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Comparative performance of incidence-based estimators of species richness in temperate zone herpetofauna inventories

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ABSTRACT

Species inventories provide the basic information for biodiversity studies. Designing cost-effective species inventories is important in estimating the species richness or the number of additional species expected in a study area. Complete species inventories are difficult to achieve and a variety of estimation methods are available to counter the underestimation of species richness associated with incomplete sampling. A main criterion of selecting an estimation method requires deciding on a sampling unit type. The sampling unit may vary across study and estimating species richness using different sample units may produce different results. We evaluated the ability of incidence-based estimators of species richness to provide reliable estimates of species richness of temperate herpetofauna (i.e. amphibian and reptile) communities using two different types of sampling units (i.e. numbers of sampling days and the number of sampling sites, respectively). Our results showed that incidence-based estimators varied in their performance according to the two sampling units used. The incidence-based coverage estimator performed best when sampling unit was the number of sampling days whereas second-order Jackknife was the best estimator using sites as sampling unit. We draw attention on the lack of robustness of incidence-based estimators to sampling unit and recommend using species richness estimators in inventories of herpetofauna depending on the sampling unit.

1. Introduction

The worldwide amphibian and reptile decline is a major issue of concern (e.g., Beebee and Griffiths, 2005; Böhm et al., 2013). To assist amphibian and reptile conservation much of the research has focused on developing and implementing inventory and monitoring programs. Despite differences in morphology, reproductive biology and ecological and behavioral traits, amphibians and reptiles are often combined in a single group, called herpetofauna, for inventory and monitoring purpose. A critical issue in the development and implementation of inventory and monitoring programs for herpetofauna is selecting the appropriate sampling design to reduce the uncertainty in estimation the status or trend of amphibians and reptiles communities. A variety of sampling methods and units can be employed to inventory and monitor the herpetofauna communities, but due to limited resources available there is a critical need for standardized and optimized sampling protocols. Standardized protocols guarantee the comparability of data across studies and communities, whereas optimization guarantees the efficiency, so that time and resources are not reduced (Lindenmayer and Likens, 2010).

Species richness assessment is the primary step in field studies (Boulinier et al., 1998) and the most commonly used indicator to describe the diversity on local (e.g. community) and regional (e.g., species pool) level (Colwell and Coddington, 1994; May, 1988). Although species richness is a natural measure of biodiversity, it is an elusive quantity to measure properly (May, 1988). Species richness is defined as the actual number of species present in a given area (Brown et al., 2007). A complete census of the number of species in an extensive area is theoretically possible, but generally not feasible especially in species-rich taxa. Consequently, one

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Table 1
Characteristics of the five study areas.

	Name	Short name	Country	Latitude (north)	Longitude (east)	Altitudinal range (m)	Area (ha)
1	Măcin Mountains National Park	Măcin	Romania	45°12′	28°21′	7–467	11149.15
2	Siriu Mountains	Siriu	Romania	45°28′	26°14′	548–1663	6230
3	Defileul Jiului National Park	Jiu	Romania	45°16′	23°23′	234–1690	11,156
4	Maramureş Mountains Natural Park	Maramureş	Romania	47°46′	24°33′	340–1957	150,000
5	Western Black Sea Coast	Black Sea Coast	Bulgaria and Romania	43°24′	28°08′	0–70	12,000

first assesses the completeness of the species inventory. Species accumulation curves (SACs) (Soberón and Llorente, 1993), in which the cumulative number of species is plotted against a measure of the sampling effort (e.g., number of samples, number of individuals), are commonly used to evaluate the completeness of species inventory. When SACs reaches a horizontal asymptote the sampling effort is considered sufficient to capture the species diversity in a given area and the species inventory completed. When the SACs show an increase up trend one uses an estimation method to extrapolate from the data and find the 'true' number of species. A large number of estimation methods have been developed (Cogălniceanu, 2007) but incidence-based estimators of species richness are the most widely used.

Many studies have evaluated the performance of those estimators using indicators such as bias, precision and accuracy under different conditions and sample sizes (Hortal et al., 2006; Merlo et al., 2010; Walther and Moore, 2005, for a review). However, these studies used data obtained with similar sampling units. To our knowledge there is no evaluation of how the incidence-based estimators perform when different type of sampling units are used.

The aim of this study was to evaluate the performance of non-parametric incidence-based estimators of species richness in herpetofauna inventory in a temperate zone, based on two different sampling units: sampling days and sampling sites. We evaluated the performance of the estimators using five quality indicators: bias, precision, accuracy, the smallest sample size

Table 2
The observed and the expert extrapolation of total species richness of amphibians and reptiles in each of the five studied areas: 1 indicates presence, 0 absence and + not inventoried but possibly present.

Species	Order	Study area				
		Măcin	Siriu	Jiu	Maramureş	Black Sea Coast
Bombina bombina	Anura	1	0	0	0	1
Bombina variegata	Anura	0	1	1	1	0
Pelobates fuscus	Anura	1	0	+	0	+
Pelobates syriacus	Anura	1	0	0	0	1
Rana arvalis	Anura	0	0	0	+	0
Rana dalmatina	Anura	1	+	1	+	+
Pelophylax kl. esculentus	Anura	1	+	0	+	1
Pelophylax lessonae	Anura	1	0	0	0	0
Pelophylax ridibundus	Anura	1	0	1	0	+
Rana temporaria	Anura	0	1	1	1	0
Bufo bufo	Anura	1	1	1	1	0
Pseudepidalea viridis	Anura	1	+	1	+	1
Hyla arborea	Anura	1	+	1	+	1
Salamandra salamandra	Caudata	0	1	1	1	0
Ichtyosaura alpestris	Caudata	0	1	+	1	0
Triturus cristatus	Caudata	0	1	1	+	0
Triturus dobrogicus	Caudata	1	0	0	0	0
Lissotriton montandoni	Caudata	0	+	0	1	0
Lissotriton v. vulgaris	Caudata	+	1	1	+	0
Emys orbicularis	Testudines	1	+	+	+	1
Testudo graeca	Testudines	1	0	0	0	1
Testudo hermanni	Testudines	0	0	0	0	+
Anguis fragilis	Sauria	1	1	1	1	0
Ophisaurus apodus[*]	Sauria	0	0	0	0	1
Ablepharus kitaibelii	Sauria	1	0	0	0	+
Darevskia praticola	Sauria	0	0	1	0	0
Eremias arguta	Sauria	0	0	0	0	0
Lacerta agilis	Sauria	0	1	1	1	0
Lacerta trilineata	Sauria	1	0	0	0	1
Lacerta viridis	Sauria	1	0	1	0	1
Podarcis taurica	Sauria	1	0	0	0	1
Podarcis muralis	Sauria	+	+	1	0	1
Zootoca vivipara	Sauria	0	1	1	1	0
Coronella austriaca	Serpentes	1	+	+	1	0
Elaphe sauromates	Serpentes	1	0	0	0	+
Dolicophis caspius	Serpentes	1	0	0	0	1
Natrix natrix	Serpentes	1	1	1	1	1
Natrix tessellata	Serpentes	+	1	+	0	+
Vipera ammodytes	Serpentes	1	0	1	0	1
Vipera berus	Serpentes	0	1	1	1	0
Zamenis longissimus	Serpentes	1	+	1	0	+
Total number of observed species		24	13	20	12	15
Number of species possibly present		3	9	5	8	8
Total		27	22	25	20	23

[*] Known only from the herpetofauna of Bulgaria.