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FIRST DISTRIBUTION AND POPULATION ASSESSMENT OF *SALAMANDRINA PERSPICILLATA* IN MONTI LIVORNESI (TUSCANY, ITALY)

Abstract - A. Sergenti, D. Canaccini, M. Morelli, M.B. Morelli, P. Fazzi, M. Lucchesi, V. Maglieri, R. Sacchi, M.A.L. Zuffi, *First distribution and population assessment of* Salamandrina perspicillata *in Monti Livornesi (Tuscany, Italy).*

This study has been aimed at establishing the presence/absence and the abundance of the Italian endemic Spectacled salamander *Salamandrina perspicillata* in a Mediterranean forest within "Monti Livornesi", in Central-West Tuscany. To date, this area has been poorly investigated, and reports of this species are sporadic and anecdotal. Hence, this work represents the first attempt to investigate some important population parameters in this area, using a standardized protocol, by means of linear transects located in streams and rivers during the reproductive period of this species. Each transect was sampled 1-4 times during the study, and for each sampling day the number of adults, eggs and larvae were recorded. We also added some information about the vegetation surrounding the transects, to investigate the relationship between presence and abundance of *Salamandrina perspicillata* with habitat features. *S. perspicillata* was found in six and five out of 12 streams in 2022 and 2023 respectively, with a total of 178 records (59 adults, 79 eggs and 40 larvae) and the estimate of abundance resulted in 37 ± 18 individuals in 2022 (range 7-90) among all the selected sites. The species is therefore present and relatively abundant, however with a localised distribution, also depending on local drying up situation of streams. Our approach allowed gathering useful information about biology and ecology of the species, and data on its distribution and abundance are fundamental prerequisites for planning successful land management and conservation plans.

Key words - *Salamandrina perspicillata*, distribution, abundance

Riassunto - A. Sergenti, D. Canaccini, M. Morelli, M.B. Morelli, P. Fazzi, M. Lucchesi, V. Maglieri, R. Sacchi, M.A.L. Zuffi, *Prima valutazione della presenza e della popolazione della* Salamandrina perspicillata *sui Monti Livornesi.*

Lo scopo di questo studio è stato quello di stabilire la presenza/assenza e l'abbondanza della salamandrina dagli occhiali, endemica italiana, Salamandrina perspicillata in una foresta mediterranea all'interno dei "Monti Livornesi", nella Toscana centro-occidentale. In realtà quest'area è stata scarsamente studiata e le segnalazioni di questa specie sono sporadiche e aneddotiche. Questo lavoro rappresenta quindi il primo tentativo di indagare alcuni importanti parametri della popolazione di quest'area, utilizzando un protocollo standardizzato, mediante transetti lineari localizzati in torrenti e fiumi durante il periodo riproduttivo di questa specie. Ciascun transetto è stato campionato da 1 a 4 volte durante lo studio e per ogni giorno di campionamento è stato registrato il numero di adulti, uova e larve. Abbiamo inoltre aggiunto alcune informazioni sulla vegetazione che circonda i transetti, per indagare la relazione tra presenza e abbondanza di Salamandrina perspicillata con le caratteristiche dell'habitat. S. perspicillata è stata trovata in sei e cinque flussi su 12 rispettivamente nel 2022 e nel 2023, con un totale di 178 segnalazioni (59 adulti, 79 uova e 40 larve) e la stima dell'abbondanza ha prodotto 37 ± 18 individui nel 2022 (intervallo 7-90) tra tutti i siti selezionati. La specie è quindi presente e relativamente abbondante, tuttavia con distribuzione localizzata, dipendente anche dalla locale situazione di prosciugamento dei corsi d'acqua. Il nostro approccio ha consentito di raccogliere informazioni utili sulla biologia e sull'ecologia della specie, e i dati sulla sua distribuzione e abbondanza sono prerequisiti fondamentali per pianificare piani di gestione e conservazione del territorio di successo.

Parole chiave - *Salamandrina perspicillata*, distribuzione, abbondanza

Introduction

Biodiversity is facing the strongest crisis since the last mass extinction, with extinction rates estimated to be 100 times higher than background rates (Ceballos *et al.*, 2015). In this scenario, Amphibians are one of the most abundant taxa in many forest ecosystems, and they represent the most threatened class among vertebrates, suffering the fastest decline around the world (Falaschi *et al.*, 2022). The main threats include habitat alteration, introduction of alien species and by climate change and nowadays the 41% of total species of amphibians are considered threatened of extinction (Hoffmann *et al.*, 2010).

