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IS TAIL A GOOD PROXY FOR ESTIMATING INDIVIDUAL BODY CONDITION IN SALAMANDERS?

SUMMARY

Body condition indexes (BCIs) are useful tools to estimate body fat mass in animals. These methods are various and widely employed with different taxa, despite some inherent limitations. Recently, tail width has been used to estimate body condition in salamanders. Since this organ represents an important site of fat storage, variation of tail width should reflect changes of salamanders' body condition. However, this approach presents some constraints and must be validated. For this reason, we calculated a scaled measure of tail width for six Mediterranean taxa of salamanders, comparing it with the related Scaled Mass Index (SMI), which has proven to be a very reliable body condition estimator for amphibians. We found that tail width can be used as a BCI proxy only in some salamander species, while in others this measure is mostly influenced by the ecological and sexual traits of individuals, rather than their physiological status.

Key words. Body condition index, ecological traits, salamanders, tail width

RIASSUNTO

La coda è un buon stimatore della condizione corporea individuale nelle salamandre? Gli indici di condizione corporea rappresentano uno strumento utile per stimare il grasso corporeo negli animali. Questi metodi sono molteplici e, nonostante alcune limitazioni, largamente utilizzati. Recentemente, la larghezza della coda è stata usata per stimare la condizione corporea nelle salamandre. Dato che questo organo rappresenta un importante sito di stoccaggio dei lipidi, le variazioni della sua larghezza dovrebbero riflettere la quantità di riserve energetiche presenti negli urodeli. Questo approccio, tuttavia, possiede alcuni limiti e necessita di una validazione. Per questo motivo abbiamo calcolato una misura scalare della larghezza della coda per sei taxa di salamandre mediterranee, raffrontandola al corrispettivo Indice di Massa Scalare, che si è dimostrato essere un ottimo stimatore della condizione corporea per gli anfibi. I nostri risultati mostrano che la larghezza della coda può

essere usata come indicatore della condizione corporea solo per alcune specie di salamandre, mentre in altre questo parametro è influenzato soprattutto dalle caratteristiche ecologiche e sessuali degli individui, piuttosto che dalla loro condizione fisica.

Parole chiave. Indice di condizione corporea, aspetti ecologici, salamandre, larghezza della coda

Introduzione

In salamanders, the tail is mainly composed of trophic muscle and fat and represents a storage organ of lipids, which could be used during hibernation, droughts period, reproduction, or metamorphosis (Pond, 2011). Consequently, changes in tail width (TW), should reflect changes in lipid and/or protein content (Fraser, 1980). Recently, the measure of TW has been employed, without being validated as a BCI of *Eurycea sosorum* and *E. tonkawae* (Bendik & Gluesenkamp, 2013; Pierce & Gonzalez, 2019; Nissen & Bendik, 2020).

To evaluate the reliability of tail width as BCI in salamanders, we calculated individuals' TW, related to snout-vent-length (SVL), in six salamanders' taxa. However, the methodology possesses inherent issues since TW could be influenced by multiple factors (e.g. ecological constraints, reproductive strategy and anatomical structure). Therefore, we related this measure to the Scaled Mass Index (SMI), a BCI which is based on the relationship between body mass and a linear predictor of body size, taking into consideration measurement error and accounting for allometric growth (Peig & Green, 2009). The SMI reliably predicts body fat in many animals and specifically in salamanders (McCracken & Stebbings, 2012).

Material and Methods

We randomly selected 345 individuals of *Salamandrina perspicillata*, *Salamandra atra*, *Salamandra atra aurorae*, *Speleomantes imperialis*, *Euproctus montanus* and *Triturus cristatus*. All individuals were weighted with a digital scale (precision 0.01g), while SVL and TW were estimated using digital images of the ventral side of animals, taken against a reference ruler and imported in software ImageJ. This approach has several advantages as it provides good data quality, with minimal stress for animals (Lunghi *et al.*, 2020).

Permits for temporary capture were issued by: Italian Ministry of Environment (Prot. 10210/PNM of 21/05/2015) and Sardinia Region (Det. 14951 N 465 of 01/07/2015) for *S. imperialis*; Italian Ministry of Environment (Prot. PNM-II-2012- 0015691; PNM-EU-2017-005370; PNM-EU-2017-005370) for *S. perspicillata*, *S. atra atra* and *S. a. aurorae*, respectively; Prefecture of Haute Corse (2B–2018–01–92–004) for *E. montanus*, and Prefect Bouches-du-Rhône (2010 252-0001) for *T. cristatus*.

