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Russian Journal of Herpetology Vol. 23, No. 3, 2016, pp. 224 – 230

PREDICTED DISTRIBUTION PATTERNS OF *Pelias kaznakovi* (NIKOLSKY, 1909) IN THE CAUCASUS HOTSPOT WITH A NEW LOCALITY RECORD FROM TURKEY

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Submitted Submitted August 16, 2015.

We represent climatic preferences of *Pelias kaznakovi*, which is a Caucasus endemic viper species together with a new locality record. Male *P. kaznakovi* specimen has morphological similarities in terms of pholidosis characters and color and pattern like other specimens in the literature. According to species distribution modeling, bioclimatic variables as of precipitation of driest month appear to have the most useful information on geographic distribution of *P. kaznakovi*. Distribution model of *P. kaznakovi* under current climatic conditions showed better adaptation to the northwest of the Caucasus hotspot.

Keywords: biodiversity; Caucasus; climate; hotspot; *Pelias kaznakovi*; Rize; Viperidae.

INTRODUCTION

Turkey is hosting three biodiversity hotspots (The Caucasus, the Irano-Anatolian hotspot and the Mediterranean Basin). The Caucasus hotspot is one of 34 hotspots with the most biodiversity on Earth determined by Conservation International (Mittermeier et al., 2004; Tarkhnishvili et al., 2008) and is also one of the 200 global most outstanding and representative areas of biodiversity (Olson and Dinerstein, 2002). The Caucasus hotspot consists of an area of approximately 580, 000 km^2 covering the nations of Azerbaijan, Armenia, Georgia, the northeastern part of Turkey known as the Transcaucasia, the Russian Federation including the northern part of the Caucasus known as the Ciscaucasia, and a small part of northwestern Iran (Zazanashvili, 2009).

The family Viperidae (Vipers and Pit Vipers) is generated from three subfamily, thirty-eight genus (Pyron et al., 2013) and three hundred twenty nine species (from The Reptile Database 2015). The genus *Vipera* (Laurenti, 1768) is recognized as subgenus *Vipera*, *Montivipera* (Nilson et al., 1999), and *Pelias* (Merrem, 1820) (Venchi and Sindaco, 2006), and is consisted of thirty two species inhabiting Asia Minor, Europe, and Northern Africa (Ananjeva et al., 2006; from The Reptile Database 2015). Up to now, 14 – 15 species belongs to the family Viperidae have been recognized in Turkey. Taxonomically, genus *Pelias* was recognized the first as subgenus of genus *Vipera* (Venchi and Sindaco, 2006), and many authors used "*Pelias*" as subgenus (Ananjeva et al., 2006; Venchi and Sindaco, 2006; Afsar and Afsar, 2009; Avcı et al., 2010; Gül, 2015), but later according to a catalogue of living and extinct species in recent years, *Pelias* was sated as a genus of family Viperidae that includes *P. altaica*, *P. anatolica*, *P. barani*, *P. berus*, *P. darevskii*, *P. dinniki*, *P. ebneri*, *P. eriwanensis*, *P. kaznakovi*, *P. lotievi*, *P. magnifica*, *P. nikolskii*, *P. olguni*, *P. orlovi*, *P. pontica*, *P. renardi*, *P. sachalinensis*, *P. seoanei*, and *P. ursinii* species (Wallach et al., 2014; Gül, 2015). Accordingly, we prefer to use *Pelias* as genus in this study. *P. kaznakovi* (Caucasus Adder) is an endemic viper species for the Caucasus hotspots, and its distribution range covers northeast of Turkey, western Georgia, Abkhazia and the Krasnodar Territory of Russia (Ananjeva et al., 2006). Firstly, Nikolsky (1909) described *P. kaznakovi* as the Caucasus Adder from Tsebelda in Abkhazia as *Vipera kaznakovi*. Başoğlu (1947) also described it as *Vipera berus* ornata from the settlement of Hopa, Artvin Vilayet, Turkey. Then, Orlov and Tuniyev (1990) addressed distribution of three species in the *P. kaznakovi* complex in the Caucasus in detail, and they showed that *P. kaznakovi* was inhabited in the settlement of Hopa, Turkey; Mikhailovsky Pass; the settlement of Ubinskaya; the town of Maikop; the mouth of the Urushten River. Baran et al. (2005) found the expansion of its distribution with a new record from Borçka, Artvin, Turkey. Finally, Afsar and

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Afsar (2009) indicated a new locality from Camili Biosphere reserve.

