

# A new population and subspecies of the critically endangered Anatolian meadow viper *Vipera anatolica* Eiselt and Baran, 1970 in eastern Antalya province

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**Abstract.** We report on a new population of *Vipera anatolica* from the Geyik Mountain Range in eastern Antalya Province, Turkey. It represents only the second known location, and is situated in a valley about 200 km east from the terra typica at Kohu Dağ in western Antalya Province. We compare both populations and, based on marked differences in morphology, habitat, genetics, and its geographically isolated location, we describe the recently discovered population as a new subspecies. Aspects of ecology, threats, and conservation needs are discussed.

**Keywords:** conservation, distribution, food, genetics, habitat, morphology, Turkey, *Vipera anatolica*.

## Introduction

Rarity, difficulty of access to remote areas, and/or insufficient information on morphological variation have limited the understanding of the distribution, biology and taxonomy of a number of palaearctic viper species. For example, in Turkey, several species of vipers are regarded as rare and threatened (see IUCN Red List of Threatened Taxa at [www.iucnredlist.org](http://www.iucnredlist.org)), and only recent field researches have revealed their more extensive distributions (e.g., Göçmen et al., 2014a, 2015a, 2015b; Mebert et al., 2015, 2016). But in particular one Turkish viper, the Anatolian meadow or mountain steppe viper (*Vipera anatolica* Eiselt and Baran, 1970), a small, mainly insectivorous species from high altitude stony or rocky grasslands (alpine to sub-alpine meadows) was the subject to a very small number of publications with limited content. Originally, this viper was described by Eiselt and Baran (1970) as a subspecies, *Vipera ursinii anatolica*,

of the widely known European meadow viper, *V. ursinii* (Saint Girons, 1980). The description was based on two specimens collected in 1969 by A. Budak and F. Spitzenberger from the Kohu Dağ (Dağ=Mountain), part of the western Taurus Mountain Range, in Antalya Province of southwestern Turkey. The terra typica lies within the protected area of the Cedar Forest Reserve, Çıglikara Ormanları, in southwestern Elmalı District. Since then, only three more specimens became officially registered, all from the same locality: (1) a juvenile male collected 1984 by H. Sigg (Billing, 1985; Sigg, 1987), (2) a specimen collected in the 19th century by one of the Boie brothers (Saint Girons, 1978; Nilson and Andren, 2001), its mark placed on the Bey Dağları (massif) just east of Kohu Dağ (see map in Saint Girons, 1980), but without any additional information for that locality, and (3) a specimen kept in captivity in the 1990s (refs. in Nilson and Andren, 2001). The few known specimens, the extremely restricted range of less than 10 km<sup>2</sup>, as well as threats from killing by local farmers and illegal pet trade, resulted in listing *V. anatolica* as critically endangered in the IUCN Red List files (Tok et al., 2009). However, information on the threat status has partly been adjusted by Zinenko et al. (2016a), who described the finding of additional

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specimens from three areas situated two kilometres from each other and next to the terra typica.

Systematically, this taxon was elevated to species status, *V. anatolica*, by Nilson and Andren (2001). More recently, genetic analyses demonstrated that this viper represents an old evolutionary lineage within the subgenus *Pelias* (Zinenko et al., 2015), with several morphological differences from other steppe and meadow viper taxa (Nilson and Andren, 2001). For more than four decades, the five individuals of *V. anatolica* mentioned in the publications above remained the only specimens known to science, despite frequent visits by herpetological parties to the terra typica (e.g., Nilson, Andren and Flärdh, 1988; Nilson and Andren, 2001; M. Schweiger, B. Halpern, pers. comms.). A few years ago, two independent research groups located additional 26 specimens during several excursions to the terra typica in 2013 and 2014 (Göçmen et al., 2014b; Stümpel et al., 2015; Zinenko et al., 2016a). This newly published information on *V. anatolica* greatly increased our knowledge on its morphology and habitats, prey items, and life history. However, the perception of this species being an old, very isolated relict and rare species remained.

It came as a big surprise, when the first author received a photo by Murat Şenlik on 19 May 2016, requesting the identification of a viper from the eastern part of Antalya Province, ca. 200 km air distance from the terra typica of *V. anatolica* (see fig. 1A, B). The resemblance of the photographed viper with *V. anatolica* triggered four field excursions to this location. The aims for the study herein were: i) analyse and compare the external morphology of individuals from the newly discovered population of the Anatolian meadow viper with those from the terra typica; ii) evaluate the genetic divergence between the two populations; iii) describe and compare the habitat between the new site and the terra typica of *V. anatolica*; iv) incorporate the newly acquired information to describe individuals from the new site as a new subspecies

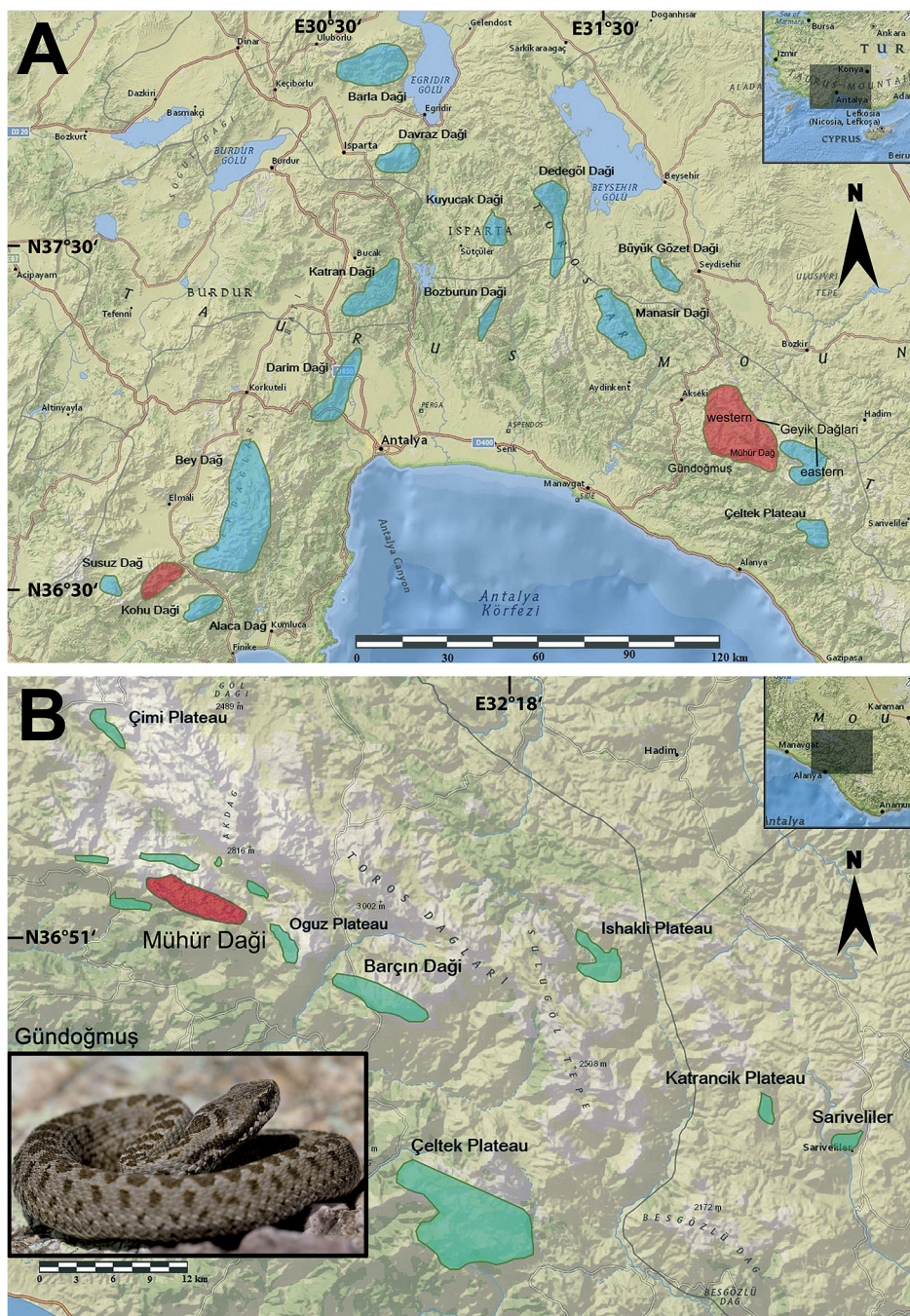
of *V. anatolica*; v) present perceived threats for the population of the new site and suggest conservation measures.

## Material and methods

Four excursions of a total of 20 days with a maximum of 5 persons per excursion were conducted from May to July 2016 to investigate the new site located on Mühür Dağ, western Geyik Mountain Range, north of Gündoğmuş town (36°48'45.32"N, 32°00'8.36"E), Gündoğmuş District, Antalya Province, Turkey (fig. 1B). Meadow vipers found were collected by hand and GPS information taken from the capture sites with a Magellan XL GPS receiver. Metric and meristic characters of half of the individuals were measured in the field, after which the vipers were released, whereas the other half was transported to the laboratory at Ege University, Izmir, Turkey, for measurements and additional analysis. The exact geographic locations for each viper are not given for conservation purposes, but can be requested to the authors for scientific purposes. Samples of local plants were photographed for subsequent identification by botanists. Additionally, 12 nearby potential habitats (plateaus, slopes, or valleys) within the Geyik Mts., as far as 20 km east and west and a few km north and south of the new site were visited twice each to search for additional populations (fig. 1B).

We measured metric characters and calculated ratios of body proportions, including several head sizes. Latter morphometric measurements were taken with a digital calliper of 0.02 mm accuracy (Mitutoyo 500-181 U), whereas snout-vent length and tail length were recorded with a millimetre tape. Head length was measured axially as the distance from the posterior end of the jaws to the tip of the snout. Meristic counts included pholidotic characters, such as dorsal scale rows, ventrals, subcaudals and various scale counts on the head, as well as the number of windings and interruptions of the dorsal zig-zag band. The ventral scales were counted according to Dowling (1951). Bilateral pholidotic features on the head were recorded on both sides (L/R), but summed to represent one character. The complete list of these characters, as originally measured, is presented in supplementary table ST-1 (online). A few colouration pattern characters were also scored by absence/presence for a particular expression (see definition and comments for these characters in the diagnosis below and in the supplementary table ST-2).

