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HABITAT MODELING AND CONSERVATION OF THE ENDEMIC LATIFI'S VIPER (*MONTIVIPERA LATIFII*) IN LAR NATIONAL PARK, NORTHERN IRAN

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***Abstract*.—Latifi's Viper (*Montivipera latifii*), an endemic viper in the Alborz mountain chains in Iran, is facing serious threats within its last stronghold, the Lar National Park. The little information available on the distribution, population dynamics, and ecology of this scarce species, as well as its major threats, has hampered effective conservation planning. The present study was carried out to identify the main threats that affect Latifi's Viper within Lar National Park. We accomplished this by conducting a threat matrix analysis, based on discussion with herpetological experts in this region. We also attempted to better understand the ecology of this species through habitat modeling, based on presence-absence surveys. We found that overgrazing, illegal collection, and intentional killing, as well as isolation of populations and consequently inbreeding depression, are the main threats facing Latifi's Viper. The results of habitat modeling indicated that slope, herbaceous vegetation, and stone cover significantly affected habitat selection in spring while slope, tall and short herbaceous vegetation, tall grass cover, and stone cover affected habitat selection in summer. Our results confirm a slight difference in habitat preference of Latifi's Viper between the two seasons. These findings are important in identifying the most suitable habitats for this species within Lar National Park. They can also be crucial for adjusting the park's Latifi's Viper conservation and management plans accordingly.**

Key Words.—analytic hierarchy process; binary logistic regression; habitat selection

INTRODUCTION

Latifi's Viper (*Montivipera latifii*) is endemic to the Alborz Mountain chain in Iran (Latifi 2000; Rajabizadeh et al. 2012). Although several species exist within this genus, Latifi's Viper can be distinguished from congeners by its polymorphic color pattern (Fig.1). This species is categorized as Endangered on the International Union for Conservation of Nature's (IUCN) Red List of threatened species due to its limited distribution range (< 500 km^2) and population size (< 2,000 mature individuals; Nilson 2009). Although earlier records of Latifi's Viper exist from various localities in the central Alborz Mountains, it is now likely restricted to the upper Lar River Valley in Lar National Park, an area that receives partial protection from the Iranian Government (Nilson 2009). The previously occupied regions that fall outside of Lar National Park boundaries are now heavily populated and unlikely to be suitable for Latifi's Viper.

As a group, vipers are generally considered at-risk due to various factors. These include their small home-range size, low dispersal rate (Gregory et al. 1987), slow growth rate, delayed sexual maturation (Parker and Plummer 1987), low reproductive frequency (Saint Girons 1992), seasonal shifts in habitat use (see Prestt 1971; Moser et al. 1985), and high specialization in feeding habits (Bea et al. 1992; Santos et al. 2006). Moreover, being venomous snakes, vipers are often either disliked and killed by people or illegally collected for the pet-trade (Dodd 1987). Habitat loss also substantially impacts viper species, because it can result in population fragmentation, loss of genetic diversity, and local extinctions (Jäggi et al. 2000; Ujvari et al. 2002).

Very little is known about the ecology of Latifi's Viper in Iran. Furthermore, information is lacking on the primary threats that impact this species. The primary goal of our research was to create a framework for the enactment of conservation initiatives related to Latifi's