In this study, we aim (1) to determine climatic conditions affecting distribution of *P. kaznakovi* using species distribution modeling, (2) to indicate a new locality of *P. kaznakovi*, (3) to describe morphological features of *P. kaznakovi*.

MATERIAL AND METHODS

Studied Species

A male *P. kaznakovi* specimen was found in Çağlayan village of Fındıklı, Rize, at 203 m a.s.l., on July 22, 2015 (Fig. 1). This locality is 40 km away from Hopa where is first found in Turkey. *P. kaznakovi* was seen for the first time with this locality in Rize province. After analysis of morphological features of the specimen at the Zoology Research Laboratory, Recep Tayyip Erdoğan University, it was safely released back into its natural habitat.

Fig. 1. Overview to male *Pelias kaznakovi* found in Çağlayan village of Fındıklı, Rize.

Occurrence Data and Environmental Variables

19 bioclimatic variables were downloaded from global climate layers in the highest resolution at 2.5 arc-minutes under current conditions (~1950 – 2000) (Hijmans et al., 2005). The global climate layers were clipped to the borders of the Caucasus Hotspot using Extract by Mask in ArcGis ver. 10.1. Many of the bioclimatic variables are very similar to each other. Therefore, all bioclimatic variables were examined for Pearson correlation coefficient ($0.75 < r < -0.75$) using ENMTools 1.3 (Warren et al., 2010) and redundant variables were excluded. 6 bioclimatic variables such as Bio-14 (Precipitation of Driest Month), Bio-15 (Precipitation Seasonality), Bio-9 (Mean Temperature of Driest Quarter), Bio-8 (Mean Temperature of Wettest Quarter), Bio-3 [Isothermality (BIO2/BIO7) (×100)] and Bio-2 (Mean Diurnal Range) were eventually selected for the model.

Species distribution modeling was performed using Maxent software ver. 3.3.3e with default parameters as maximum 500 iterations, convergence threshold 10^{-5}, regulation multiplier 1 and crossvalidate with 10 replicates (Philips et al., 2006). In order to develop species

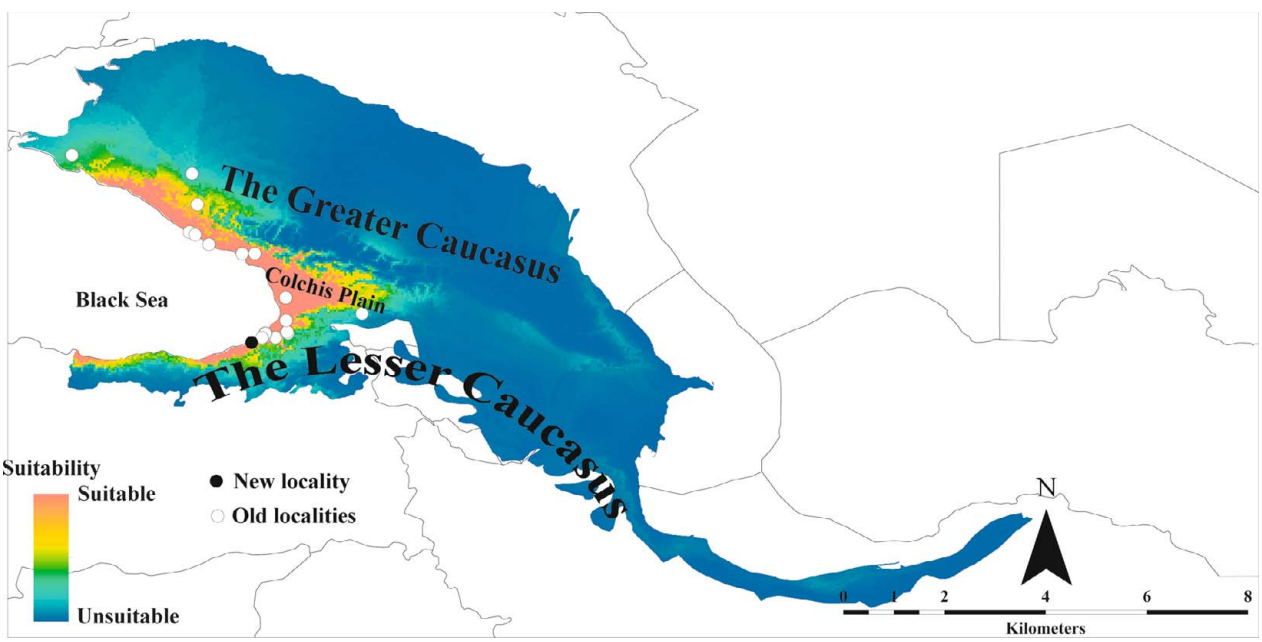

Fig. 2. This picture is a representation of the model for *Pelias kaznakovi* based on both literature data and new locality record. Warmer colors show areas with better predicted conditions in the Caucasus hotspot.