For all individuals, features of colour pattern and cephalic scale arrangements were photographed dorsally, laterally, and for the body also ventrally. Morphological characteristics of the new *V. anatolica* population were compared with equivalent data from seven previously measured specimens from the historic location on Kohu Dağ (Göçmen et al., 2014). For dorsal and cephalic colour pattern characters, seven additional specimens from Kohu Dağ depicted in the literature were added to augment the initially low sample size from the species' terra typica, and applied only in the descriptive diagnosis of the new subspecies. These were:



**Figure 1.** Geographic areas: (A) red encircled areas display the terra typica of *Vipera anatolica* at Kohu Dağı, Elmalı District, western Antalya Province, and the Geyik Mountains (= Geyik Dağları), Gündoğmuş District, eastern Antalya Province. The blue encircled areas represent some, but not all, mountain ranges with alpine meadows and steppe habitats that might constitute relatively recent or historic migration corridors to link the two populations of *V. anatolica*; (B) closer view of the new site of *Vipera anatolica* and described subspecies *Vipera a. senliki* ssp. nov. at Mühür Dağı within the western Geyik Mountain Range, and 12 other sites visited nearby in green-blue, where the viper was not found, but more searches would be required. Inset shows photo of first specimen from Mühür Dağı provided by Murat Şenlik on 19 May 2016, revealing a new population of *V. anatolica*.

two specimens in Eiselt and Baran (1970); one and the same specimen in Billing (1985) or Sigg (1987); one specimen in Nilson and Andrén (2001); and three specimens in Zinenko et al. (2016a, and unpubl. report).

Each morphological character was checked for linearity using a Shapiro-Wilk test. Differences between the two viper populations were tested by GLM for each linear meristic and metric character with populations and sex as covariables using R 3.3.2 (R Core Team, 2016). Nonlinear parameters (DSRa, DRm, DSRp, P, GSR and SP) were analysed using Mann-Whitney U test. The evaluations of all statistical analyses were two tailed with a significance level of  $p \leq 0.05$ , but also with Bonferroni correction based on the number of morphological characters (20) tested. Categorical characters (related to different colourations by absence/presence scores) were tested using a Chi-square test for each sex separated with R. Furthermore, to control for allometric bias of raw metric characters, only ratios ([each metric character/SVL]  $\times$  100) have been statistically analyzed according to Werner (1971). Finally, Principal Component Analyses (PCA) were conducted separately on scalation and head ratios with the function *lda* from the MASS package with R, whereas a Factor Analysis of Mixed Data (FAMD) with the *FactoMineR* 1.34 package in R was applied to test for significance among all characters of colour pattern (meristic and categorical).

For the diet analysis, faeces were collected and stomach content palpated and subsequently analysed by an entomologist under a stereomicroscope. The prey items were identified to the lowest possible taxa.

Tissue samples to obtain DNA material for a phylogenetic analysis were acquired by cutting non-invasively distal ends (dead outer edges) of ventral scales. DNA extraction and PCR amplification of a portion of the cytochrome *b* (cyt *b*) were conducted following the protocol described in Ferchaud et al. (2012) for three samples of each population. Genetic diversity and differentiation were calculated with *p*-distance using the software MEGA 7.0.16 (Kumar et al., 2016). The obtained sequences were compared to *V. anatolica* (GenBank: KC316113) analysed by Zinenko et al. (2015). Additionally, sequences from GenBank of close species and 13 additional species (as mentioned in Ferchaud et al., 2012) have been added in order to evaluate the divergence time within *V. anatolica* samples using the same calibration points and methods as mentioned in Ferchaud et al. (2012) for the model 4 (two partitions: 1st and 2nd positions concatenated and 3rd position separately) with BEAST 1.8.3 (Drummond et al., 2002; Drummond and Rambaut, 2003).

## Results

A total of 25 meadow vipers were found on three contiguous plateaus, Senir (Ayıotu), Gelesandra, and Serinyaka plateau, along the southern slope of Mühür Dağ. Nine specimens from the May and June excursions were kept as vouchers, whereas the other 10 specimens and

all six specimens captured in July were released back into their habitat unharmed. Additional 16 specimens were located, some photographed, during excursions to Mühür Dağ in September and October 2016, and May 2017, but no further data except coordinates taken. Hence, these specimens were excluded from following analysis.

The collected specimens were fixed by a 96% ethanol injection and deposited in the Zoology Museum of Adiyaman University (ZMADYU), Adiyaman Province, Turkey (ZMADYU 2016/95 1-3; /96 1-3. /97 1-3). None of the searches in nearby sites yielded any additional meadow vipers (fig. 1B). Relevant individual data (field- or voucher-ID, age group, sex, body size, dorsalia counts, capture-date, -location, altitude) for the 19 specimens from Mühür Dağ are summarised in the supplementary figs SF-1 to SF-10 (online); for comparison, the morphological details of seven *V. anatolica* from Kohu Dağ (see Göçmen et al., 2014b) are also available in supplementary figs SF-1 to SF-10 (online). Principal statistics for relevant morphological characters of specimens from Mühür Dağ and Kohu Dağ are presented per sex in table 1, and the remainder of characters in table ST-1.

Significant morphological differences (with a *p*-value  $< 0.0025$  after Bonferroni correction) were detected between both populations for the meristic characters, including ventral scales *V* ( $p = 0.0001$ ), subcaudals *SC* ( $p < 0.0001$ ), infralabials *IFL* ( $p < 0.0001$ ), circumoculars *CO* ( $p = 0.0003$ ), dorsal scale rows anterior *DSRa* ( $p < 0.0001$ ), number of interruptions of the dorsal zig-zag band *NIZB* ( $p = 0.0002$ ) and head shape *HL/HW* ratio ( $p = 0.0014$ ). Differences were also detected between populations for the tail length *TL* ( $p = 0.0232$ ), laterals *L* ( $p = 0.0111$ ), and dorsal scale rows posterior *DSRp* ( $p = 0.0207$ ), but these were not significant after Bonferroni correction. Sex had a significant impact on the tail length *TL* ( $p < 0.0001$ ), subcaudals *SC* ( $p < 0.0001$ ), the number of windings of the dorsal zig-zag



**Table 1.** Summarised statistics of relevant morphological characters of *Vipera anatolica senliki* ssp. nov. and *V. a. anatolica*. Metric characters and ratios: SVL = snout-vent length (incl. juveniles and subadults), TL = tail length, SVL/TL, HL/HW = head length/head width ratio. Scallation and other meristic characters; DSRa = dorsal scale rows (anterior), V = ventrals, SCr = subcaudals (right), SCl = subcaudals (left), IFLr = infralabials (right), IFLl = infralabials (left), COr = circumoculars (right), COl = circumoculars (left), NWZB = number of windings of the dorsal zig-zag band, NIZB = number of interruptions on the dorsal zig-zag band. Statistics of additional characters are displayed in the supplementary table ST-1, online.

Characters	Males						Females						
	N	Min.	Max.	Mean	SD	SE	N	Min.	Max.	Mean	SD	SE	CV
<i>V. a. senliki</i> ssp. nov.													
SVL	10	201.00	364.00	316.20	47.79	15.113	9	165.00	349.00	263.67	68.73	22.912	0.217
TL	10	31.00	55.00	47.40	7.26	2.296	9	19.00	33.00	26.78	5.02	1.673	0.106
SVL/TL	10	5.75	7.49	6.69	0.50	0.159	9	8.38	11.31	9.73	1.01	0.336	0.151
HL/HW	6	1.42	1.57	1.49	0.06	0.023	7	1.33	1.53	1.42	0.07	0.027	0.047
DSRa	10	19.00	21.00	20.80	0.63	0.200	9	19.00	21.00	20.78	0.67	0.222	0.032
V	10	121.00	125.00	122.10	1.45	0.458	9	119.00	125.00	122.11	1.76	0.588	0.014
SCr	10	31.00	34.00	32.40	1.26	0.400	9	22.00	25.00	23.44	1.13	0.377	0.035
SCl	10	32.00	35.00	33.40	1.26	0.400	9	23.00	26.00	24.44	1.13	0.377	0.034
IFLr	10	8.00	9.00	8.70	0.48	0.153	9	8.00	9.00	8.56	0.53	0.176	0.061
IFLl	10	8.00	9.00	8.80	0.42	0.133	9	8.00	9.00	8.56	0.53	0.176	0.060
COr	10	8.00	10.00	9.20	0.63	0.200	9	7.00	9.00	8.44	0.73	0.242	0.079
COl	10	8.00	9.00	8.60	0.52	0.163	9	8.00	9.00	8.33	0.50	0.167	0.058
NWZB	10	52.00	66.00	60.60	4.14	1.310	9	50.00	59.00	55.89	2.85	0.949	0.047
NIZB	10	5.00	22.00	11.50	5.68	1.797	9	5.00	18.00	9.44	4.85	1.617	0.421
<i>V. a. anatolica</i>													
SVL	5	181.00	321.00	252.80	51.81	23.170	2	230.00	269.00	249.50	27.58	19.500	0.109
TL	5	26.00	47.00	38.80	7.76	3.470	2	21.00	25.00	23.00	2.83	2.000	0.073
SVL/TL	5	5.97	6.96	6.53	0.43	0.194	2	10.76	10.95	10.86	0.14	0.096	0.021
HL/HW	5	1.50	1.65	1.59	0.06	0.025	2	1.50	1.52	1.51	0.02	0.014	0.013
DSRa	5	18.00	19.00	18.40	0.55	0.245	2	19.00	19.00	19.00	0.00	0.000	0.00
V	5	116.00	120.00	118.20	1.48	0.663	2	118.00	119.00	118.50	0.71	0.500	0.006
SCr	5	29.00	30.00	29.60	0.55	0.245	2	22.00	22.00	22.00	0.00	0.000	0.000
SCl	5	30.00	31.00	30.60	0.55	0.245	2	23.00	23.00	23.00	0.00	0.000	0.000
IFLr	5	9.00	10.00	9.80	0.45	0.200	2	9.00	10.00	9.50	0.71	0.500	0.051
IFLl	5	10.00	10.00	10.00	0.00	0.000	2	10.00	11.00	10.50	0.71	0.500	0.050
COr	5	9.00	11.00	9.80	1.10	0.490	2	9.00	11.00	10.00	1.41	1.000	0.102
COl	5	9.00	11.00	9.80	0.84	0.374	2	10.00	10.00	10.00	0.00	0.000	0.000
NWZB	5	56.00	63.00	58.60	2.70	1.208	2	51.00	56.00	53.50	3.54	2.500	0.043
NIZB	5	0.00	5.00	1.20	2.17	0.970	2	1.00	2.00	1.50	0.71	0.500	0.592

band NWZB ( $p = 0.0018$ ); difference was also observed between males and females for the head shape HL/HW ratio (HL/HW ratio,  $p = 0.028$ ), but this is not significant after Bonferroni correction. The qualitative colouration characters, including PC (Pileus colouration), CSC (colouration of subcaudals), DCTT (dorsal colouration of tail tip in adults), DSHA (drop-shaped head angle markings), were all significant except between females of both populations for DCTT ( $p = 0.209$ ) and CSC for males ( $p = 0.302$ ) and females ( $p = 0.0934$ ).