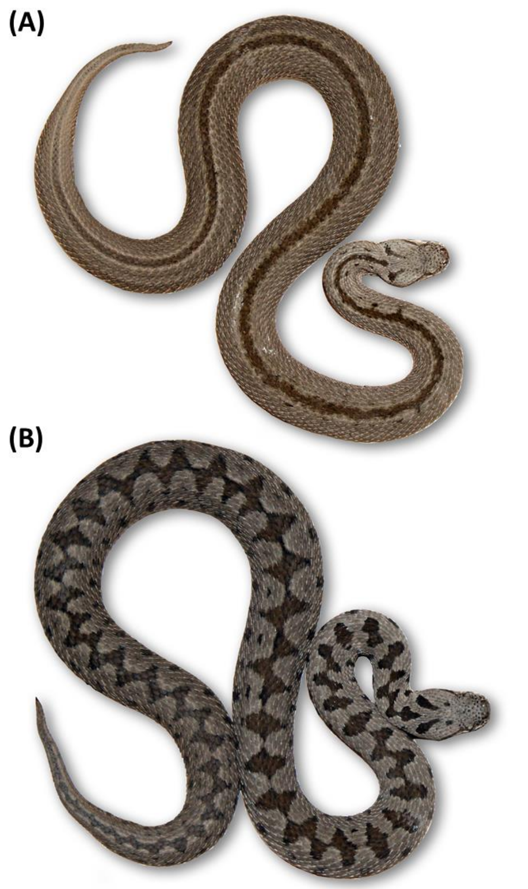

FIGURE 1. Color patterns of Latifi's Viper, *Montivipera latifii*. Two general morphs have been identified (Rajabizadeh et al. 2012): stripy morph (A) and zigzag morph (B). (Photographed by Alireza Hashemi).

Viper in Lar National Park. To compensate for the little published data available on the conservation concerns associated with this species, we set out to identify the most important threats through analysis of expert knowledge via Analytic Hierarchy Processes (AHP). We also attempted to elucidate aspects of this species ecology, specifically related to environmental parameters affecting habitat selection in each season. We believe a better understanding of this snake's habitat needs will provide a mechanism to develop effective strategies for habitat management and/or conservation related to Latifi's Viper.

MATERIALS AND METHODS

***Study area.*—**We studied vipers in the 27,547 ha Lar National Park (35°52'–36°05'N, 51°33'– 52°59'E), 70 km northeast of the capital city of Tehran, Iran (Fig. 2). Lar National Park was originally designated as a protected area for large mammals such as Alborz Red Sheep (*Ovis orientalis*), Wild Goat (*Capra aegagrus*), Persian Leopard (*Panthera pardus*), and Brown Bear (*Ursus arctos*). Lar National Park is located at an elevation range of 2,505–4,253 m a.sl., in an area of the Alborz Mountains that receives heavy snow fall in the winter. The Lar Valley, with a length 70 km and a width of 7 km, supports various reptiles such as *Laudakia caucasia*, *Vipera ebneri*, and *Gloydiushalys*. Alpine steppe vegetation dominates the landscape, comprised largely of *Eremurus spaectabilis*, and *Onobrychis cornuta*, with *Dactylorrhiza umbroza*, growing in the marshy areas of the valley (Shahrab Mohit Consulting Engineers, unpubl. report). Vegetation cover is highest in spring, reaching 75% of land area, but is reduced as nomadic herders settle in the park in summer, when only bushes and shrubs such as *Astragalus* sp. and remains of some other herbs can be found (Shahrab Mohit Consulting Engineers, unpubl. report).

***Identification of threats.*—**Data on the threats to Latifi's Viper are few, and limited to observations of researchers or park rangers who are familiar with the species and have worked in the study area. We used this expert knowledge, through the Analytic Hierarchy Process (AHP), to gain a basic understanding of the most important threats facing Latifi's Viperin Lar National Park. Developed by Saaty (1980), AHP belongs to the family of multi-criteria decision-making techniques. This method is particularly useful because it weighs conflicting objectives via paired-comparisons (Saaty et al. 2003). The AHP uses a fundamental scale of absolute numbers from 1 to 9 (see Appendices) to express individual judgments and then ranks criteria or conflicting objectives based on the weights calculated from expert opinions. The AHP also determines inconsistency of judgments mathematically through calculation of a consistency ratio (CR). The CR is based on the proportion of reciprocal matrices, and a CR value of 0.1 or less indicates that the elicited responses are acceptable (Saaty 1980). The AHP analysis was based on a questionnaire (Appendix 1) completed by 15 professionals whom we considered experts on this species based on past research or interactions with it. We conducted the AHP analysis with the Expert Choice software (Expert Choice 1999) to calculate the quantitative scale of the expert opinion as the criteria weight.

