



A Late Autumn Feeding: Diet of *Salamandra salamandra* (Linnaeus, 1758) (Amphibia: Salamandridae) in October and November in the Iron Gates Natural Park, Romania

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Abstract: The fire salamander (*Salamandra salamandra*) is a cold-tolerant amphibian species. Recent data proved that it feeds intensely at the beginning of spring at low temperatures, and we hypothesised that the same is also true for the autumn. To verify this, we analysed the feeding of a population of *S. salamandra* from Iron Gates Natural Park during three different days from mid-October to mid-November 2020. During the study period, *S. salamandra* fed normally, as the number of prey items, prey taxa and food diversity were high. The feeding intensity did not decrease constantly toward winter but fluctuated. The most common preys were of Limacidae and Diplopoda. Most prey categories were flightless and characteristic for humid areas and forests, including some endemic terrestrial isopods distributed only in southwestern Romania (*Armadillidium banaticum*). This fact highlights the importance of such habitats for the survival of both the fire salamander and its prey.

Key words: fire salamander, endemic prey, seasonal variations, protected area

Introduction

Amphibians offer numerous ecosystem services as they contribute to the regulation of invertebrate populations but are also involved in the nutrient cycles (HOCKING & BABBITT 2014). This is also valid for *Salamandra salamandra*, a species influencing the functioning of forest ecosystems by reducing litter decomposition rate (LAKING et al. 2021). This is important because *S. salamandra* is a predator consuming numerous invertebrates (BALOGVÁ et al. 2015), many of which are detritivorous (LAKING et al. 2021). Although it is in decline in many areas across Europe (BOSCH & MARTÍNEZ-SOLANO 2006, SPITZEN-VAN DER SLUIJS et al. 2013, SANDVOß et al. 2020), in Romania it is widespread (COGĂLNICEANU et al. 2013). Nevertheless, in Romania data on this

species diet come only from studies implemented in spring and early autumn (COVACIU-MARCOV et al. 2002, CÍCORT-LUCACIU 2009, CÍCORT-LUCACIU et al. 2007, FERENTŐ et al. 2008, 2010a, 2010b, LEZAU et al. 2010). A single recent study made on a cold rainy day at the beginning of March proved that in such conditions the feeding of *S. salamandra* was similar to other periods: the feeding intensity was high and the prey taxa were generally the same (MAIER et al. 2020). This is significant, as this species is related with low temperatures, having a high metabolic rate requiring higher trophic and energetic resources (CATENAZZI 2016). Thus, we hypothesized that if at low temperatures in early spring this species is active and feeds intensely, this may also happen at the end of autumn, in similar weather conditions. To this end, we chose to study the diet of another population

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of *S. salamandra* from the Iron Gates Natural Park (IGNP), similar to the one from the previous study (MAIER et al. 2020) but this time in October and November. Previous studies in Romania were made at one date, without tracking the seasonal changes of the diet (COVACIU-MARCOV et al. 2002, CICORT-LUCACIU 2009, CICORT-LUCACIU et al. 2007, FERENȚI et al. 2008, 2010a, 2010b, LEZAU et al. 2010). In the case of other salamander species, there are few data on the seasonal variation of the trophic resources (SALVIDIO et al. 2012). Nevertheless, there are seasonal differences in prey availability, which is higher in spring compared with autumn (SALVIDIO et al. 2012). Thus, we have studied the diet of fire salamanders in autumn in order to observe if the feeding intensity will reduce as the weather cools down, just like in the case of other amphibian species (JENSSEN & KLIMSTRA 1966, COVACIU-MARCOV et al. 2005a, 2005b, MOLLOV et al. 2010, BOGDAN et al. 2012). We set the following objectives: (1) to establish the food composition of a population of *S. salamandra* in IGNP in October and November and (2) to assess whether the diet changes during the study period.