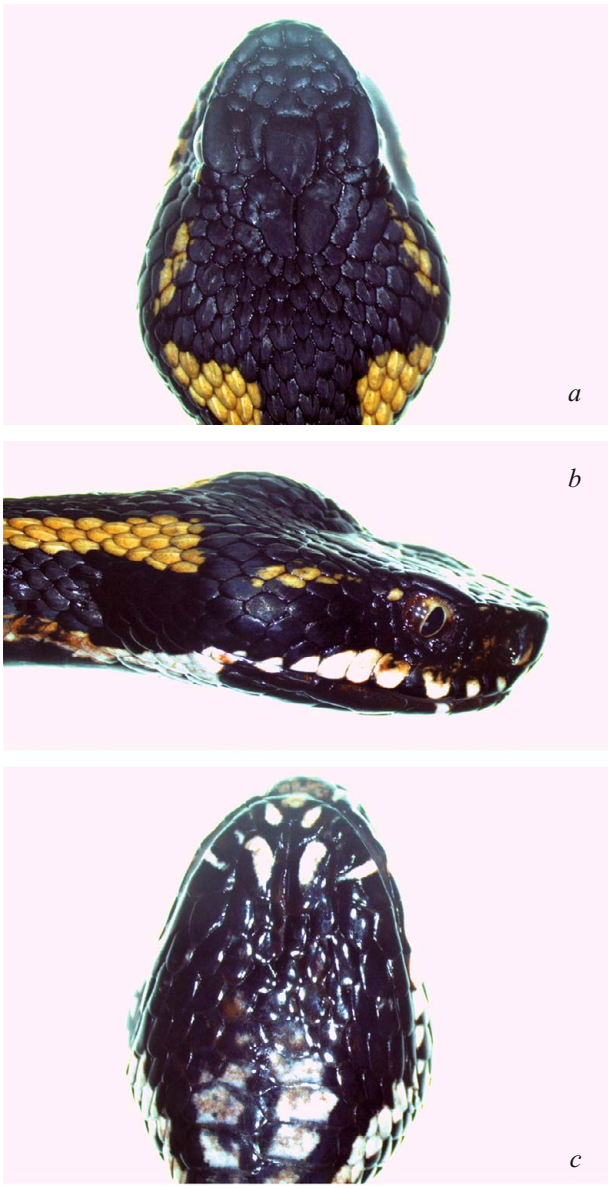

Fig. 3. A view of dorsal (*a*), lateral (*b*), and ventral (*c*) side of typical head pattern of *Pelias kaznakovi* in male specimen from Çağlayan village of Fındıklı, Rize.

distribution modeling, 23 presence localities were used based on the new locality record and literature data (Fig. 2). These locality data were gathered from several museums [like Herpetology Database in Swedish Museum of Natural History and Global Biodiversity Information Facility (GBIF)], available literature (Nilson et al., 1995; Arıkan et al., 2003; Afsar and Afsar 2009; Baran et al., 2005; Mebert et al., 2014) and HerpNET, which is a global network of herpetological collections data (http://www.herpnet.org). The final model was composed of the average the AUC of ten replicates.

RESULTS

Morphology of the new specimen of *Pelias kaznakovi*

The number of ventral scales of the specimen caught from Fındıklı is 133 and the number of subcaudal scales is 34. The scales on longitudinal rows of dorsal at mid-body were 21. The specimen had two apicals in contact with rostral and also had two canthals on each side of the head. Loreal scales between the preocular and the post-nasal were 6 – 5. Numbers of small scales around the eyes were 9 – 9 in the specimen. Supralabials were 9 – 10. Inter canthalia and intersupraocularia were 22. The specimen had a total length of 450 mm (head and body length 450 mm; tail length 80 mm) (Table 1).

Color patterns of *Pelias kaznakovi*

The head of male specimen that caught in Fındıklı is clearly large (Fig. 3*a*). The dorsal color pattern is zig-zag-looking strip of orange color on the upper side of the body. The ventral color is black without spots and also ground color of the ventral side is lighter than dorsal side. The lower part of head color includes many different shades of brown, sometimes darkish, or whitish brown (Fig. 3*c*). This color variation continues across both upper labials and lower labials on each side of head (Fig. 3*b*).