The principal component analysis (PCA) based on the scalation characters clearly separated both populations, with 47.4% of the variance explained by the first two axes (supplementary fig. SF-15A, online). The PCA based on the head lengths and ratios was less able to discriminate the origin of individuals (see supplementary fig. SF-16, online), whereas the FAMD based on mixed (meristic and qualitative) characters related to the colouration and the dorsal pattern clearly distinguished between both populations (supplementary fig. SF-15B).

The general phenotype of *Vipera anatolica* from Mühür Dağ clearly resembles that of the terra typica. However, there are still significant differences in scalation, colour pattern, and habitat between the two populations from Mühür Dağ and Kohu Dağ. For instance, specimens from Mühür Dağ possess more ventral and subcaudal scales and a wider head (table 1). The head scalation yielded also differences, as vipers of the population from Mühür Dağ had significantly fewer infralabials and circumoculars, but higher numbers of dorsal scale rows at the neck (table 1), a character being frequently used to distinguish species or subspecies among meadow vipers (see Nilson and Andrén, 2001). The vipers from Mühür Dağ showed a significantly increased interruption of the mid-dorsal zig-zag band, more frequently reddish subcaudal scales (not significant due to low number of females of *V. a. anatolica*, but see comment in the diagnosis), yellowish dorsal tail tips, a darker pileus (head top between posterior end of parietals and snout tip), and only rarely drop-shaped head angle markings compared to specimens from Kohu Dağ.

The genetic analyses demonstrated a marked difference with 1.14% divergence for the 1086 bp of cyt b between the populations of Mühür Dağ and the terra typica, whereas no variation has been detected among the three specimens tested in both populations. The sequences of both haplotypes are available on GenBank (*V. anatolica* from the terra typica: KX865130; *V. anatolica* ssp. nov. from the new population: KX865131). Our sequences of meadow vipers from the terra typica are identical to the previously published sequences by Zinenko et al. (2015). The phylogenetic reconstruction however showed a clear close relationship of all genetic samples of *V. anatolica* with a most recent common ancestor dated to 1.10 million years (95% confidence interval: 0.49–1.80 million years).

The habitat at Mühür Dağ is steeper and wetter, crossed by many streams, exhibits more rock slides and a denser cover of herbaceous plants and small bushes than the habitat from

the terra typica at Kohu Dağ. Furthermore, the two populations are separated by multiple lowlands or valley plains, mostly < 1000 m asl., across the distance of 200 km straight line (see also fig. 1A and Discussion). In conclusion, the morphological differences, the genetic distinctiveness and the lack of a corridor and intermittent populations suggest isolation and local divergence, and thus lead us to describe a new subspecies for the population at Mühür Dağ, Gündoğmuş District.

*Vipera anatolica* senliki ssp. nov.

**Holotype.** Adult male (fig. 2), ZMADYU 2016/97-2♂, Leg. 23 May 2016, Bayram Göçmen, Mert Karış, Mehmet Anıl Oğuz, Murat Şenlik, Erdem Bulut.

**Paratypes.** Eight specimens from ca. 3 km east and west of the holotype on Mühür Dağ, Gündoğmuş District, Antalya Province, Turkey. For locality details and voucher numbers see figs SF-1 to SF-5.

**Terra typica.** Serinyaka Plateau, Mühür Dağ, Gündoğmuş District, Antalya Province, Turkey, 1755 m asl. (36°51'N, 32°02'E).

**Diagnosis.** A small viper (SVL < 40 cm, tail length < 6 cm) closely related and resembling to the Anatolian meadow (mountain steppe) viper *Vipera anatolica* Eiselt and Baran, 1970. Based on 19 *Vipera a. senliki* ssp. nov. from Mühür Dağ and 7 *Vipera a. anatolica* from Kohu Dağ (increased to 14 concerning colour pattern characters only, see Material and methods), *Vipera a. senliki* ssp. nov. differs from the nominotypic subspecies by:

- (1) significantly more anterior dorsal scale rows with mostly (90%) 21 dorsal scale rows behind the head (vs. 18 or 19 rows in *V. a. anatolica*)
- (2) higher ventral scales count with a mean of 122.11 (vs. 118.27 in *V. a. anatolica*)
- (3) smaller number of infralabials with mostly 9 scales (vs. 10 in *V. a. anatolica*)

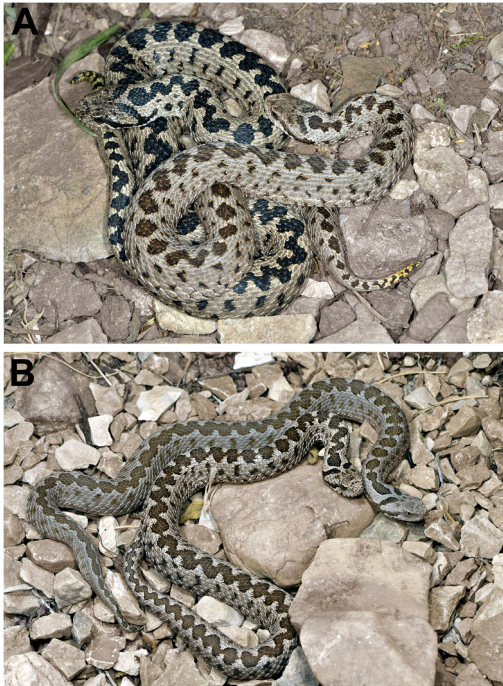


**Figure 2.** Holotype (Voucher No. ZMADYU 2016/97-2) life *Vipera anatolica senliki* ssp. nov. A male from Serinyaka Plateau, Mühür Dağ, Gündoğmuş District, eastern Antalya Province, Turkey, collected on 23 May 2016, altitude 1755 m asl., SVL 364 mm, tail length 51 mm, dorsalia rows (anterior-mid-posterior) 21-21-17.

- (4) fewer circumoculars with mostly 9 scales (vs. mostly 10 in *V. a. anatolica*)
- (5) fewer loreals with mostly 4 scales (vs. mostly 5 in *V. a. anatolica*)
- (6) a relatively wider head, i.e. lower 'head length/head width' ratio
- (7) showing a higher number of interruptions of the mid-dorsal zig-zag band (NIZB) between the head and the dorsal position of the anal plate, with 5-22 interblotch-spaces lacking any clear dorsal-band connection (vs. 0-4 interruptions in *V. a. anatolica*). Interruptions are defined as the lack of dark dorsal colour (brownish to blackish) visibly connecting two mid-dorsal blotches, but not counting scales with only very light suffusion by speckling or with dark

colour only along the edges of those scales or adjacent interscalar skin.

- (8) showing a remarkable reddish colouration of subcaudals (CSC) in 90% of females and 40% of males (vs. none or light brownish in the two female and five males of *V. a. anatolica*).
- (9) dorsal colouration of tail tip (DCTT) yellow in 90% of individuals, including adults (vs. grey ground colour in *V. a. anatolica* with yellow being present only on the subcaudal part of the tail tip)
- (10) darker pileus colouration (PC), as all individuals exhibit an increased speckling and/or darker ground colour anterior to the head angle marks (= pileus colouration), visibly contrasting with the lighter



**Figure 3.** Female and male (more contrasting colour pattern) of (A) *Vipera anatolica senliki* ssp. nov. from Mühür Dağ, Gündoğmuş District, Antalya; and (B) *Vipera a. anatolica* from Kohu Dağ, terra typica, Elmalı District, Antalya.

body posterior that blotch (vs. only ca. 40% in *V. a. anatolica* show a darker PC)

- (11) a decreased frequency of drop-shaped head angle marks (DSHA), with 90% of the angle marks evenly ended and only two individuals show one angle slightly wider (drop shaped) on the parietal side (vs. wider half on parietal side for both angle marks present in ca. 60%, only one side in ca. 30%, and none in ca. 10% of *V. a. anatolica*).

A comparison between a female and male of each subspecies can be found in fig. 3, whereas all specimens are depicted in figs SF-1 to SF-14. For the scoring results of colouration characters (7) to (11), that included additional seven specimens of *V. a. anatolica* depicted in the literature, see also table ST-2.

**Description of the holotype.** An adult male, snout-vent length 364 mm, tail 51 mm, rostral, frontal and head longer than wide ( $RL/RW =$

1.28,  $FL/FW = 1.53$ ,  $HL/HW = 1.47$ ), head depth 8.15 mm, distance between the nostrils 4.13 mm, two supraoculars, two parietals and a large frontal plate on top of head, one canthal and one supranasal plate on each canthus rostralis, a single apical plate, 11 crown scales on top of head, rostral bordering with two supralabials, two internasal and apical plates, eye surrounded by nine circumoculars on left side and 10 on right side, upper preocular contact with nasal on each side, four loreals on left side and five on right side, eight supralabials and nine infralabials on each side, five gular scale rows, one preventral and 122 ventrals, single anal plate, 31/31 + 1 subcaudals, dorsal scale rows (anterior-mid-posterior) 21/21/17, respectively.

Dorsal pattern consisting of a zig-zag band which is mostly fragmented with 57 blotches/windings, lateral blotches present, parietal bands do not unify and form a Y or furcular shape with temporal stripes on each side, dorsal ground colour greyish-brown, ground colour of anterior part of the parietal stripes darker than posterior part, dorsal colouration of the tail tip yellow, ventral part of head dark due black-edged chin and gular scales, ventral side of body whitish-coloured and well-speckled, ventral part of tail reddish yellow and gradually becoming more yellowish towards the tail tip.

**Etymology.** *Vipera anatolica senliki* ssp. nov. (derived from the Turkish surname Şenlik, herein pronounced in English as sen-LI-kee, or in German as sen-LI-ki) is named after Mr. Murat ŞENLİK who was the first to photograph the new taxon and is also an avid nature observer and a member of The Amphibians and Reptiles Monitoring and Photography Society in Turkey ([www.turkherptil.org](http://www.turkherptil.org)).