Materials and Methods

The fieldwork was carried out in the autumn of 2020 (on 17 October, 31 October and 14 November). The study area was near the Sirinia Valley, in the central part of IGNP, in Caraș-Severin County. The fire salamanders were encountered between a forest road and the valley, in a relatively flat, 10–40 m wide area, with a length of approximately 500 m. The forest road branches out from the main road leading to the Bigăr locality. The region is covered by beech, oak and hornbeam forests; alders are also present near the watercourse. On the surrounding slopes, there are beech recoveries and occasionally coniferous plantations, which indicate the deforestations from the past. Searches in the area were conducted in the morning, after rainy nights, at temperatures between 8–10°C. We studied 56 individuals of *S. salamandra*; the number was different in the three study days (Table 1). No individual was harmed; the stomach flushing method (SOLÉ et al. 2005) was used to collect the samples. This method was previously used for the fire salamanders from IGNP (FERENȚI et al. 2010a, MAIER et al. 2020) as well as for other salamander species (RONER et al. 2020). After the samples were collected, the individuals were released in their habitat. The prey items were determined in the laboratory, generally at a higher taxa level (Table 1). The species could be determined only in the case of the majority of terrestrial isopods, similarly to a pre-

vious study (MAIER et al. 2020). Thus, the prey was identified at a similar level with other studies from Romania (COVACIU-MARCOV et al. 2002, FERENȚI et al. 2008, 2010a, 2010b, LEZĂU et al. 2010, MAIER et al. 2020) or recent studies on other amphibian species (e.g. SALVIDIO et al. 2012, ÇIÇEK et al. 2020, LE et al. 2020, RÖNER et al. 2020, ALVEAL & DÍAZ-PÁEZ 2021). Subsequently, we calculated the percentage abundance and the frequency of occurrence of each prey taxon for each study day and for the total duration of the study. We also calculated prey diversity (Shannon index: SHANNON 1948) and homogeneity (Pielou index: PIELOU 1966).

Results

All individuals had stomach contents and the total number of prey items was 533, belonging to 28 taxa. The highest percentage abundance and the frequency of occurrence were registered for Limacidae and Diplopoda (Table 1). Beside animal prey, the fire salamanders also ingested vegetal remains, inorganic elements and shed skin fragments. These were consumed almost in every study period (only shed skins lacked on 17 October). Among the 28 prey taxa, 14 had percentage abundance below 1 % (Table 1). The food composition was different between the three study dates (Table 1). The lowest number of prey taxa, prey items and diversity was registered on 14 November, and the highest – on 31 October (Table 1). On 17 October, the values were intermediate between the other two dates (Table 1). On all study dates, Limacidae occupied the first position, both as percentage abundance and as frequency of occurrence (Table 1). Among the 28 prey taxa, 13 were consumed in each study day and six – only in one day (Table 1). *Salamandra salamandra* from the Sirinia Valley fed on eight taxa of terrestrial isopods (Table 2). In two cases, we could only identify the isopods at the generic level; in one case, even this was not possible. Most of the isopods belonged to the genus *Ligidium* (Table 2). The differences between the study dates were also obvious in the case of the terrestrial isopods (Table 2). Thus, the higher species number was recorded on 17 October, and the highest individual number on 31 October.

Discussion

Although the study was conducted relatively late in the year, in the middle and in the end of autumn, all captured fire salamanders had consumed prey. In contrast, at least in spring, some individuals had no stomach contents (COVACIU-MARCOV et al. 2002,

Table 1. Percentage abundance (P %) and frequency of occurrence (f %) of preys consumed by *Salamandra salamandra* from the Sirinia Valley.