Ecology of *Pelias kaznakovi*

Specimen found in Çağlayan village of Fındıklı, Rize inhabits typical Black Sea land cover including cool and warm temperate forest, and temperate grassland. Biotope of *P. kaznakovi* is represented by a piece of land planted with fruit trees and areas with dry and wet meadows (Fig. 4). Rize province is nearly humid subtropical climate with cool winters and warm summers. According to the average values over long years (1950 – 2014; available on MGM), the annual mean temperature is 14.15°C. Rize is the highest precipitation in western Asia and has the greatest amount of precipitation in Turkey. The annual mean precipitation is 186.57 mm. In the same habitat, some reptile specimens such as *Darevskia rudis*, *Darevskia derjugini*, *Anguis fragilis*, and *Coronella austriaca* were found.

Species distribution modeling

Based on current climatic conditions distribution model of *P. kaznakovi* showed that northeast of Turkey, the Krasnodar Territory of Russia and western Georgia was the areas represented with better predicted condi-

TABLE 1. Morphometric Measurements and Counts of Known Specimens Based on Published Data Together with New Locality

Character	Nilson et al., 1995		Baran et al., 2005		Afsar and Afsar, 2009				This study
	Sochi-Adler, Russia	Hopa, Artvin, Turkey	Hopa, Artvin, Turkey	Borçka, Artvin, Turkey	Baltacı, Artvin, Turkey	Efeler, Artvin, Turkey	Camili, Artvin, Turkey	Düzenli, Artvin, Turkey	Çağlayan Fındıklı Rize, Turkey
Sex	—	—	Female	Male	Male	Male	Male	Female	Male
SVL, mm	—	—	430	355	—	324	—	435	450
Tail length, mm	—	—	59	59	60	45	50	45	80
Ventrals	130 – 138	124 – 136	138	126	—	135	—	135	133
Subcaudals	—	—	24	36	35	34	35	26	34
Loreal scales	7 – 16	5 – 12	—	—	5/5	6/6	4/5	7/7	6/5
Dorsal scales	—	—	21	22	21	17	16	22	21
Apicals	1.5 ± 0.13	1.64 ± 0.14	1	2	2	2	2	1	2
Supralabials	—	—	7/7	9/9	9/8	10/No	9/9	10/9	9/10
Number of small scales around the eyes	—	—	9/10	9/9	8/8	13/13	9/9	10/10	9/9
Canthals	—	—	—	—	2	2	2	2	2
Intercanthalia and intersupraocularia	—	—	—	—	21	17	16	22	22

— Unspecified.

tions for *P. kaznakovi*'s habitat (Fig. 2). As a result of estimates of relative contributions of the environmental variables with Maxent, the most environmental variables with highest gain that explains more than 10% of the presence of *P. kaznakovi* were Bio-14 (Precipitation of driest month, 88.6%). Other variables had a percent contribution less than 5%. The average test AUC (the area under the receiver operating characteristic curve) value of the distribution model of *P. kaznakovi* was 0.942 ± 0.056 and 10 percentile training presence logistic threshold was 0.1358. Predicted suitability was highest in northeast of Turkey, the Krasnodar Territory of Russia and western Georgia with extreme precipitation conditions that influence potential range of *P. kaznakovi* during the year.

DISCUSSION

Morphological Patterns

Several similarities were clearly seen when the specimen found in the Çağlayan village of Fındıklı, Rize was compared with literature information (Nilson et al., 1995; Baran et al., 2005; Afsar and Afsar, 2009). Both male *P. kaznakovi* in this study and literature data indicated that the color patterns of all the specimens are pronounced black and dorsal longitudinal bands, and yellow or orange ground color. Especially, Nilson et al. (1995) stated that specimens from the southernmost population in Hopa, Turkey are more yellowish in ground color, whereas specimens in the north (Russian) are the orange or reddish ground color. Our sample is similar to Russian sample in terms of the orange ground color (Fig. 1). Baran et al. (2005) reported that the pholidosis, color and pattern of specimens found from Borçka correspond to those given on previous studies; however, we cannot talk about the works in those years because literature data are between 1947 and 1988 years. Therefore, we were unable to gain access to evaluate the papers in those years. Afsar and Afsar (2009) did definitively not state from the lateral band color on dorsal along body of the specimens. They just mentioned that upper and lower labials were yellow. We understand that the lateral band color of the specimens is yellow along body, but our sample has more orange color along body. Additionally, our sample with regard to the pholidosis characters showed morphologically very little difference with literature data (see Table 1 in detail).