**Habitat and weather.** The site of the newly discovered population of *Vipera anatolica* from Mühür Dağ is marked by a steep, southerly exposed slope between 30-40° with few trees, but

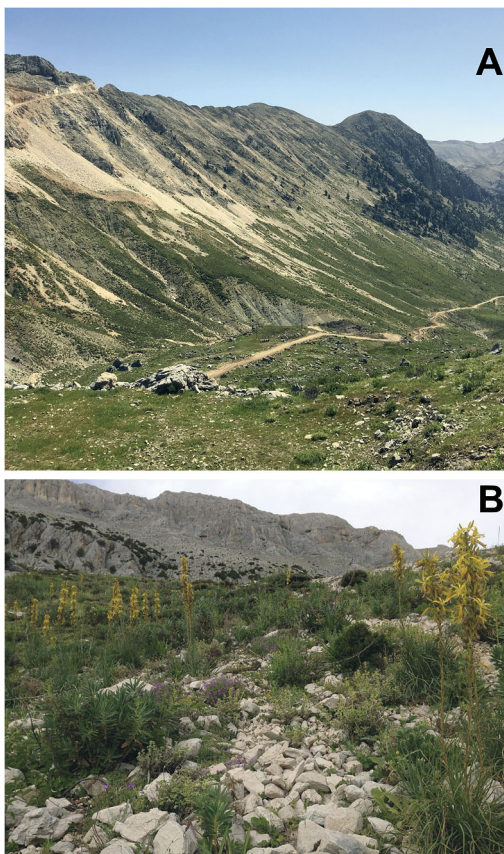


luscious vegetation cover with grasses, herbaceous plants, and small bushes. The eastern portion of the site is embedded in a steep V-shaped valley with an altitude ranging from ca. 1400 m asl. to 2000 m asl., whereas the western portion is more open towards the south and rises up to 2400 m asl. (fig. 4A). The total horizontal extent of the slope, where vipers were located, is 7 km long. The slope continues for another 6 km west upon which the mountain ridge decreases < 1900 m asl. and becomes substantially more wooded along its southernmost flank. The habitat contains following plants: *Asphodeline lutea*, *Astragalus* sp., *Festuca* sp., *Verbascum* sp., *Euphorbia nicaeensis*, *Cruciata*

*taurica*, *Daphne gnidioides*, *Erysimum* cf. *caricum*, *Satureja* sp. and *Juniperus oxycedrus*.

Adjacent western, eastern, and northern valleys provide additional highland steppe habitats. However, vipers were neither reported from there nor has our personal search effort in 12 additional sites yielded any other individuals. *Vipera anatolica senliki* ssp. nov. were only found between 1559–1875 m asl. at Mühür Dağ, mostly on the southern slope, but with a few individuals located on the lower stretches (ca. 20° inclination) of the northern slope within the eastern part of the V-shaped-valley. Compared to other regionally visited sites around Mühür Dağ, the habitat of *V. a. senliki* ssp. nov. offers more rock slides, screes with multiple layers of calciferous rocks and stones covering the slope. This produces a dense interstitial network in a three-dimensional space, where the numerous crevices provide shelter for the vipers, and possibly some of their prey. A dense cover of herbaceous plants and small bushes renders stability to the rock slide. Most other regionally visited sites within 20 km around Mühür Dağ, where no meadow vipers were detected, revealed a less dense rocky network with mostly single granite stones surrounded by soil instead of other stones, and thus, being devoid of the multi-layered, crevice-rich stone cover found at Mühür Dağ. Yet, the few and short visits to the Geyik Mountains did not allow to efficiently evaluate the potential for more populations of the secretive meadow vipers. In particular, a few sites, such as the Alibeyler Yaylasi, southern slope of Akdağ north of Mühür Dağ, appear to provide similarly structured and vegetated slopes as potential habitat for *V. a. senliki* ssp. nov.

A comparison between the habitat of *V. a. senliki* ssp. nov. at Mühür Dağ and the terra typica of *V. a. anatolica* at Kohu Dağ concludes similar. The meadow vipers at Kohu Dağ inhabit mainly a dry karst and doline habitat, whereas those at Mühür Dağ occupy a wetter habitat with many springs and small streams running down the steep slope. Two vipers were even



**Figure 4.** Habitat of *Vipera anatolica senliki* ssp. nov.: (A) the southern slope (Gelesandra Plateau) of Mühür Dağ, Gündoğmuş District, Antalya; (B) Senir Plateau on Mühür Dağ with a mixture of loose rock slides and luscious herbaceous vegetation.



**Figure 5.** *Vipera anatolica senliki* ssp. nov. drinking water from a spring, Mühür Dağ, Gündoğmuş District, Antalya.

observed drinking water directly from a spring (fig. 5). The Mühür Dağ habitat evidently provides sufficient water to produce a denser cover of understory and herbaceous plants than the grassy karst plains and slopes around Kohu Dağ (for Mühür Dağ see fig. 4B; and for Kohu Dağ see figures in Göçmen et al., 2014b; Stümpel et al., 2015). Twelve of the 25 specimens were uncovered from underneath rocks during cloudy-rainy weather and even hail, one was found under a rock and two on the surface in cloudy-sunny weather, and the remainder were active or basking out in the open in sunny conditions. Density at the new site may be high, as six specimens observed in July were detected within one hour.

**Diet.** Faecal analysis indicated that centipedes (*Scolopendra* sp.) and millipedes (*Julus* sp.) are the principal food for *Vipera anatolica senliki* ssp. nov. Additionally, remains of following invertebrates were identified: *Chorthippus* sp. (an acridid grasshopper), *Acrida* sp. (*hungarica*?), *Acinipe* sp. (Pamphagidae), *Lampyris noctiluca* (Glow worm or Firefly), *Cephalostenus demaisonii* (Tenebrionidae), *Blaps abbreviata* (Tenebrionidae), *Mesobuthus gibbosus anatolicus* (Scorpionida), *Euscorpius gocmeni* (Scorpionida), *Lycosa praegrans* (Aranea), *Iurus krapelini* (Scorpionida), *Trypocapris amedei* (Scarabidae), and also frequently snails (*Helix* sp.). Some of the invertebrates may represent

secondarily ingested prey from the centipedes and scorpions.

**Herptile associations.** A diverse array of herptiles was found sympatric with *V. anatolica senliki* ssp. nov. at Mühür Dağ. These include lizards: *Ablepharus budaki anatolicus*, *Stellagama stellio*, *Anatololacerta pelasgiana ibrahimi* (= *A. oertzeni ibrahimi*); snakes: *Montivipera xanthina* (even under the same stone), *Platyceps najadum*, *Eirenis modestus*, *Zamenis hohenackeri*; one frog species: *Pelophylax bedriagae*; and one tortoise species: *Testudo graeca*.

## Discussion

Designation of a new taxon can be a contentious issue, as it often relies on the reflection of a few specimens sampled across a small geographic extent. The new and the historic localities of Anatolian meadow vipers compared in this study represent two hitherto discrete and differentiated populations. The designation of *Vipera anatolica senliki* ssp. nov. as a new subspecies follows in the sense of Mayr and Ashlock (1991:43): “A subspecies is an aggregate of phenotypically similar populations of a species inhabiting a geographic subdivision of the range of that species and differing taxonomically from other populations of that species.” The subspecies designation fulfills also more contemporaneous approaches, such as by Braby et al. (2012) who recommend that: “under the general lineage (unified) species concept (Queiroz, 2007), the definition of subspecies be restricted to extant animal groups that comprise evolving populations representing partially isolated lineages of a species that are allopatric, phenotypically distinct, and have at least one fixed diagnosable character state, and that these character differences are (or are assumed to be) correlated with evolutionary independence according to population genetic structure.” Applied to our study, the recognition of a subspecies *V. a. senliki* ssp. nov. is based on

following differentiating criteria: (1) a multitude of morphological differences in scalation and colour pattern with the number of interruptions on the mid-dorsal zig-zag band being diagnosable and easy to verify, (2) marked genetic differentiation, (3) some different habitat constituents, (4) distinct sympatric herpetofauna, and (5) geographic isolation, thus allopatry, due to physiographic barriers (lowlands) and a large distance of 200 km between the two only known conspecific populations of *Vipera anatolica* at Kohu Dağ and Mühür Dağ (fig. 1A).

According to the extensive study of the meadow vipers (the *V. ursinii* complex *sensu lato*) of Nilson and Andrén (2001), the number of ventral scales and the position of the reduction of the dorsal scale rows are important elements to discriminate among taxa in this group. In our study, ventral scales and the number of dorsal scale rows at the neck are significantly different ( $p < 0.0001$ ) between the two *V. anatolica* subspecies. Head scalation also presented significant differences, with *V. a. senliki* ssp. nov. exhibiting a comparatively wider head but with a smaller number of scales (infralabials, circumoculars and loreals). Nilson and Andrén (2001) indicated a limited variability within single taxa for the first two characters (number of ventral and dorsal scale rows), and thus, these characters are valuable elements to distinguish between species/subspecies in this group. Consequently, the significant morphological differences observed particularly in conservative scalation characters between the populations of Kohu Dağ and Mühür Dağ strongly contributed to the recognition of *V. a. senliki* ssp. nov. as a distinct taxon. However, it is uncertain, whether such differences reflect fixed genetic differences or are the result of phenotypic plastic traits under local environmental pressures (e.g. predator type and numbers), as might be reflected by the remarked difference in colour pattern characters between both populations of *V. anatolica*.

Alternatively, geographic variations of morphological characters may correlate with climatic differences, suggesting selection and adaptations to local or regional environmental conditions. For example, a higher number of dorsal blotches and ventral scales and a lower number of loreal scales in Iberian *Vipera latastei* and *V. aspis* are significantly correlated with higher precipitation and cooler temperatures, in particular at a regional scale (Brito et al., 2008; Martinez-Freiria et al., 2009). There, vipers with a higher number of dorsal marks maybe more cryptic in habitats with denser vegetation. Concordantly, the higher scale numbers (ventrals, anterior dorsals) and frequent breakup of the dorsal zig-zag band in *Vipera anatolica senliki* ssp. nov. from Mühür Dağ, compared to *V. a. anatolica* from Kohu Dağ, may reflect increased precipitation at the new site, visualized by the many permanent streams in its habitat, denser vegetation, and vipers drinking directly from streams (figs 3, 4, 5).

Similarly, Shine (2002) proposed the existence of morphological adaptation to different dietary habits in snakes, as a high number of dorsal scale rows would increase stretching capacity and so facilitate the ingestion of larger, bulkier prey (Gans, 1974; Fabien et al., 2004). The high number of anterior dorsal scale rows and the prominent yellow (dorsally) tail tips could indicate such a dietary shift in *V. anatolica senliki* ssp. nov., suggesting that the new taxon may include larger prey (centipedes and millipedes were most common prey) and such that can efficiently be lured with colourful tails (e.g. small lizards) compared to *V. a. anatolica* from Kohu Dağ, where orthopterans (grasshoppers) are presumed to be the primary prey (Zinenko et al., 2016a). However, more data on diet composition of the two populations is needed to further elaborate on this hypothesis.

Another Iberian viper, *V. seoanei*, shows an opposite trend of higher scale numbers with drier and warmer areas (Martinez-Freiria and

Brito, 2013). This result exemplifies that correlations between scale numbers and climatic factors should be investigated and interpreted on a per case basis, i.e. species and regionally and including other selective agents such as thermoregulation efficiency, habitat selection, crypsis, predation pressure, sexual selection, or temperature regime during embryogenesis.

