

Morphometric characteristics of Alpine salamanders: a support for subspecies validation and conservation?

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Abstract. The subspecies concept is not only useful to assess the evolutionary history of species and therefore describe their evolutionary potential, but it also has corollaries for defining conservation units and their management. Within Alpine salamanders, the subspecies status of *Salamandra atra prenzensis*, isolated in the Dinarides from its nominal subspecies *Salamandra atra atra* that occurs in the Alps, has been under debate. To remediate this fuzzy taxonomy, the present study investigates 14 morphological traits of Alpine salamanders originating from Austria and from Bosnia and Herzegovina (B&H). Multivariate analyses support a geographical structuring of morphological variation and the differentiation between the Dinaric (B&H) and Alpine (Austrian) populations. Within populations, a different correlation pattern among traits is registered, reflecting the distinct genetic architecture of multivariate phenotypes. This morphometric study supports recent molecular evidences of a strong differentiation between the Dinaric and Alpine populations and pleads in favour of the separate subspecies status, although a wider sampling of other populations and the inclusion of additional characters would be necessary to reinforce this conclusion. The recognition of *Salamandra atra prenzensis* as a distinct subspecies would highly contribute to the better conservation of this emblematic salamander.

Keywords: Alps, conservation status, Dinarides, salamander evolution, salamander morphology, taxonomy.

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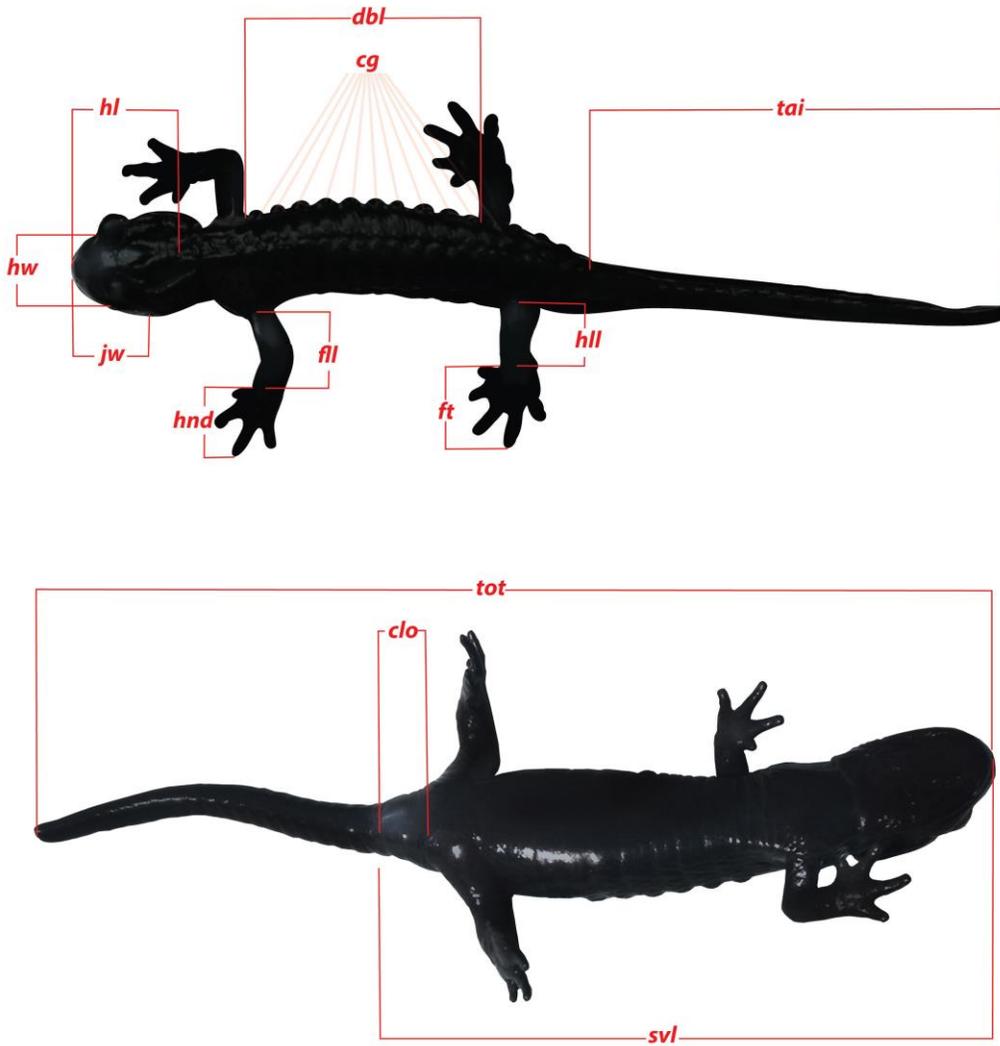
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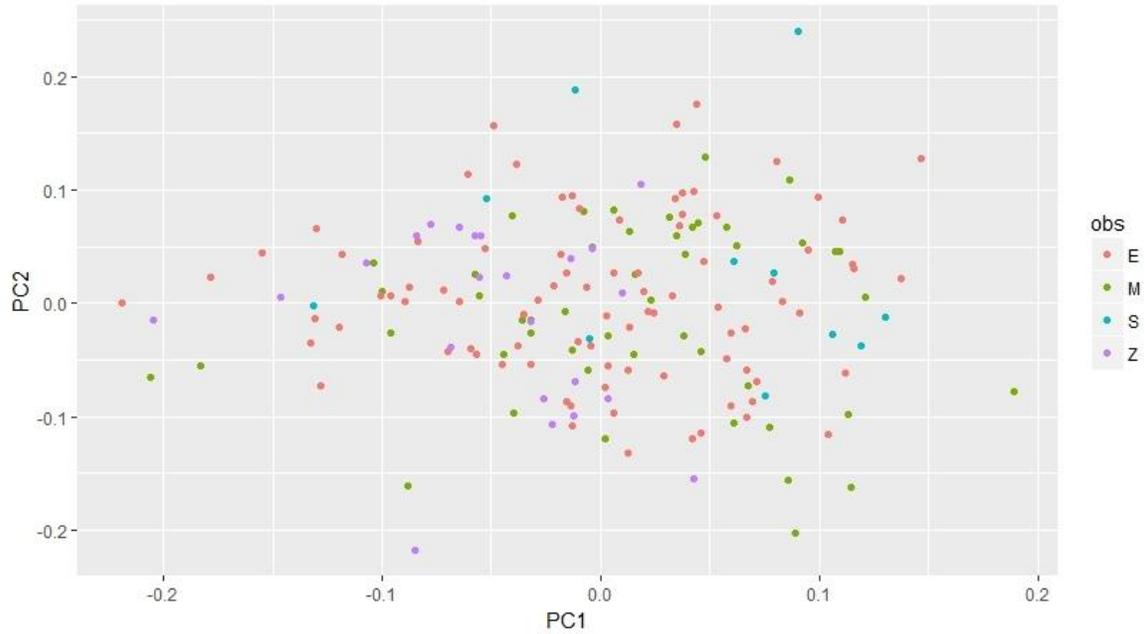
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Supplementary material