Species Distribution Patterns

P. kaznakovi has actually been detected in particular regions under very rainy environmental conditions on the northeast Anatolian and the western Caucasus range. We found that the model, which explains the current distribution pattern of *P. kaznakovi*, is based on the precipitation of driest period (Bio-14). Other variables (Bio-2, Bio-3, Bio-8, Bio-9, Bio-15) did not provide a significant contribution much more than Bio-14. Summer precipitation are probably a limitation factor of *P. kaznakovi*'s dispersion (Fig. 2). Therefore, *P. kaznakovi* inhabits towards to the northeast Anatolia of Turkey, and west and northwest coast of the Caucasus hotspot. Similarly, Brito et al., (2008) showed that distribution of the viperid snakes

Fig. 4. Habitat of *Pelias kaznakovi* in the westernmost part of distribution range.

(*Vipera latastei* and *Vipera monticola*) were influenced by the precipitation of driest period for Eastern Iberia, Algeria, and Rif and Middle Atlas, and High Atlas except Western Iberia. In addition, Gül (2015) revealed that *P. barani* has actually been detected in particular regions under very rainy environmental conditions on the Anatolian range. Biogeographically, the present climatic distribution of genus *Pelias* was shaped 5 – 11 mya (million years ago; Late Miocene and Early Pliocene) (Martinez et al., 2015; Zinenko et al., 2015). Martinez et al. (2015) summarized biogeographic scenarios of *Vipera seoanei*, and they indicated that distribution of genus *Pelias* can be expanded from the north Black Sea region toward Europe between the late Miocene and early Pliocene. During Late Miocene, the Mid-Aegean Trench brought about a wide divergence between the Anatolia and Balkan landmasses, and as a result of the Messinian Salinity Crisis in this time, the fist land that is connection with the Greater Caucasus landmass occurred (Popov et al., 2006; Wielstra et al., 2010). After this paleogeographical event, *P. kaznakovi* would probably have created a colony between with the Greater Caucasus and the western Lesser Caucasus with the northwest Transcaucasus mountains. Geographic distribution of *P. kaznakovi* clearly indicates distinct glacial refugia and way of postglacial colonization of populations of *P. kaznakovi*. Tarkhnishvili et al. (2000) indicated that there were two distinct evolutionary lineages of the Caucasus salamander *Mertensiella caucasica* (Waga, 1876) in the Caucasus hotspot, and they similarly revealed that as a result of paleogeographical events occurred two evolutionary lineages, and after these processes, several refugias occurred simultaneously for several species in the Caucasus hotspot (Tarkhnishvili, 2012; Tarkhnishvili et al., 2012; Gabelaia et al., 2015). Especially, the Colchis played a decisive role for several amphibians and reptiles (Tuniyev, 1995) because Tarkhnishvili et al. (2012) indicated the presence of isolated refugia in Colchis during the glacial time.

Conservation Status of *Pelias kaznakovi*

According to IUCN Red List, *P. kaznakovi* (*Vipera kaznakovi* in IUCN) is listed as Endangered (EN) and it is known as the Caucasus endemic. Anthropogenic factors such as habitat loss, tourism activities have negative effect on the status of the populations of *P. kaznakovi*. Recently, several hydroelectric power plants have been thought to be established on the Çağlayan Valley, Fındıklı

in Rize province of Turkey. The process of construction and operation of these hydroelectric power plants can negative affect natural habitats of *P. kaznakovi* as well as river systems and wildlife populations on the valley because the plants will cause habitat loss and deaths of *P. kaznakovi*. This is a serious situation for a species at risk of extinction. Additionally, bio-smuggling began to be problem for several regions of Turkey. The northeastern Black Sea has reached the peak related to bio-smuggling. 12th regional offices connected to the Ministry of Forest and Water Affairs revealed that two Swiss citizens were caught attempting to bio-smuggle *Pelias* (*Vipera*) *kaznakovi*, *Coronella austriaca*, and *Anguis fragilis* species of snake in Artvin [available at http://www.hopam.com/icerikdetay.php?iid=11268 (in Turkish)]. When all these are taken into account, number living of *P. kaznakovi* should be preserved across the Caucasus hotspot because a species reducing in its number living on the northern periphery of the distribution range (Ananjeva et al., 2006).

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