The Spectacled salamander, *Salamandrina perspicillata* (Savi, 1821), is a mainly terrestrial salamander, occurring principally in hilly and mountain-forested areas, as well as in the Mediterranean maquis (Angelini *et al.*, 2008) of Northern and Central Apennines (Romano *et al.*, 2010). *S. perspicillata* is a carnivore species that feeds mainly on Collembola, Diptera, Acarina, Araneidae (Romano *et al.*, 2010), clams and earthworms; and it can adopt a generalist feeding

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strategy (especially during the spring) as well as a specialistic one (usually in autumn) (Salvidio *et al.*, 2012). The main predators are represented by many aquatic arthropod species (Trichoptera, Coleoptera, Odonata), that can prey on the eggs and the larval stages of *Salamandrina.*

Despite a huge knowledge about the ecology of this species, little is known about its distribution and abundance in most of the Tuscany territory (Vanni & Nistri, 2006) and, specifically, in the Livorno Province (see Romano & Costa, in press). Here, the species has been recorded only recently (Lefosse *et al.*, 2014) and known only in three sectors of the incoming National Atlas (Romano & Costa, in press), all of them related to Pliocenic fossil islands (Lanza, 1984), as the Monti Livornesi, separated and distant from the Apennine chain. The Monti Livornesi represent an area poorly investigated, and reports of the Spectacled salamander are sporadic and anecdotal (Lefosse *et al.*, 2014). Therefore, our study has been aimed at i) verifying the present distribution range, ii) the relative abundance of *Salamandrina perspicillata* in this area, and iii) suggesting any further approach and study for the conservation of the species.

Materials and Methods

Data collection and dataset preparation

The area of "Monti Livornesi" is located in the southeast of the city of Livorno, in the territory of the municipalities of Livorno, Collesalvetti and Rosignano (Fig. 1). *Monti Livornesi*, spanning from 0 to 462 m a.s.l. are characterized by the presence of Mediterranean vegetation, that includes holm oak forests with *Quercus ilex* L., *Fraxinus ornus* L., *Arbutus unedo* L. and *Phillyrea latifolia* L., constituting dense and shady forests. Strong anthropogenic conditioning (grazing, logging, fire) has severely degraded the ilex forests, thus creating the various stages of degradation, such as high patches, low patches and garigues. Large areas are covered by low scrub related to the presence of summer fires, characterized by many typical species of the Mediterranean environment, such as *Erica arborea* L., *Arbutus unedo*, *Phillyrea latifolia*, *Myrtus communis* L., *Cistus monspeliensis* L. and *Cistus salviifolius* L.

The naturalistic association Selvatica APS started a first pilot survey in 2021, to verify the presence/absence of the species in the area (Tab. 1). In 2022, we collected data with the supervision of University of Pisa during the entire reproductive period of the species, from the latest part of the winter (30th of January) to the middle part of spring (15th of May). In 2023, we collected data from 15th of January to 12th of June. We surveyed the area selecting 12 transects along major creeks and streams, covering as much as possible the whole territory (Fig. 2): each one was repeated one-four times by two-three operators and the number of individuals (adults, eggs and larvae) were recorded in a specific field sheet (See Supplementary Materials) during each sampling session. The transects length ranged from 154 m (Botro Grande) to 197 m (Fontanelle) (see Tab. 1).

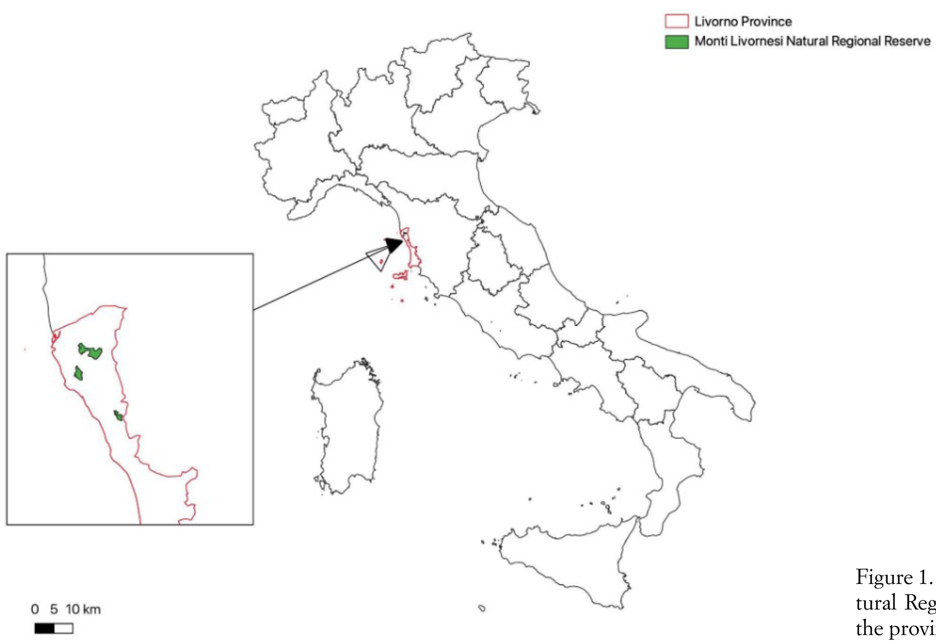

Figure 1. Location of the Monti Livornesi Natural Regional Reserve in Italy and (inset) in the province of Livorno.