In order to compare SMI to TW, we calculated a scaled measure of tail width (STwI), by relating TW (measured immediately after the cloaca region), instead of body mass, with SVL. We used a linear regression, for all species and sex separately, to investigate if there was a relationship between SMI and STwI, assuming the latter as a predictor of the former.

Furthermore, we used ANCOVA to test for variation in those taxa where slopes between sexes did not differ.

Results and Discussion

The relationship of linear regression between SMI and STwI was significant for both sexes in *S. perspicillata* ($p_M < 0.001$ and $p_F = 0.002$), *S. atra* ($p_M = 0.026$ and $p_F = 0.003$) and *S. a. aurorae* ($p_M < 0.001$ and $p_F = 0.011$). In *S. imperialis* and *E. montanus* slope of the regression model was significant only for females ($p_F = 0.006$) and males ($p_M < 0.001$) respectively, while it was not significant for neither sex in *T. cristatus* (Fig. 1).

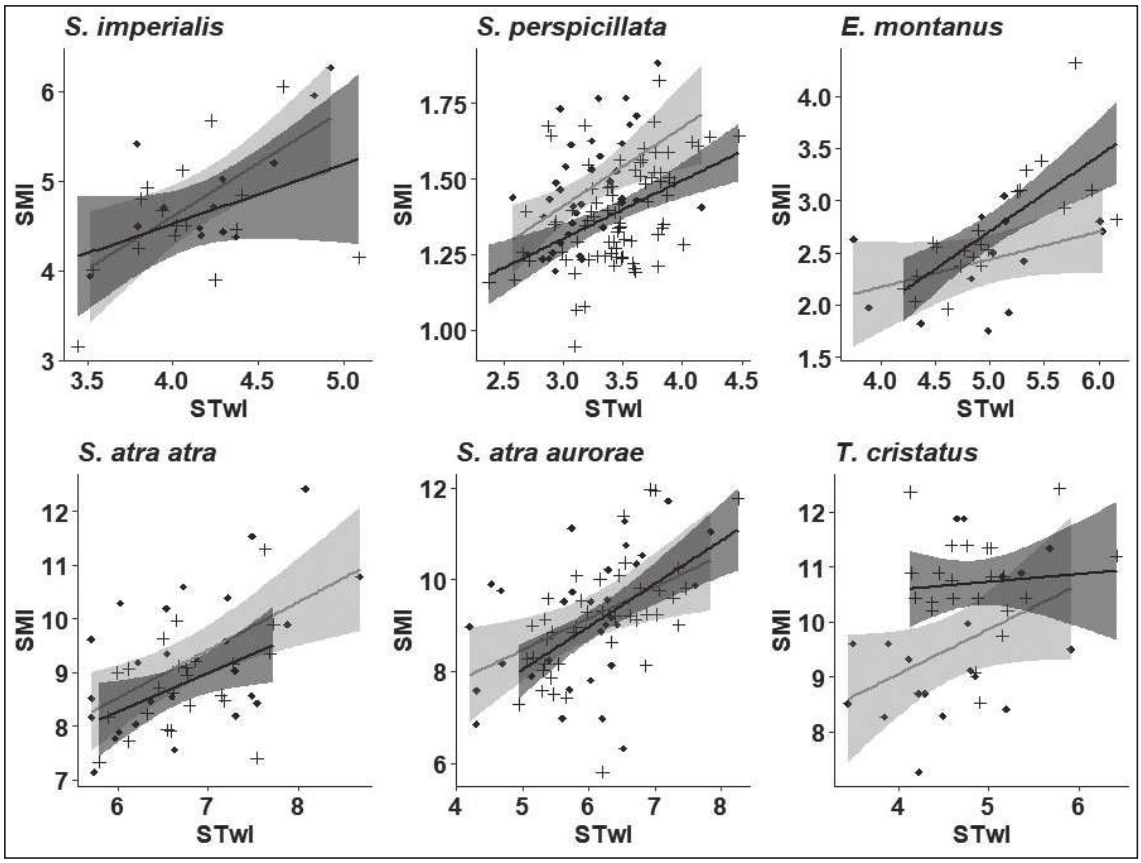

Fig. 1 — Scatterplots representing the relationship between SMI and STwI for six salamander taxa, divided by sex. Sexes are coded by colours and dots shape, as follows: light grey and diamond= females, dark grey and cross = males.

The ANCOVA highlighted a significant difference in slope between *S. perspicillata* and the two subspecies of *S. atra* ($p < 0.001$), while no significant differences in slope were found between the two alpine salamanders.

Since tail width can be subjected to a wide range of biological and ecological processes, we do not recommend employing tail as a proxy of body condition without a validation by using a conventional method for estimate lipid content. This measure may be an indicator of body condition only for those species where tail is not involved in environmental or reproductive specializations.

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