***Field surveys and data collection for modeling.*—**Previous studies on vipers have suggested that factors such as topography (e.g., altitude, slope), climate (e.g., precipitation, evapotranspiration, and minimum and maximum temperature), and land cover are the best predictors of occurrence (Martínez-Freiría et al. 2008). Prey abundance (Sawant et al. 2010) and human-related variables, such as landscape alterations and human density (Santos et al. 2006), have also been identified as

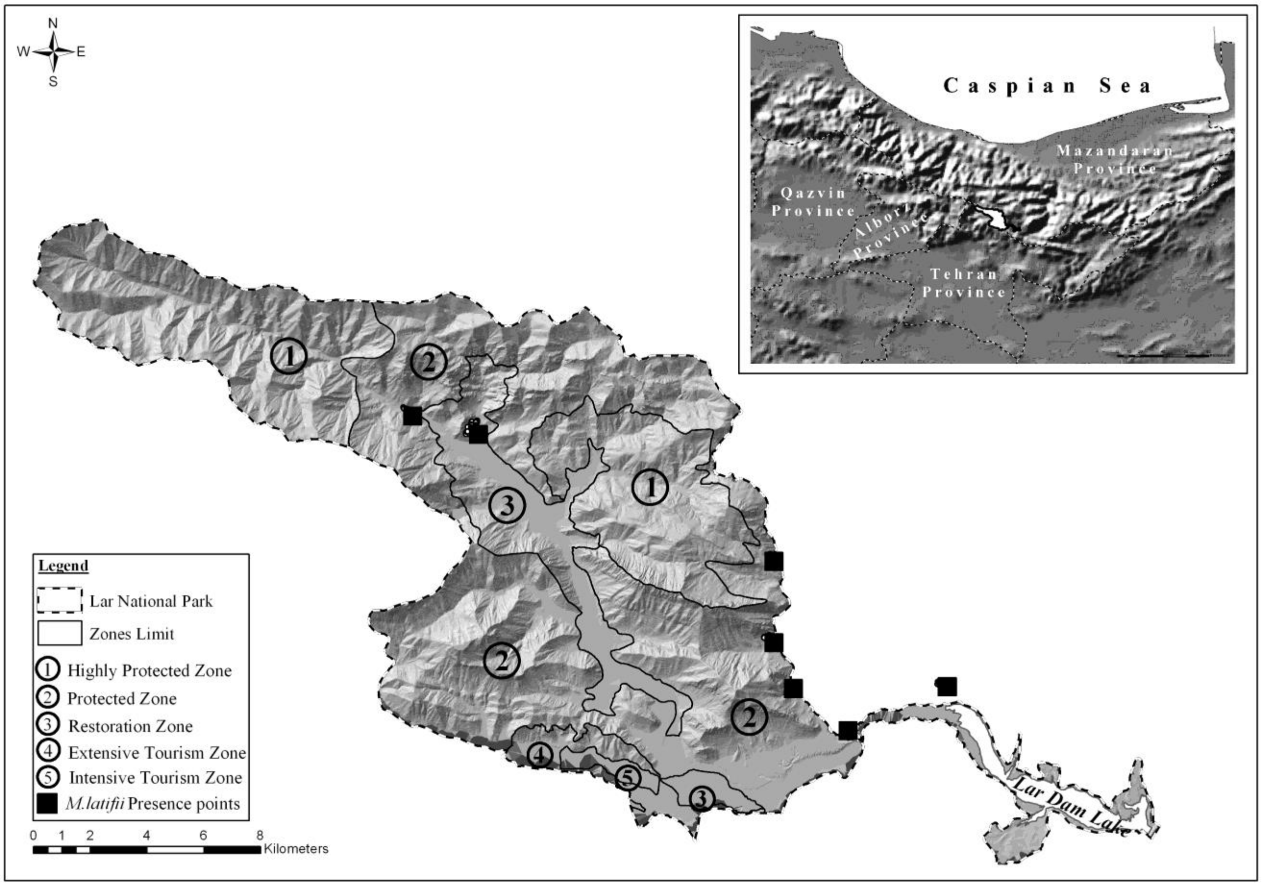

FIGURE 2. Location of Lar National Park within Alborz mountain chain. Zonation of the park based on its present management plan is shown. The Lar Dam, with a height of 105 m and crown length and width of 52.3 and 35.4 m, respectively, has a maximum reservoir area of 17 km^2. The dam is used for producing hydroelectric power and also to provide drinking water for the capital city of Tehran.

affecting viper habitat selection. Based on this knowledge and our observations of Latifi's Viper behavior in Lar National Park, the following variables were recognized to be the most important in the habitat selection of this species: (1) elevation, (2) slope, (3) aspect (degrees), (4) distance to rivers, (5) distance to roads, (6) herbaceous, non grass-like vegetation, < 25 cm (designated Hlow), (7) herbaceous, non grass-like vegetation, > 25 cm (Hhig), (8) tall grass, leaves >25 cm high (Ghig), (9) Chamaephytes (Cham) and (10) stone cover. Classification of vegetation types follows Kaboli et al. (2007).