Table 1. Name and identification code of selected transects and their length.

Name	Code	length (m)
Botro Grande	GRA	154
Botro Castello	CAS	159
Ginestraia	GIN	160
Corbaia	COR	164
Botro del Diavolo	DIA	164
Calafuria	CAL	174
Camorra	CAM	177
Rogiolo	ROG	182
Calignaia	IGN	186
Botro del Lupo	LUP	193
Ugione	UGI	195
Fontanelle	FON	197

In addition, we recorded the type of vegetation surrounding the investigated streams (i.e.: open or bushed vegetation; wooded vegetation) and the climate condition (temperature in °C, sunny, windy, cloudy sky, etc.). Population size was estimated using Poisson N-mixture models for closed population (Royle, 2004; Ficetola *et al.*, 2018) on the data set collected through each repeated transect. We used only 2022 data to estimate population size, given an unsuitable number of replicates in 2023, due to drying up of many streams. To help stabilizing the numerical optimization algorithm, we standardized all the covariates. Detection was modelled in function of transect length (meters), hour and survey duration (minutes), whereas abundance was modelled in function of the habitat only. It is general recognized that a low number of spatial replicates provide unreliable estimates and identifiability problems (Dennis *et al.*, 2015; Kéry & Royle 2015), although some applications of N-mixture models based on few spatial replicates are present in the literature (Ficetola *et al.*, 2018, 2021; Kidwai *et al.*, 2019). However, fitting the model within a Bayesian framework still provides unbiased estimates even with low number of replicates since it has the great advantage of being exact for any sample size (Kéry & Royle, 2015), and supplies the possibility of checking model adequacy with posterior predictive checks (Conn *et al.*, 2018).

Results

In 2022 we obtained presence data of *S. perspicillata* in four out of 12 transects, and in 2023 we obtained presence data *S. perspicillata* in five out of 12 transects (Tabs. 2-3), with 178 records (59 adults, 79 eggs and 40 larvae).

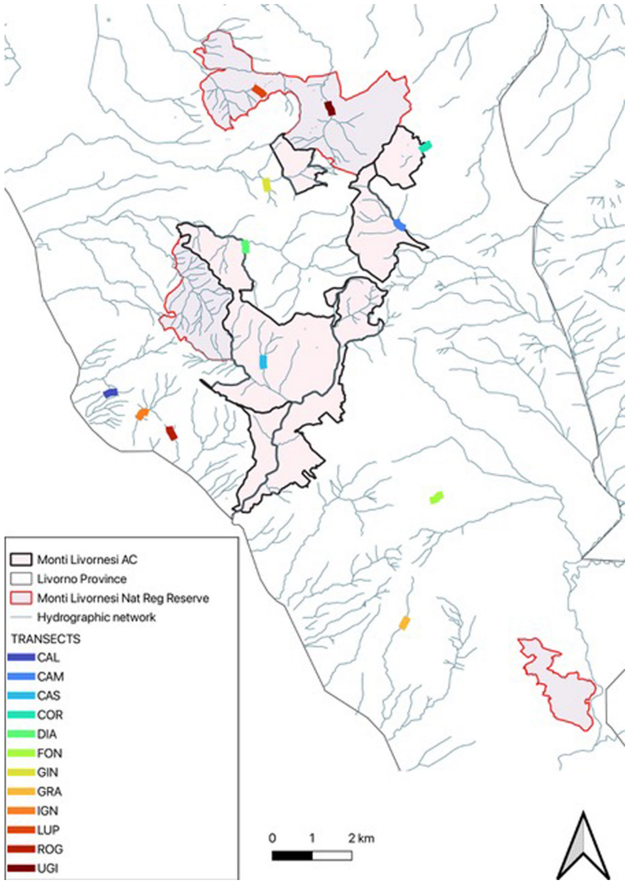

Figure 2. Distribution of transects and streams in the study area within the network of protected areas.

The best model (Tab. 4) showed a difference in species abundance among sites, with no effect on detectability, which remains constant over transects (p = 0.05). The model supported the absence of the species in the seven sites where we did not find the species in any survey (Tab. 3, Fig. 3), while in the five sites where the species was observed, the abundance estimates varied from about 7 to 90 individuals per site (Tab. 5). The overall average abundance was assessed at 37 ± 18 individuals/transect.