Genetically, about 1.14% of divergence was observed on the cyt b between *V. a. anatolica* and *V. a. senliki* ssp. nov. This difference is comparable to what has been observed among species or subspecies of the *V. renardi* group (Zinenko et al., 2015), e.g. between *V. ebneri* and *V. lotievi* (1.4%), *V. r. tienshanica* and various haplogroups of the *V. r. renardi* subclade (0.9-1.5%), though *V. lotievi* is highly polyphyletic (see possible alternative explanations to phylogenesis in Zinenko et al., 2015, 2016). Similar differences were found among the different subspecies or clades within *V. berus* (*V. b. bosniensis*, *V. berus* “Italian clade” and *V. berus* “northern clade”; Ursenbacher et al., 2006), or between *V. u. moldavica* and *V. u. rakosiensis* (concatenated cyt b+ND4 dataset in Ferchaud et al., 2012; or only cyt b in Gvozdk et al., 2012; Zinenko et al., 2015). However, Gvozdk et al. (2012) showed a higher subspecies divergence in cyt b of about 4% when comparing *V. u. macrops* with either, *V. u. rakosiensis* or *V. u. moldavica*, similar to other cyt b *p*-values among *V. ursinii* spp. Consequently, such divergence has often been associated with the recognition of subspecies in closely related species or species-complexes. Even though a small divergence in mtDNA genes is not necessarily the primary reason to suggest a new species or subspecies, the existing divergence combined with the large geographic distances and isolation are corroborative arguments for the recognition of the population at Mühür Dağ as a different taxon. This stands in contrast with the situation among several taxa and geographic populations of the *renardi* complex, that includes several subspecies and established

species, such as *V. lotievi*, *V. ebneri* and *V. erivanensis*, with similar genetic divergence (Zinenko et al., 2015) as between the two *V. anatolica* ssp., albeit introgression confounds taxon delineation in viperids from the Caucasus to central Asia (e.g. Zinenko et al., 2015, 2016b), and thus, further research is needed.

While differences in morphology, genetics, and habitat could be viewed as mere extensions of the species’ geographic variation in phenotype, genotype and ecological niche (differentiation criteria 1-3, see above), the coherent differences in the herpetofaunistic associations (criteria 4) and geological history (criteria 5) indicate that a deeper evolutionary history underlies these differences. Regarding criteria 4, the distribution of *V. a. anatolica* at Kohu Dağ in western Antalya Province coincides (while excluding that of *Vipera a. senliki* ssp. nov.) with the ranges of: a1) Lycian Salamander *Lyciasalamandra luchani finikensis*, b1) the small Snake-eyed Skink *Ablepharus chernovi*, c1) Snake-eyed Lizard *Ophisops elegans macrodactylus*, and d1) the Green Lizard *Lacerta trilineata diplochondrodes*. In contrast, the population of *V. a. senliki* ssp. nov. at Mühür Dağ in far eastern Antalya Province is associated with different, but related, taxa to those from the more western nominotypic subspecies, including (related taxa between the two *Vipera anatolica* sites are indicated by their shared *ith*-letter, but different number): a2) *Lyciasalamandra atifi* (Göçmen et al., 2013), b2) *Ablepharus budaki anatolicus* (Göçmen et al., 1996; Schmidtler, 1997; Sindaco and Jeremčenko, 2008; Skourtanioti et al., 2016), c2) *Ophisops elegans basoglui* (Franzen et al., 2008), d2) and a contact region of *L. media isaurica* and *L. trilineata pamphylica* (Ahmadzadeh et al., 2013). These herpetofaunistic differences parallel that between *V. a. anatolica* and *V. a. senliki* ssp. nov. and reflect a coherent scenario in microevolutionary processes among these taxa.

Even though no exhaustive phylogeographic analysis could be executed with only two



known populations, geological history can explain some of the observed differentiation between both subspecies. The entire coastal mountain ranges in Antalya Province has been under heavy tectonic turmoil prior to 5 Mya, with the mountain massifs in the region of *V. a. anatolica* having experienced a 20° counterclockwise rotation, whereas the area farther east towards *V. a. senliki* ssp. nov. was accommodated by a massive East-West compression, giving rise to the North-South oriented mountain ranges in Antalya Province (e.g., Van Hinsbergen et al., 2010; Poisson et al., 2011 and references therein). Such tectonic movements likely have promoted separation and isolation of biota. Even though, this period predated the split of the two Anatolian meadow viper populations (taxa), it has separated early *V. anatolica* from the entire clade of *V. ursinii-renardikaznakovi* complex in the Pliocene a little over 5 Mya after the end of the Messinian crisis (Zinenko et al., 2015). Subsequently, the two meadow viper taxa might have become separated and differentiated during climatic fluctuations in the middle Pleistocene (beginning approximately 900 kya), when the dominant periodicity of glacial response changes from 41 to 100 kya (Milankovitch, 1941; Paillard, 2001). The accompanying climatic fluctuations probably motivated the ancestor of *V. anatolica* to move up and down the mountains following their preferred local climate. These movements and especially the isolation of these vipers on rocky meadows restricted to isolated mountain tops and plateaus during one or more interglacial (warm) periods are probably the causes of the observed genetic differentiation following the processes suggested by Hewitt (1996). Several mountain ranges in Antalya, Burdur and Isparta provinces span an arc, albeit often interrupted by lower valleys, between the two meadow viper sites, e.g., Bürükgözet Dağı, Dedegöl Dağları, Kuyucak Dağı, Davras Dağı, Barla Dağı, and Katrancik Dağı. Most of these mountain ranges contain high-altitude steppes at >1700 m asl., that today are isolated from

each other. These high-altitude areas, as well as those north and east of Mühür Dağ (site of *Vipera a. senliki* ssp. nov.) in the provinces of Konya, Karaman, and Mersin, should be inspected in the near future, because they could yield additional populations of *V. anatolica*. For example, the river Göksu Nehri breaks the Taurus Mountains with a valley bottom < 250 m asl. between the towns Göksu and Silifke in Mersin Province. This river acts as a barrier for the dispersal of montane organisms, e.g., dividing *Montivipera* populations into an eastern (*bulgardaghica*) and a western (*xanthina*)-clade (Stümpel et al., 2016). Further upstream near Hadim, Konya Province, 40 km northeast of the *V. a. senliki* ssp. nov. site, exists a high-altitude corridor > 1000 m asl. between Mühür Dağ and the Eastern Taurus Mountains, providing an interesting situation to test the exchange of western and eastern biota in the future.

### Conservation outlook

Originally, the rarity of *Vipera anatolica* with five previously known specimens until recently, the putative very restricted range of <10 km<sup>2</sup>, the historically stated threat of collection for the pet-trade (although no cases are known for more than two decades and only one captive specimen was ever mentioned by Nilson and Andren, 2001) and the persecution by local farmers were justification to list the species as Critically Endangered (Tok et al., 2009). The rediscovery in 2013/14 of additional 26 specimens (Göçmen et al., 2014b; Zinenko et al., 2016a) was a great success to confirm the persistence of *V. anatolica* at its original site. The find of 25 new specimens from a completely new population of *V. anatolica* at a 200-km distant location is even more stunning and opens various questions on the conservation of this taxon.

Even though the habitat at Kohu Dağ lies within the Ciglikara Ormanları National Park, and thus, is relatively well protected, Sigg (1987) and Zinenko et al. (2016a) already observed a negative influence of heavy overgrazing that leads to the degradation of vegetation

cover and subsequent decrease of Orthoptera prey at Kohu Dağ, but also on nearby mountains Bey Dağ, Alaca Dağ and Susuz Dağ, where localities with lower densities of grasshoppers did not yield any meadow viper populations in otherwise suitable habitats. Similar threats are perceived for other meadow viper populations in Europe (Filippi and Luiselli, 2004; Luiselli, 2004; Zamfirescu et al., 2011; Miszei et al., 2016). Hence, we echo the suggestions put forward by Zinenko et al. (2016a) for the conservation and the monitoring of the Kohu Dağ population, and now also for the Mühür Dağ population and can propose complement conservation actions, including:

- Further evaluate the distribution of *V. anatolica senliki* ssp. nov. around Mühür Dağ and across the entire Geyik Mountain Range.
- Expand exploration to mountain ranges farther east in neighbouring Konya, Karaman, and Mersin provinces, as well as farther northwest such as in the Dedegöl, Kuyucak, Davras, Barla and other mountains.
- Search for non- or little-grazed patches that potentially provide stable and biodiverse habitat conditions for meadow vipers.
- Evaluate the effect of overgrazing on the biodiversity in general, and the meadow vipers in particular.
- Contact local shepherds who use the viper habitats for grazing and inform them on the value of the ecosystem values of meadow vipers.
- Consult shepherds on how to recognise bitten livestock early to treat and reduce mortality.
- Produce printable material for educational purpose, e.g. leaflets, flyers, etc.
- Assess the population size of *V. a. senliki* ssp. nov. by monitoring the population trend with a capture-mark-recapture study.
- Elaborate population viability and vulnerability by genetic means to study putative historic bottleneck, isolation effect, gene flow (see for instance Ferchaud et al., 2011).
- Develop an action plan.
- Assess the threat through the mining activities, which literally dissects the Mühür Dağ population into two segments (fig. 6).
- If several populations will be found, the impact of different levels of grazing could be evaluated on the biodiversity and habitat quality.
- Develop protection of regionally known populations by limiting grazing and anthropogenic disturbances, while educating local communities about the value and threat of this species.
- Evaluate the correlation between the density of vipers and the availability of crevice-rich rock/stone slides.

This study has revealed, that assessment of a once thought to be rare and locally very restricted species, did not reflect the real situation on the ground. Indeed, our (Göçmen et al., 2014b) and others' (Zinenko et al., 2016a) discoveries at the terra typica of *Vipera a. anatolica* and the new population described herein suggest that a secretive species may need a bigger scrutiny added by species distribution modeling before establishing its conservation status. Yet, it also stresses out the need for drastic expansion of field work, in particular in a country like Turkey, that harbors a large number of unexplored mountain ranges which likely will bring more findings, as was demonstrated by our recent field research (Göçmen et al., 2014a, 2015a, 2015b; Mebert et al., 2015, 2016), and analogously demonstrated with recent discoveries of new populations in Albania of the related Greek meadow viper *Vipera graeca* (Miszei et al., 2016, 2017). Yet, our in-situ perception for years on the low abundance of small, grassland (steppes, meadows) associated viper species like *V. anatolica*, but also *V. eriwanensis* and *V. darevskii*, is that of a real threat to these species due to mining actions, extensive agriculture, and in particular, massive livestock



**Figure 6.** *Vipera anatolica senliki* ssp. nov. and the threat of mining visible in the background on Mühür Dağ, Gündoğmuş District, Antalya. Much of the barren surface visible in the image is caused by the erosion through the mining activities.

grazing, that will reduce availability of invertebrate prey and decrease habitat quality by reduced protection from dehydration, overheating and visual predators. We urge, that conservation measures take into account the negative impact by these devastating anthropogenic modifications.