We identified occupied vs. unoccupied locations in the study area and compared the above-mentioned environmental variables between them to determine which microhabitat features are preferred by Latifi's Viper. We carried out our field observations in spring/summer of 2008 and 2009. Before starting the actual sampling, we set out to determine the minimum number of visits to each plot that would be necessary to ascertain the absence of Latifi's Viper. We carried out these preliminary surveys by randomly placing 30 plots (12 m × 12 m following Watling and Donnelly 2006), which were searched for Latifi's Vipers on three occasions. The three replicate surveys of a given plot were conducted at 24-h intervals (about 0700–1000) and the level of effort was standardized by time (about 10 min). This number of repetitions (n = 3) has been effectively employed in studies of reptiles with ecological traits and habitat conditions similar to our study species (Kéry 2002; Tibor et al. 2009).

We used this preliminary survey data to estimate the likelihood of detection and minimum number of surveys (N_{min}) necessary to confirm presence/absence of Latifi's Viper in plots of this size (PRESENCE ver. 6.4, single-species/single-season model, assumptions of one group and a constant detection probability [P]; Hines 2006). We chose this model because it generates simultaneous probability estimates for site occupancy and species delectability (Mackenzie 2005a; MacKenzie 2005b; MacKenzie et al. 2002). In a series of sampled sites, site occupancy is estimated based on detection probabilities obtained through multiple sampling attempts at each site. Use of this model assumes that, for the duration of surveys, sites remain occupied, neither mortality nor migration occurs, the detection probability is greater

TABLE 1. Aggregated matrix of the experts' evaluation for the conflicting factors affecting Latifi's Viper in Lar National Park.

	Overgrazing	Development	Roads	Removal	Isolation	Precipitation	Dam	Disturbance	Weights
Overgrazing	1	6.27	5.454	1.863	4.473	7.09	4.634	4.818	0.353
Development		1	1.257	1.024	0.871	1.560	1.927	1.551	0.092
Roads			1	1.009	1.426	2.899	1.421	1.657	0.098
Removal				1	4.576	6.382	6.195	4.654	0.211
Isolation					1	3.848	3.727	3.076	0.107
Precipitation						1	1.355	0.996	0.043
Dam							1	1.155	0.049
Disturbance								1	0.048

than zero, and that detection in a given plot is independent of detection in others. We estimated detection probability as P = 0.538 (CI = 0.400–0.671) and minimum number of visits as N_{min} = 3.03. This result indicated that the number of visits necessary to confirm absence (with 95% confidence) was at least three per survey plot.

After determining the minimum number of surveys, we began data collection by searching the survey plots for Latifi's Viper, with the assistance of a professional snake collector. When snakes were detected, we collected associated data on various environmental variables. We also needed to collect data at "unoccupied" survey plots for comparison. We selected locations for these plots by walking in random directions from known snake locations for 200–500 m, until an observable change in habitat characteristics made it unlikely for Latifi's Vipers to occur. We made three subsequent visits to each established unoccupied plot (determined by N_{min} calculated by data collected at the preliminary survey) to further ensure that Latifi's Viper did not use the location. In total, we measured these variables in 102 plots in spring and 88 plots in summer, with equal numbers of presence and absence plots sampled in each season.

