same situation is in national parks where DoE and FRWO lack cooperation and coordination in managing illegal grazing and logging. Poaching control is the responsibility of DoE alone. Thus, there is much uncertainty in mechanisms of cooperation between these two organizations and the development of inter-agency policy is a priority need. Inadequate cooperation between DoE and FRWO can be illustrated by the example of adverse effects of logging on red deer. Red deer is the only studied large mammal strongly preferring mixed forests with dense shrubs (Kiabi et al., 2004), but its populations suffer from habitat deterioration caused by the even-aged tree management system and removal of fallen or dead woods (Sagheb-Talebi et al., 2014; Müller et al., 2017).

5. Conclusions

We conclude that the existing governmental actions are insufficient to alleviate the pressure of human activities on large mammals in the Hyrcanian forest. Fragmented distribution of such sensitive species as the leopard, red deer and roe deer may reflect systemic failures of management, law enforcement and budget constraints (Watson et al., 2014; Rauset et al., 2016) while the satisfactory status of grey wolf, brown bear and wild boar is achievable due to their high tolerance to humans. However, even these common species may need stronger conservation action as wolves and wild boars have been intensively persecuted for livestock and crop damage, respectively (Ripple et al., 2014). We emphasize the need for stricter law enforcement regarding overgrazing and poaching under the consideration of improvements of rural livelihoods. Furthermore, clear land use zoning of reserves should be developed and stringently managed (Kolahi et al., 2012). All these efforts should be participatory to minimize conflicts with local communities (Rauset et al., 2016) and coordinated by DoE and FRWO.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2017.11.020.

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