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A new population and subspecies of the critically endangered Anatolian  
meadow viper *Vipera anatolica* (Eiselt and Baran, 1970) in eastern Antalya  
province

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**Supplementary Materials**

**Table ST-1.** Summarised statistics and complete list of metric and meristic characters of *Vipera anatolica senliki* ssp. nov. from Mühür Dağ and *V. a. anatolica* from the terra typica Kohu Dağ, both Antalya province. The following characters were measured: Mensural characters and ratios: SVL = snout-vent length, TL = tail length (inc. juveniles and subadults), RW = Rostrale width, RL = rostrale length, RL/RW, HW = head width, HL = head length, HL/HW, HH = head height, FW = frontal width, FL = frontal length, FL/FW, DBN= distance between the nostrils. scalation characters; DSRa = dorsal scale rows (anterior), DSRm = dorsal scale rows (mid-body), DSRp = dorsal scale rows (posterior), V = ventrals, P = prefrontals, GSR = gular scale rows, SCr = subcaudals (right), SCl = subcaudals (left), SPLr = SUPRALABIALS (right), SPLl = supralabials (left), IFLr = infralabials (right), IFLl = infralabials (left), COr = circumoculars (right), COl = circumoculars (left), Lr = loreals (right), Ll = loreals (left), CP = crown plates (intercanthals and intersupraoculars), NWZB = number of windings of the dorsal zig-zag band, NIZB = number of interruptions on the dorsal zig-zag band.

Characters	Males						Females					
<i>V. a. senliki</i> ssp. nov.	N	Min.	Max.	Mean	SD	SE	N	Min.	Max.	Mean	SD	SE
<b>SVL</b>	10	201.00	364.00	316.20	47.79	15.113	9	165.00	349.00	263.67	68.73	22.912
<b>TL</b>	10	31.00	55.00	47.40	7.26	2.296	9	19.00	33.00	26.78	5.02	1.673
<b>SVL/TL</b>	10	5.75	7.49	6.69	0.50	0.159	9	8.38	11.31	9.73	1.01	0.336
<b>RW</b>	6	1.85	2.58	2.42	0.28	0.115	7	1.84	2.55	2.24	0.24	0.091
<b>RL</b>	6	2.43	3.13	2.94	0.25	0.104	7	2.05	3.21	2.76	0.38	0.143
<b>RL/RW</b>	6	1.16	1.31	1.22	0.06	0.026	7	1.11	1.40	1.23	0.12	0.045
<b>HW</b>	6	9.36	13.64	12.03	1.49	0.610	7	8.55	15.06	12.31	2.19	0.827
<b>HL</b>	6	14.38	19.40	17.86	1.92	0.784	7	12.41	20.26	17.39	2.60	0.981
<b>HL/HW</b>	6	1.42	1.57	1.49	0.06	0.023	7	1.33	1.53	1.42	0.07	0.027
<b>HD</b>	6	5.77	8.15	7.26	0.83	0.337	7	4.93	8.48	7.01	1.29	0.488
<b>FW</b>	6	1.78	2.89	2.46	0.38	0.154	7	1.54	2.58	2.19	0.33	0.126
<b>FL</b>	6	3.45	4.42	3.93	0.42	0.173	7	2.29	4.37	3.34	0.70	0.265
<b>FL/FW</b>	6	1.37	1.94	1.62	0.23	0.093	7	1.04	1.76	1.53	0.25	0.094

<b>DBN</b>	6	2.79	4.13	3.63	0.47	0.191	7	2.66	4.26	3.45	0.58	0.220
<b>DSRa</b>	10	19.00	21.00	20.80	0.63	0.200	9	19.00	21.00	20.78	0.67	0.222
<b>DSRm</b>	10	19.00	21.00	20.20	1.03	0.327	9	19.00	21.00	19.67	1.00	0.333
<b>DSRp</b>	10	17.00	17.00	17.00	0.00	0.000	9	17.00	17.00	17.00	0.00	0.000
<b>V</b>	10	121.00	125.00	122.10	1.45	0.458	9	119.00	125.00	122.11	1.76	0.588
<b>P</b>	10	0.00	2.00	1.10	0.74	0.233	9	0.00	2.00	1.11	0.60	0.200
<b>GSR</b>	10	4.00	6.00	4.70	0.67	0.213	9	4.00	6.00	5.11	0.60	0.200
<b>SCr</b>	10	31.00	34.00	32.40	1.26	0.400	9	22.00	25.00	23.44	1.13	0.377
<b>SCI</b>	10	32.00	35.00	33.40	1.26	0.400	9	23.00	26.00	24.44	1.13	0.377
<b>IFLr</b>	10	8.00	9.00	8.70	0.48	0.153	9	8.00	9.00	8.56	0.53	0.176
<b>IFLI</b>	10	8.00	9.00	8.80	0.42	0.133	9	8.00	9.00	8.56	0.53	0.176
<b>COr</b>	10	8.00	10.00	9.20	0.63	0.200	9	7.00	9.00	8.44	0.73	0.242
<b>COI</b>	10	8.00	9.00	8.60	0.52	0.163	9	8.00	9.00	8.33	0.50	0.167
<b>Lr</b>	10	3.00	6.00	4.50	0.85	0.269	9	1.00	5.00	3.33	1.22	0.408
<b>LI</b>	10	2.00	6.00	3.70	1.25	0.396	9	1.00	5.00	3.33	1.50	0.500
<b>CP</b>	10	11.00	19.00	13.70	3.06	0.967	9	10.00	20.00	15.00	3.12	1.041
<b>NWZB</b>	10	52.00	66.00	60.60	4.14	1.310	9	50.00	59.00	55.89	2.85	0.949
<b>NIZB</b>	10	5.00	22.00	11.50	5.68	1.797	9	5.00	18.00	9.44	4.85	1.617

(Continued →)



Characters	Males						Females					
<i>V. a.</i>												
<i>anatolica</i>	N	Min.	Max.	Mean	SD	SE	N	Min.	Max.	Mean	SD	SE
SVL	5	181.00	321.00	252.80	51.81	23.170	2	230.00	269.00	249.50	27.58	19.500
TL	5	26.00	47.00	38.80	7.76	3.470	2	21.00	25.00	23.00	2.83	2.000
SVL/TL	5	5.97	6.96	6.53	0.43	0.194	2	10.76	10.95	10.86	0.14	0.096
RW	5	1.58	2.25	2.01	0.29	0.130	2	1.64	2.07	1.86	0.30	0.215
RL	5	2.03	2.76	2.38	0.31	0.136	2	2.21	2.59	2.40	0.27	0.190
RL/RW	5	1.12	1.23	1.19	0.07	0.026	2	1.25	1.35	1.30	0.07	0.048
HW	5	6.92	11.82	9.47	1.76	0.789	2	10.27	11.05	10.66	0.55	0.390
HL	5	14.07	19.12	16.39	2.09	0.933	2	15.38	16.85	16.12	1.04	0.735
HL/HW	5	1.50	1.65	1.59	0.06	0.025	2	1.50	1.52	1.51	0.02	0.014
HD	5	4.92	7.67	6.26	1.01	0.453	2	5.82	6.29	6.06	0.33	0.235
FW	5	1.59	2.15	1.96	0.22	0.096	2	1.88	2.44	2.16	0.40	0.280
FL	5	2.63	3.46	3.10	0.32	0.141	2	3.35	3.69	3.52	0.24	0.170
FL/FW	5	1.59	2.15	1.96	0.22	0.197	2	1.51	1.78	1.65	0.19	0.135
DBN	5	2.59	3.65	3.21	0.44	0.197	2	2.92	3.37	3.15	0.32	0.225
DSRa	5	18.00	19.00	18.40	0.55	0.245	2	19.00	19.00	19.00	0.00	0.000
DSRm	5	19.00	19.00	19.00	0.00	0.000	2	19.00	21.00	20.00	1.41	1.000
DSRp	5	15.00	17.00	16.40	0.89	0.400	2	17.00	17.00	17.00	0.00	0.000
V	5	116.00	120.00	118.20	1.48	0.663	2	118.00	119.00	118.50	0.71	0.500
P	5	0.00	3.00	1.40	1.34	0.600	2	0.00	1.00	0.50	0.71	0.500
GSR	5	4.00	6.00	5.00	0.71	0.316	2	4.00	5.00	4.50	0.71	0.500

<b>SCr</b>	5	29.00	30.00	29.60	0.55	0.245	2	22.00	22.00	22.00	0.00	0.000
<b>SCI</b>	5	30.00	31.00	30.60	0.55	0.245	2	23.00	23.00	23.00	0.00	0.000
<b>SPLr</b>	5	8.00	8.00	8.00	0.00	0.000	2	8.00	9.00	8.50	0.71	0.500
<b>SPLI</b>	5	8.00	8.00	8.00	0.00	0.000	2	8.00	9.00	8.50	0.71	0.500
<b>IFLr</b>	5	9.00	10.00	9.80	0.45	0.200	2	9.00	10.00	9.50	0.71	0.500
<b>IFLI</b>	5	10.00	10.00	10.00	0.00	0.000	2	10.00	11.00	10.50	0.71	0.500
<b>COr</b>	5	9.00	11.00	9.80	1.10	0.490	2	9.00	11.00	10.00	1.41	1.000
<b>COI</b>	5	9.00	11.00	9.80	0.84	0.374	2	10.00	10.00	10.00	0.00	0.000
<b>Lr</b>	5	4.00	7.00	5.60	1.14	0.510	2	4.00	7.00	5.50	2.12	1.500
<b>LI</b>	5	4.00	6.00	5.20	0.84	0.374	2	3.00	6.00	4.50	2.12	1.500
<b>CP</b>	5	10.00	15.00	12.60	1.82	0.812	2	13.00	18.00	15.50	3.54	2.500
<b>NWZB</b>	5	56.00	63.00	58.60	2.70	1.208	2	51.00	56.00	53.50	3.54	2.500
<b>NIZB</b>	5	0.00	5.00	1.20	2.17	0.970	2	1.00	2.00	1.50	0.71	0.500

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**Table ST-2.** Data on time and weather at capture, and coded or meristic characters of colour pattern of individual *Vipera anatolica* from Kohu Dağ (terra typica) and Mühür Dağ (*Vipera a. senliki*, ssp. nov.), both in Antalya province. PC (Pileus colouration) with no = 0, and yes = 1, for increased speckling and/or darker ground colour anterior head; NIZB (number of interruptions of the dorsal zig-zag band); CSC (marked reddish tone of subcaudals) with yes = 1, and 0 = no ; DCTT (dorsal colouration of tail tip in adults) with yellowish = 1, and not yellowish = 0; DSHA (drop-shaped head angle mark): number of drop-shaped dorso-cephalic angled marks with wider half on parietal side, none due even halved DSHA = 0, one DSHA = 1, or two DSHA = 2.