Statistical analysis.—For each season, correlation between variables was tested through a correlation analysis. Two variables, Cham and Hhig, were highly correlated in the in spring (r > 0.70). Subsequently, single-variable logistic regression (Hosmer and Lemeshow 2000) was carried out to identify which of these two variables best fit the data. Hhig produced a model with higher G-value and was therefore chosen for further analyses. Binary logistic regression (Hosmer and Lemeshow 2000) was then applied to all variables that were not correlated to identify important predicting variables for Latifi's Viper habitat selection in each season. Best subsets method based on Akaike's information criterion (AIC) was used to search for the best subset of effects to fit the best model. All regression analyses were performed in STATISTICA 10 (StatSoft, Inc., Tulsa, Oklahoma, USA). To assess model goodness-of-fit, Pearson, Deviance, and Hosmer-Lemeshow tests were applied. The Hosmer-Lemeshow test groups data by their estimated probabilities from lowest to highest, and performs a Chi-square test to determine if significant differences exist between the observed and expected frequencies. These tests were performed in MINITAB 16 (Minitab, Inc., State College, Pennsylvania, USA).

To evaluate the performance of regression models, we used Receiver-Operating Characteristic (ROC) plots (DeLong et al. 1988; Zweig and Campbell 1993). ROC plots show the true-positive rates (sensitivity; rate of occasions when presence is correctly predicted) against the false positive rate (specificity; rate of occasions when presence is incorrectly predicted). The area under the ROC curve (AUC) represents a measure of predictive performance of a model between 0.5 (no predictive value) and 1 (perfect predictive ability). We performed ROC analysis in STATISTICA 10. To determine whether seasonal variation exists between spring and summer habitats, we calculated differences between the values of habitat variables in spring and summer. Because our data did not follow normal distribution (indicated by Ryan-Joiner test), we used the non-parametric Mann-Whitney U test in STATISTICA 10 to determine which variables showed a significant (P < 0.05) seasonal difference.

RESULTS

For the 15 expert surveys returned, the CR value of 0.052 indicated a high consistency among survey responses. The experts considered overgrazing to be the most important threat (relative weight = 0.353) followed by over-collection and intentional killing (relative weight = 0.211) and isolation of remnant populations (relative weight = 0.107; Table1). Hence we considered

TABLE 2. Summary of binary logistic regression analysis of the relationship between Latifi's Viper presence and nine predictor variables. The coefficients, standard errors (SE) and significance of the Wald test (*P*-value) are presented.

Model	Variables included	Coefficient	SE	*P*-value
Spring	Slope	+0.133	0.063	0.035
	Hhig	+0.738	0.302	0.014
	Hlow	-0.747	0.298	0.012
	Stone cover	+0.114	0.037	0.002
Summer	Slope	-0.167	0.069	0.015
	Hhig	-0.314	0.116	0.007
	Ghig	+0124	0.051	0.015
	Hlow	+0.648	0.211	0.002
	Stone cover	+0.119	0.040	0.003

TABLE 3. Results of Pearson, Deviance and Hosmer-Lemeshow tests of goodness-of-fit for spring and summer habitat models.

Model	Method	Chi-square	df	*P*
Spring	Pearson	36.82	92	1.000
	Deviance	32.76	92	1.000
	Hosmer-Lemeshow	2.458	8	0.964
Summer	Pearson	57.37	74	0.924
	Deviance	49.70	74	0.987
	Hosmer-Lemeshow	5.798	8	0.670

these factors as the most likely threats to the long term survival of Latifi's Viper in Lar National Park.

Habitat selection of Latifi's Viper in spring was significantly related to slope, tall and short herbaceous vegetation cover (Hhig and Hlow), and stone cover (Table 2). The most important determinants of habitat selection in summer also included slope, tall and short herbaceous vegetation cover (Hhig and Hlow), tall grass vegetation cover (Ghig), and stone cover (Table 2). Tests indicated a suitable goodness-of-fit for the model (Tables 2 and 3). AUC of the ROC plots showed that predictive ability of both the spring (*AUC*= 0.985) and summer (*AUC*= 0.951) models were high (Fig.3). Significant differences exist between spring and summer habitats in slope ($Z = 7.83$, df = 93, $P < 0.010$), aspect ($Z = 3.88$, df = 93, $P < 0.010$), distance to river ($Z = 5.59$, df = 93, $P < 0.010$, stone cover ($Z = 4.69$, df = 93, $P < 0.010$), tall herbaceous vegetation cover ($Z = 2.52$, df = 93, $P = 0.010$), and short herbaceous vegetation cover ($Z = -3.22$, df = 93, $P < 0.010$; Fig.4).