Discussion

In our study we have shown that the Spectacled salamander, *Salamandrina perspicillata*, is relatively well distributed in the Monti Livornesi area, more abundant than expected from the few published (Lefosse *et al.*, 2014) or unpublished (Romano & Costa, in press) papers. The biological data collected (e.g., adults, eggs and larvae) support the existence of a stable population. The recorded phenology, starting from the first adults entering in water, to first eggs up to last larvae detected, range from the beginning of February in

Table 2. Occurrence results of monitoring for *S. perspicillata* in 2022.

Transect	Code	Presence	First adults	Last adults	First eggs	Last eggs	First larva	Last larva
Botro Grande	GRA	No						
Botro Castello	CAS	No						
Ginestraia	GIN	Yes	05/03		05/03	07/04	15/05	
Corbaia	COR	Yes	07/02	21/02	07/02	05/03		
Botro del Diavolo	DIA	No						
Calafuria	CAL	No						
Camorra	CAM	No						
Rogiolo	ROG	No						
Calignaia	IGN	No						
Botro del Lupo	LUP	Yes			30/01	07/03		
Ugione	UGI	Yes	06/02	20/02	06/02	05/03		
Fontanelle	FON	No						

Table 3. Occurrence results of monitoring for *S. perspicillata* in 2023.

Name	Code	Presence	First adults	Last adults	First eggs	Last eggs	First larva	Last larva
Botro Grande	GRA	No						
Botro Castello	CAS	No						
Ginestraia	GIN	Yes	19/02		10/03			
Corbaia	COR	Yes	07/02	19/02	19/02	05/05		
Botro del Diavolo	DIA	No						
Calafuria	CAL	No						
Camorra	CAM	Yes	25/02		16/02			
Rogiolo	ROG	No						
Calignaia	IGN	No						
Botro del Lupo	LUP	Yes	04/02	19/02	04/02	19/02		
Ugione	UGI	Yes	07/02	16/02	29/01	16/02	12/06	
Fontanelle	FON	No						

Table 4. Estimation of best fit model of *S. perspicillata* abundance (in bold the selected best model).

Model	nPars	AIC	Delta	AICwt	cumltvWt
p(.)Φ(id)	12	74.51	0.00	0.4215	0.42
p(dur)Φ(id)	13	75.28	0.77	0.2862	0.71
p(lung)Φ(id)	13	76.25	1.74	0.1764	0.88
p(dur+lung)Φ(id)	14	77.10	2.59	0.1156	1.00
p(dur+lung)Φ(.)	4	89.57	15.06	0.0002	1.00
p(dur)Φ(.)	3	93.93	19.42	2.6e-05	1.00
p(lung)Φ(.)	3	99.07	24.56	2.0e-06	1.00
p(.)Φ(.)	2	104.50	29.99	1.3e-07	1.00

Table 5. Abundance of *S. perspicillata* (n/transect) as predicted by Poisson N-mixture model for surveys carried out during 2022.

id	Predicted	SE	95% CI lower	95% CI upper
CAM	7	7	0	55
COR	27	17	8	93
GIN	20	14	5	79
LUP	39	22	13	120
UGI	90	27	50	162

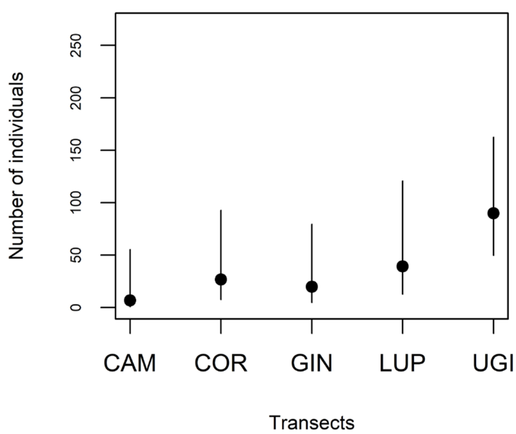

Figure 3. Number of individuals of *S. perspicillata* (n/transect) as estimated through Poisson N-mixture models for data collected during 2022.

2022 or to the end of January in 2023 ending at the end of May or June. Our data are in accordance with previously published researches and atlases (Zuffi, 1999; Barbieri & Pellegrini, 2006; Vanni & Nistri, 2006; Basile *et al*., 2017). The observed distribution covers only some sectors of the Monti Livornesi, particularly those facing inward the province of Livorno, lacking on the slopes west facing, likely due to the scarcity of water and the limited coverage of wooded areas in those sectors.

The recorded abundance seems a valuable measure of self-maintaining populations, given the relatively constant number of estimated individuals. The Ugione stream is undoubtedly the richest with this respect, suggesting a particularly suitable habitat for the species, where the management and maintenance of the wooded system arises to a fundamental tool for future conservation practices (Piraccini *et al*., 2017).

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CONFLICT OF INTEREST

Authors certify that they have no affiliation with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. Therefore, they have no conflict of interest to declare.

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