<i>Vipera anatolica</i> ssp.	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>
Air Temp.	14	10	12	13	12	11	16	17	18	19
Time	15:00	15:30	17:30	11:00	11:30	12:30	09:00	09:35	9:45	16:45
Weather	Cloudy-Rainy	Cloudy-Rainy	Cloudy-Rainy	Cloudy-Rainy	Cloudy-Rainy	Cloudy-Rainy	Cloudy-Sunny	Cloudy-Sunny	Cloudy-Sunny	Sunny
Sex	♀	♀	♀	sub ♀	sub ♂	♂	♂	♂	juv-♀	♂
PC	1	1	1	1	1	1	1	1	1	1
NIZB	18	5	8	5	12	5	12	21	8	7
CSC	1	1	1	0	0	0	0	0	1	0
DCTT	1	1	0	1	1	1	1	1	1	1
DSHA	0	0	0	0	0	0	0	0	0	0
<i>Vipera anatolica</i> ssp.	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	<i>senliki</i>	
Air Temp.	14	18	15	18	17	16	15	15	16	
Time	08:00	17:25	10:00	17:00	19:00	19:20	09:00	09:25	18:25	
Weather	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	
Sex	♂	sub-♀	sub ♀	♂	♂	juv-♀	sub-♀	♂	♂	
PC	1	1	1	1	1	1	1	1	1	
NIZB	9	8	16	22	8	12	5	10	9	
CSC	1	1	1	0	1	1	1	1	1	
DCTT	1	0	1	1	1	1	1	1	1	
DSHA	0	1	0	0	0	0	1	0	0	
<i>Vipera anatolica</i> ssp.	<i>anatolica</i>	<i>anatolica</i>	<i>anatolica</i>	<i>anatolica</i>	<i>anatolica</i>	<i>anatolica</i>	<i>anatolica</i>			
Air Temp.	10	17	20	14	16	15	14			
Time	10:00	17:00	12:00	11:30	13:00	10:30	12:30			
Weather	Cloudy-rainy	Open	Open	Open	Open	Open	Cloudy-rainy			
Sex	♂	♂	♂	♀	♂	♀	♂			
PC	0	1	0	0	0	0	1			
NIZB	0	0	5	2	0	1	1			
CSC	0	0	0	0	0	0	0			
DCTT	0	0	0	0	0	0	0			
DSHA	1	2	0	2	2	2	2			
<i>Vipera anatolica</i> ssp.	<i>anatolica</i>	<i>anatolica</i>		<i>anatolica</i>		<i>anatolica</i>				
Reference	Billing 1985	Eiselt and Baran 1970		Nilson and Andren 2001		Zinenko etal 2016		Zinenko etal 2016, unpubl. report		
Sex	♂	♀	♀	♀		♀	♂	♀		
PC	1	1	1	0		0	0	1		
NIZB	0	2	3	3		1	2	0		
CSC	not meas	not measurable		not measurable		not measurable		not meas		
DCTT	0	not measurable		not measurable		0	0	not measurable		
DSHA	1	2	1	2		0	2	1		

**Figures SF-1 to SF-14.**

Relevant individual data (field- or voucher-ID, age group, sex, body size, dorsalia counts, capture-date, -location, altitude) for the first 19 Anatolian Meadow Vipers (*Vipera anatolica senliki* ssp. nov.) from the new locality at Mühür Dağ, Gündoğmuş District, Antalya, Turkey are depicted in the following figures SF-1 to SF-10; for a comparison, the details of seven *V. a. anatolica* from the species' terra typica at Kohu Dağ, Elmalı District, are depicted in figures SF-11 to SF-14.



**1 Adult Female / SVL=334 mm / TL=33 mm / Dorsalia=21-19-17  
21.05.2016 Senir Plateau, Gündoğmuş, Antalya, 1744 m asl.**



**2 Adult Female / SVL=328 mm / TL=29 mm / Dorsalia=21-19-17  
21.05.2016 Senir Plateau, Gündoğmuş, Antalya, 1763 m asl.**

**Figure SF-1.** *Vipera anatolica senliki* ssp. nov., specimens 1 and 2.





**3 Adult Female / SVL=349 mm / TL=32 mm / Dorsalia=21-21-17  
21.05.2016 Senir Plateau, Gündoğmuş, Antalya, 1839 m asl.**



**4 Subadult Female / SVL=233 mm / TL=25 mm / Dorsalia=21-21-17  
22.05.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1559 m asl.**

**Figure SF-2.** *Vipera anatolica senliki* ssp. nov., specimens 3 and 4.





**5 Subadult Male / SVL=201 mm / TL=31 mm / Dorsalia=19-19-17  
22.05.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1662 m asl.**



**6 Adult Male / SVL=316 mm / TL=45 mm / Dorsalia=21-21-17  
22.05.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1753 m asl.**

**Figure SF-3.** *Vipera anatolica senliki* ssp. nov., specimens 5 and 6.





**7 Adult Male / SVL=322 mm/ TL=43 mm / Dorsalia=21-19-17  
23.05.2016 Serinyaka Plateau,Gündoğmuş, Antalya, 1750 m asl.**



**8 Adult Male (HOLOTYPE) / SVL=364 mm/ TL=51 mm / Dorsalia=21-21-17  
23.05.2016 Serinyaka Plateau,Gündoğmuş, Antalya, 1755 m asl.**

**Figure SF-4.** *Vipera anatolica senliki* ssp. nov., specimens 7 and 8 (holotype).





**9 Juvenile (Female type) / SVL=165 mm / TL=19 mm / Dorsalia=21-21-17  
23.05.2016 Serinyaka Plateau, Gündoğmuş, Antalya, 1727 m asl.**



**10 Adult Male / SVL=360 mm / TL=52 mm / Dorsalia=21-19-17  
03.06.2016 Senir Plateau, Gündoğmuş, Antalya, 1875 m. asl [Released]**

**Figure SF-5. *Vipera anatolica senliki* ssp. nov., specimens 9 and 10.**





**11 Adult Male / SVL=316 mm/ TL=55 mm / Dorsalia=21-21-17  
04.06.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1586 m asl. [Released]**



**12 Subadult Female / SVL=291 mm/ TL=28 mm / Dorsalia=21-19-17  
04.06.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1660 m asl. [Released]**

**Figure SF-6. *Vipera anatolica senliki* ssp. nov., specimens 11 and 12.**





**13 Suadult Female / SVL=279 mm / TL=31 mm / Dorsalia=19-19-17  
04.06.2016 Serinyaka Plateau, Gündoğmuş, Antalya, 1745 m asl. [Released]**



**14 Adult Male / SVL=359 mm / TL=53 mm / Dorsalia=21-19-17  
03.06.2016 Senir Plateau, Gündoğmuş, Antalya, 1813 m asl. [Released]**

**Figure SF-7. *Vipera anatolica senliki* ssp. nov., specimens 13 and 14.**





**15 Adult Male / SVL=296 mm / TL=46 mm / Dorsalia=21-21-17  
03.06.2016 Senir Plateau, Gündoğmuş, Antalya, 1634 m asl. [Released]**



**16 Juvenile (Female type) / SVL=176 mm / TL=21 mm / Dorsalia=21-19-17  
03.06.2016 Senir Plateau, Gündoğmuş, Antalya, 1766 m asl. [Released]**

**Figure SF-8. *Vipera anatolica senliki* ssp. nov., specimens 15 and 16.**





**17 Subadult Female / SVL=218 mm/ TL=23 mm / Dorsalia=21-19-17  
04.06.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1690 m asl. [Released]**



**18 Adult Male / SVL=334 mm/ TL=54 mm / Dorsalia=21-21-17  
04.06.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1724 m asl. [Released]**

**Figure SF-9. *Vipera anatolica senliki* ssp. nov., specimens 17 and 18.**





**19 Adult Male / SVL=294 mm/ TL=44 mm / Dorsalia=21-21-17  
04.06.2016 Gelesandra Plateau, Gündoğmuş, Antalya, 1714 m asl. [Released]**

**Figure SF-10. *Vipera anatolica senliki* ssp. nov., specimen 19.**





1

**1 Adult Male / SVL=253 mm/ TL=41 mm / Dorsalia=18-19-17  
03.05.2014 Çıvkuş Tepesi, Kohu Dağı, Elmalı, Antalya, 2112 m asl.**



2

**2 Adult Male / SVL=181 mm/ TL=26 mm / Dorsalia=18-19-17  
12.06.2014 Çıvkuş Tepesi, Kohu Dağı, Elmalı, Antalya, 2265 m asl.**

**Figure SF-11. *Vipera a. anatolica*, specimens 1 and 2.**





3

3 Adult Male / SVL=253 mm/ TL=41 mm / Dorsalia=18-19-17  
15.07.2014 Çıvkuş Tepesi, Kohu Dağı, Elmalı, Antalya, 2055 m asl.



4

4 Adult Female / SVL=230 mm/ TL=21 mm / Dorsalia=19-21-17  
03.10.2014 Çıvkuş Tepesi, Kohu Dağı, Elmalı, Antalya, 1980 m asl.

Figure SF-12. *Vipera a. anatolica*, specimens 3 and 4.