DISCUSSION

We found that Latifi's Viper shows a varying preference for environmental factors between spring and summer, suggesting that this species utilizes different niches within the habitat in each season. While this is apparently a common trait among viper species (e.g., Brito 2003; Ettling et al. 2013), we found that habitat use of Latifi's Viper is specifically related to an elevation gradient. Our habitat analyses suggested a difference in slope, aspect, and distance to water between spring and summer habitats. Stone coverage and density of tall and short herbaceous vegetation also differed among the micro-habitats that vipers preferred each season.

Latifi's Vipers hibernate for roughly five months under large boulders at mid-elevation, from November to late March. As the snow begins to melt in March, vipers start a journey to rendezvous sites at lower slopes. The snow melts faster on southern slopes due to longer hours of sunlight, providing suitable sunning conditions for vipers. This is corroborated by our models for spring habitat selection, which indicated that slope is a key determinant of Latifi's Viper presence. We also determined that stone cover and tall herbaceous vegetation were important in spring and summer, probably due to the cover that they provide. Lack of cover exposes snakes to predators, as suggested by Ettling et al. (2015). Andrén and Nilson (1979) also noted that Latifi's Viper tends to occupy steep rocky slopes with sparse vegetation. Because vegetation-type is a significant element of Latifi's Viper habitat both in spring and summer, habitat degradation through vegetation removal is likely a serious threat to this species. As our AHP analysis suggested, destruction of vegetation due to overgrazing is possibly taking a toll on this species in Lar National Park, and is exacerbated as nomadic herders settle in the area during summer (Fallahi 2011).

Our models suggest that distance to water is critical in summer and that snakes are more abundant as distance to streams and rivers decreases. Viper species generally tend to frequent dry habitats in spring, but move to humid areas in the summer, when they are found closer to river banks (Brito 2003; Naulleau et al. 1998). Our findings suggest that the same is true for Latifi's Viper, which are more likely to occur near streams and rivers in lower elevations as temperature rises, probably searching for food. At this time of the year, Common Voles (*Microtus arvalis*) and Eurasian Water Voles (*Arvicola amphibius*), which are regularly found along stream banks in valleys, could be an attractive source of food for Latifi's Vipers. Further research on the relationship between habitat and diet selection in Latifi's Viper is needed to confirm this hypothesis. However, proximity to water brings the vipers closer to yet another major source of mortality; the nomadic people who settle temporarily in valleys and riverbanks. Our AHP respondents stated that nomadic people, who settle in the park from late spring until the end of summer, traditionally kill snakes, especially near their dwellings,

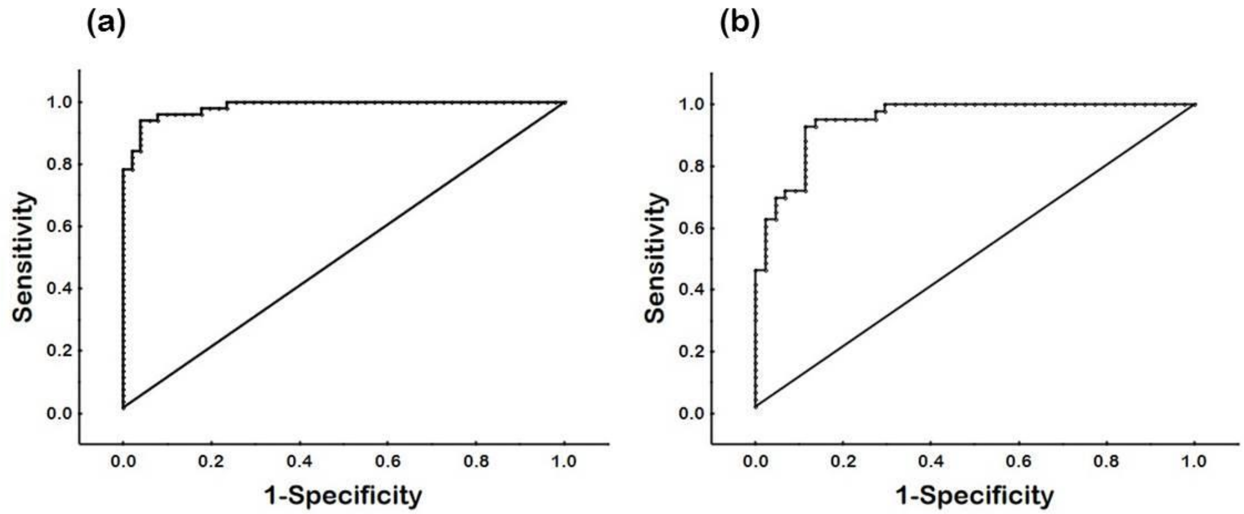

FIGURE 3. Receiver-operating characteristic (ROC) plots for binary logistic regression models for (a) spring and (b) summer. The diagonal line indicates the curve of a model with predictive abilities no better than random (AUC = 0.5).