Supplementary figure S1. Dorsal and ventral view of observed morphological traits (full trait names are given in table 1 - see text).



Supplementary figure S2. PCA analysis of B&H individuals taken by multiple observers suggests no observer effect on the measurements. Observer: E is the common observer of the two populations.

Supplementary table S1. Number of males (Nm) and females (Nf) sampled in each location. The total number of individuals measured by the common observer of both populations (Nob) is mentioned as indicative information. B&H – Bosnia and Herzegovina.

Population	Subpopulation	Location	Nm	Nf	Nob
B&H	Prenj	Kopilice	11	18	29
B&H	Prenj	Podotiš	23	26	32
B&H	Prenj	Zakantar	13	18	0
B&H	Prenj	Osobac	4	4	8
B&H	Prenj	Soplje	2	5	3
B&H	Čvrstica	Ledeno jezero	34	25	16
Austria	Bluntau	Nördlichen	8	15	3
Austria	Bluntau	Kalkalpen (Golling)			
Austria	Tappenkarsee	Radstädter Tauern	23	16	11

Supplementary table S2. Intra- and inter-class correlation coefficient (ICC/R) for the two observers (class), as assessed based on variances of linear mixed models of repeated measurements for all traits (see e.g. table 1 for full names).

Observer	clo	fl	cg	hl	hll	tot	hw	hnd	svl	jw	fl	ta	dbl
intra ICC	0.92	0.90	1	0.93	0.88	0.99	0.94	0.91	0.98	0.96	0.94	0.98	0.84
inter ICC	0.50	0.90	0.7	0.90	0.88	0.99	0.93	0.91	0.97	0.96	0.94	0.97	0.84

Supplementary table S3. Number of individuals from each subpopulation with the respective number of costal grooves (cg; column names refer to the range for cg: 9–15 – see table 1)

Subpopulation	9	10	11	12	13	14	15
Blunताल	0	2	4	9	5	2	1
Tappenkar	0	2	6	17	7	7	0
Čvrsnica	1	9	31	15	2	1	0
Prenj	7	36	47	16	11	6	0