5

**5 Adult Male / SVL=321 mm / TL=47 mm / Dorsalia=19-19-16  
03.10.2014 Çıvkuş Tepesi, Kohu Dağı, Elmalı, Antalya, 2016 m asl.**



6

**6 Adult Female / SVL=269 mm / TL=25 mm / Dorsalia=19-19-17  
04.10.2014 Çıvkuş Tepesi, Kohu Dağı, Elmalı, Antalya, 2094 m asl.**

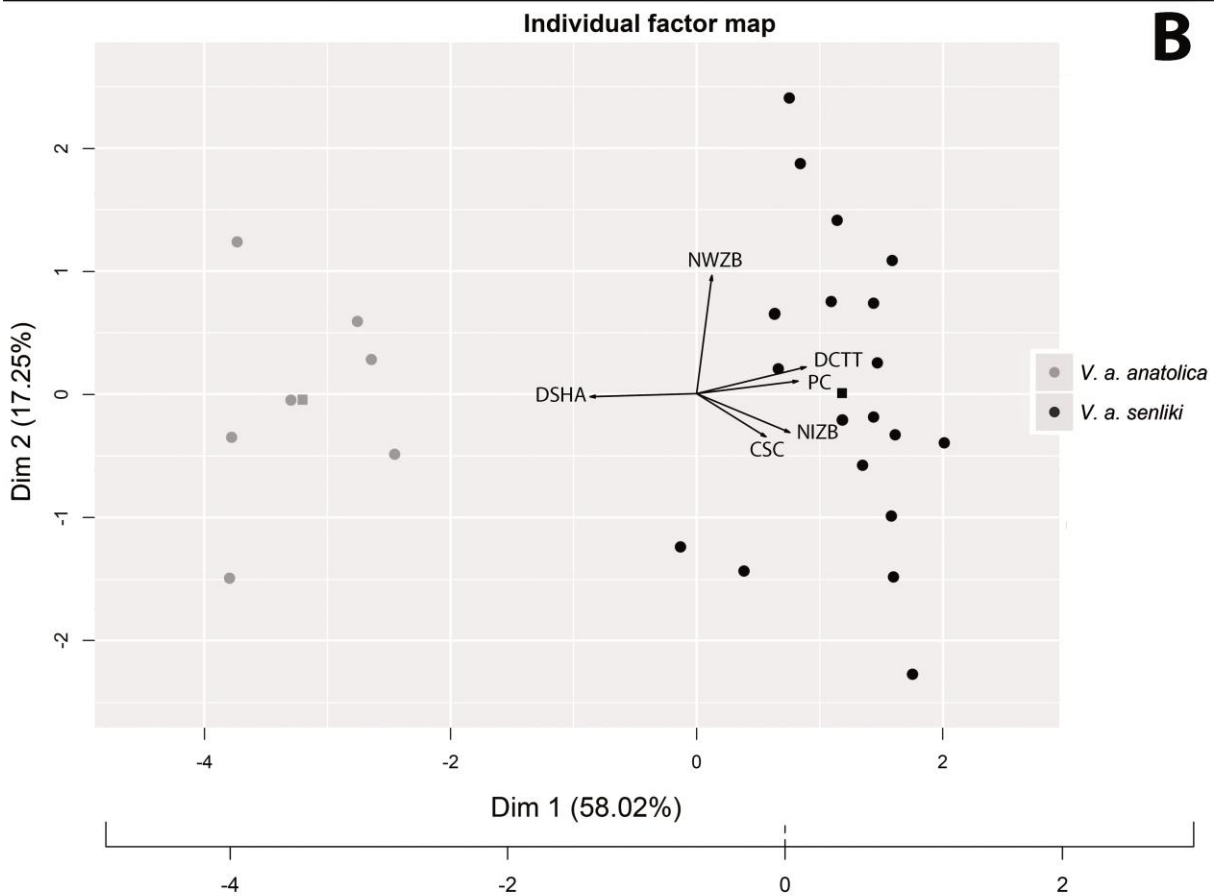
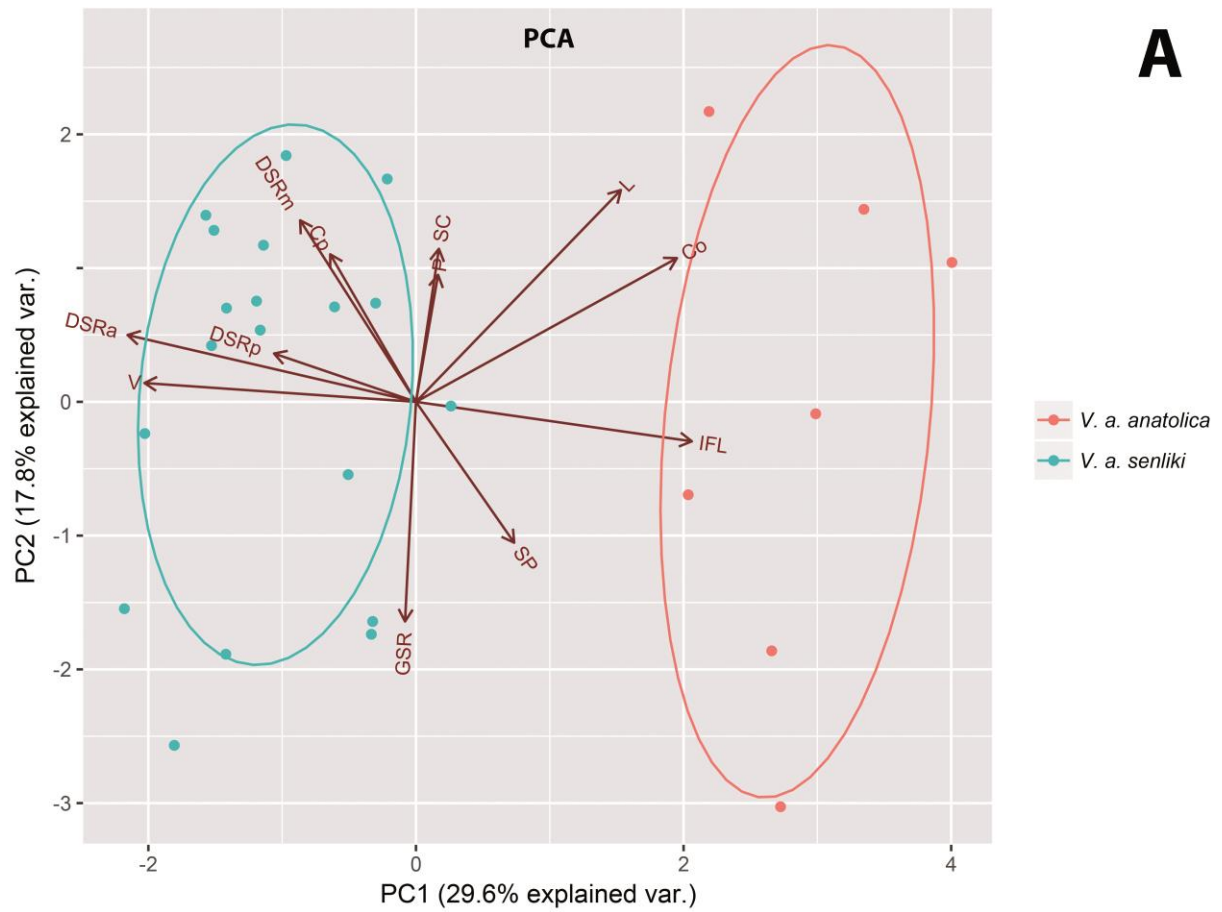
**Figure SF-13. *Vipera a. anatolica*, specimens 5 and 6.**



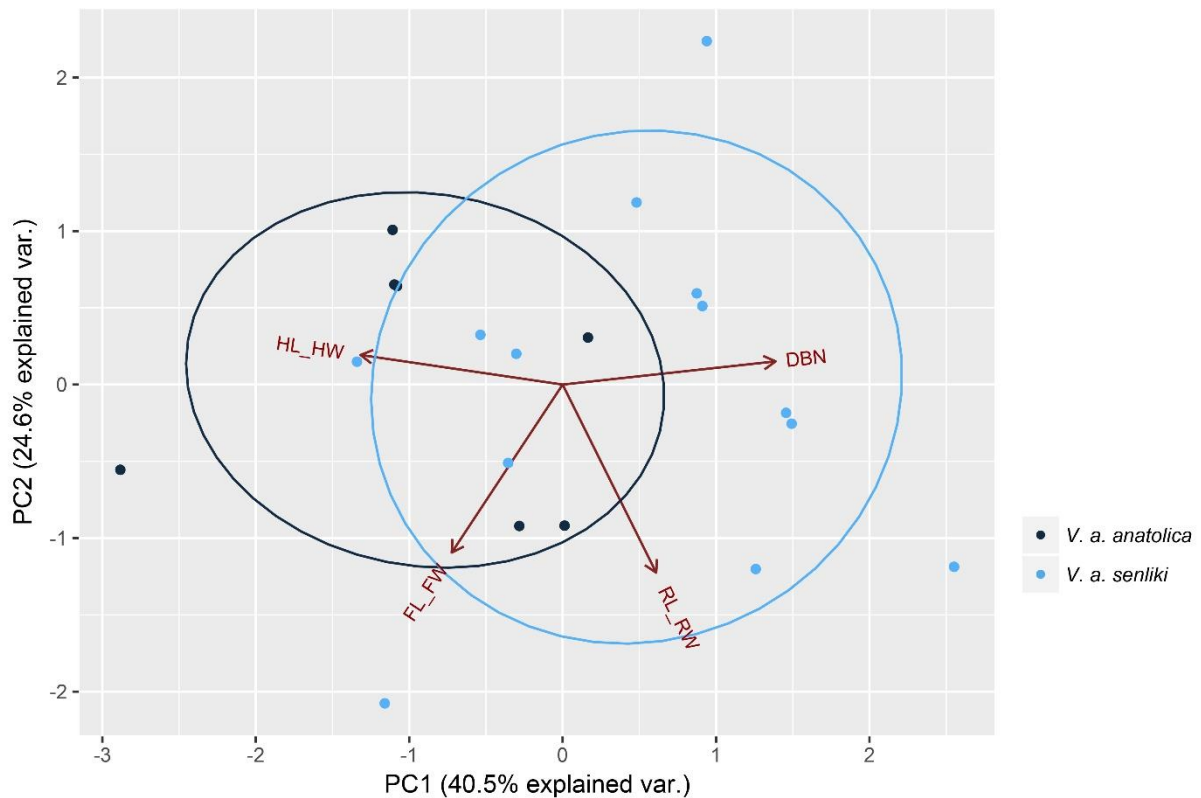


**7 Adult Male / SVL=233 mm / TL=39 mm / Dorsalia=19-19-15  
05.10.2014 Çıvkuş Tepesi, Kohu Dağı, Elmalı, Antalya, 2170 m. asl.**

**Figure SF-14. *Vipera a. anatolica*, specimen 7.**



← **Figure SF15.** Morphological comparison between *Vipera anatolica* from Kohu Dağ, and *Vipera a. senliki* ssp. nov. from Mühür Dağ, both in Antalya province. (A) Principal Component Analysis (PCA) of scalation regrouping: DSRa = Dorsal scale rows (anterior), DSRm = Dorsal scale rows (mid-body), DSRp = Dorsal scale rows (posterior), V = Ventrals, P = Preventrals, GSR = Gular scale rows, SC = Subcaudals (summed, right plus left), SP = Supralabials (summed, right plus left), IFL = Infralabials (summed, right plus left), CO = Circumoculars (summed, right plus left), L = Loreals (summed, right plus left) and Cp = Crown plates (intercanthals and intersupraoculars). (B) Factor Analysis of Mixed Model (FAMD) of colouration regrouping: NWZB = Number of windings of the dorsal zig-zag band, NIZB = Number of interruptions on the dorsal zig-zag band., CSC (colouration of subcaudals), DCTT (dorsal colouration of tail tip), PC (Pileus colouration) and DSHA (drop-shaped head angles = number of drop-shaped dorso-cephalic angled marks with wider half on parietal side).



**Figure SF-16.** PCA of head ratios: RW = rostrale width, RL = rostrale length, HW = head width, HL = head length, FW = frontal width, FL = frontal length, DBN = distance between the nostrils.