under the belief that snakes are a danger to their families and livestock. Intentional killing by park visitors who encounter snakes is also known, mainly as a perceived safety measure.

As the vipers move to lower altitudes in summer, they also become more accessible for illegal snake collectors, which our AHP analysis identified as a major threat to Latifi's Viper. The growing popularity of vipers among herpetoculturists and reptile hobbyists is a likely cause for illegal collection of this species. Throughout Iran, vipers (including *M. latifii*) are illegally collected to supply the Razi Serum Institute with snakes needed for venom extraction and antivenin production (Latifi 2000). Yet, due to the remoteness and inaccessibility of Latifi's Viper habitat, very few incidents of snakebite actually occur each year. This supports that the need for venom extraction and production of polyvalent serum is minimal. The impact of viper collection for various purposes is likely made worse by the fact that the small number of rangers in the park cannot feasibly detect all smuggling activities. In addition, even if illegally-collected vipers are confiscated and returned to park officials, it is difficult for this handful of individuals to release all vipers at appropriate locations. In recent years, Iran's Department of Environment (DOE) has initiated efforts to identify local snake collectors and to control their activities, ensuring supervised collection and release of snakes, as well as implementation of standard venom extraction methods. However, many unidentified snake collectors enter Lar National Park as visitors who locate viper congregation in the breeding season and smuggle a considerable number of snakes out of the park. Another important threat factor revealed by AHP analysis is isolation of the remaining Latifi's Viper populations. The restricted range of this species is not only affected by habitat degradation that results from overgrazing, but also by construction activities in the park. The three main roads that cross Lar National Park have fragmented available habitat, while construction of the Lar dam in 1974 submerged a large portion of suitable habitats in the Lar valley (Andrén and Nilson 1979).

Conservation implications.—Lar National Park is the last known stronghold of the endemic Latifi's Viper, although recorded occurrences of this species outside of the park boundaries were made between 2007 and 2009. The management plan of the park currently identifies conservation zones (for definitions of zone categories, see Dudley 2008) based on critical habitats of large mammal species, which mostly dwell at elevations higher than those occupied by Latifi's Viper. This species is therefore mostly found in restoration zones (equivalent to category "V" for National Parks of IUCN, highly impacted by human activities and in need for restoration) and protected zones (equivalent to category "Ib" for National Parks of IUCN, with relatively high protection measures), which are open to herders and visitors.

Our study identified the most important determinants of Latifi's Viper habitat selection, which can be used to model and map critical spring and summer habitats for this species in Lar National Park. Doing so will facilitate evaluation and modification of park zoning to include viper habitats in the strict natural zones, (equivalent to category "Ia" for National Parks of IUCN, with the highest protection measures and the least human disturbance) where public access is limited. Employing more intensive monitoring in protection zones, especially in strict natural zones, will prevent or decrease illegal activities of smugglers, tourists, and herders to collect and kill vipers.

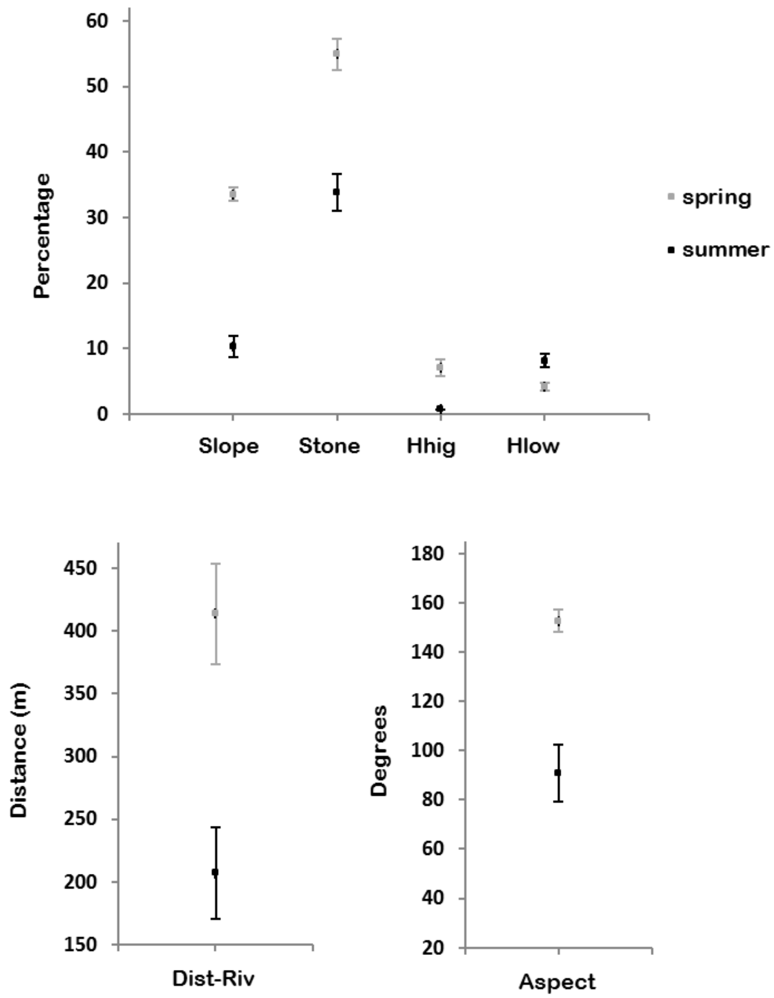

FIGURE 4. Mean slope (Slope), aspect (Aspect), distance to river (Dist-Riv), stone cover (Stone), tall herbaceous vegetation cover (Hhig), and short herbaceous vegetation cover (Hlow) for spring and summer habitats of Latifi's Viper (*Montivipera latifii*). Error bars = 95% confidence intervals.

Our threat analysis revealed that perhaps the importance of Latifi's Vipers in Lar National Park is not communicated well to either the local herders in Lar National Park or the general public visiting the park for recreation. An important step in reducing intentional killing of the vipers is to disseminate basic information about this species, its conservation status and safety guidelines in case of accidental viper encounters. Moreover, rangers of the park should be informed about the location of critical habitats in each season in order to provide more intensive monitoring in those areas. While our threat analysis provided a basic understanding of the current status of Latifi's Viper, we urge further research on quantitative assessments of scope and severity of these threat factors. Doing so will lead to creation of more refined conservation and management strategies that will benefit Latifi's Viper populations.

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Appendices

APPENDIX 1. AHP Questionnaire: Identification of threats to Latifi's Viper (*Montiviperalatifii*) in Lar National Park.
Threat factors:

- Overgrazing and vegetation destruction (Overgrazing)
- Habitat destruction due to residential, commercial and recreational development (Development)
- Roads (Roads)
- Collection by professional and amateur snake collectors; intentional killing by tourists, park visitors, and nomadic herders (Removal)
- Isolation of populations, leading to increased inbreeding (Isolation)
- Reduction in precipitation in the past and possibly future (precipitation)
- Habitat loss due to dam construction (Dam)
- Disturbance due to recreational activities, especially outside the recreation zones (Disturbance)

APPENDIX 2. The AHP pairwise comparison scale.

Degree of importance	Definition
1	Both attributes equally important
3	Very slight importance of one attribute over the other
5	Moderate importance of one attribute over the other
7	Demonstrated importance of one attribute over the other
9	Extreme or absolute importance of one attribute over the other
2,4,6,8	Intermediate values between two adjacent judgments

APPENDIX 3. Pairwise comparisons matrix.

	Overgrazing	**Development**	**Roads**	**Removal**	**Isolation**	**Precipitation**	**Dam**	**Disturbance**
Overgrazing	1							
Development		1						
Roads			1					
Removal				1				
Isolation					1			
Precipitation						1		
Dam							1	
Disturbance								1

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