	17 October		31 October		14 November		Total	
	P %	f %	P %	f %	P %	f %	P %	f %
Inorganic elements	-	29.41	-	31.82	-	41.18	-	33.93
Vegetal remains	-	70.59	-	68.18	-	47.06	-	62.50
Shed skin	-	-	-	18.18	-	23.53	-	14.29
Lumbricidae	6.32	41.18	4.74	36.36	2.36	17.65	4.69	32.14
Gastropoda (with shell)	9.77	52.94	6.03	36.36	7.87	29.41	7.69	39.29
Limacidae	20.11	70.59	19.83	90.91	27.56	76.47	21.76	80.36
Araneida	4.60	35.29	10.78	63.64	8.66	29.41	8.26	46.43
Opilionida	10.34	52.94	5.17	36.36	6.30	35.29	7.13	41.07
Isopoda: Oniscidea	5.75	41.18	8.19	31.82	10.24	35.29	7.88	35.71
Diplopoda	14.37	58.82	14.66	63.64	14.96	58.82	14.63	60.71
Chilopoda	2.30	17.65	3.45	18.18	4.72	29.41	3.38	21.43
Collembola	14.94	41.18	10.78	18.18	3.15	23.53	10.32	26.79
Thysanura	0.57	5.88	0.43	4.55	0.79	5.88	0.56	5.36
Plecoptera	-	-	0.86	9.09	-	-	0.38	3.57
Dermaptera	-	-	0.43	4.55	1.57	5.88	0.56	3.57
Heteroptera	1.72	17.65	1.72	18.18	-	-	1.31	12.50
Aphididae	-	-	0.43	4.55	-	-	0.19	1.79
Coleoptera: Carabidae	-	-	1.29	13.64	2.36	11.76	1.13	8.93
Coleoptera: Staphylinidae	1.15	5.88	-	-	-	-	0.38	1.79
Coleoptera: Lampyridae	1.15	11.76	0.43	4.55	-	-	0.56	5.36
Coleoptera: Curculionidae	0.57	5.88	-	-	-	-	0.19	1.79
Coleoptera: larvae	0.57	5.88	2.16	22.73	0.79	5.88	1.31	12.50
Neuroptera	-	-	-	-	0.79	5.88	0.19	1.79
Trichoptera	0.57	5.88	1.72	18.18	4.72	29.41	2.06	17.86
Lepidoptera	-	-	0.43	4.55	-	-	0.19	1.79
Lepidoptera larvae	0.57	5.88	1.72	13.64	-	-	0.94	7.14
Diptera: Nematocera	-	-	0.86	4.55	0.79	5.88	0.56	3.57
Diptera: Brachycera	0.57	5.88	0.43	4.55	-	-	0.38	3.57
Diptera: Brachycera larvae	2.30	17.65	2.59	18.18	2.36	17.65	2.44	17.86
Hymenoptera	1.15	11.76	0.43	4.55	-	-	0.56	5.36
Hymenoptera, Formicidae	0.57	5.88	0.43	4.55	-	-	0.38	3.57
Number of studied fire salamanders	17		22		17		56	
Prey taxa number	21		25		17		28	
Preys number	174		232		127		533	
Prey/individual average number	10.24		10.55		7.47		9.51	
Prey/individual maximum number	22		27		13		27	
Diversity	2.43		2.58		2.34		2.55	
Homogeneity	0.80		0.80		0.83		0.76	

FERENȚI et al. 2010a, 2010b). Unfed individuals have also been identified in other salamander species, even in the middle of the activity period (RONER et al. 2020). Usually, the presence of individuals without food indicates unfavourable conditions for amphibians (e.g. COVACIU-MARCOV et al. 2005a,

2010, BOGDAN et al. 2012). This is also true for salamanders: during hibernation, they do not consume animal prey but only shed skins (BALOGOVÁ et al. 2015). Thus, in the Sirinia Valley, the fire salamanders had optimal feeding conditions during the study period, even if in Romania in October – November

Table 2. Percentage abundance of terrestrial isopods in the diet of *Salamandra salamandra*.

	17 October	31 October	14 November	Total
Number of studied fire salamanders	17	22	17	56
<i>Ligidium</i> sp.	10	15.78	58.33	26.82
<i>Ligidium intermedium</i>	-	-	16.66	4.87
<i>Hyloniscus</i> sp.	10	-	-	2.43
<i>Protracheoniscus politus</i>	20	31.57	-	19.51
<i>Trachelipus nodulosus</i>	-	5.26	-	2.43
<i>Trachelipus arcuatus</i>	10	-	16.66	7.31
<i>Trachelipus rathkii</i>	10	21.05	8.33	14.63
<i>Armadillidium banaticum</i>	40	26.31	-	21.95

they prepare to begin hibernation (FUHN 1960). This fact indicates once more that fire salamanders are active at low temperatures (CATENAZZI 2016) as their feeding is optimal in such conditions (MAIER et al. 2020).

Analysing the feeding intensity, our results are similar to other studies in spring or autumn (e.g. COVACIU-MARCOV et al. 2002, CICORT-LUCACIU et al. 2007, FERENȚI et al. 2008, 2010a, 2010b, MAIER et al. 2020). Unlike this, the feeding of other salamander species has been shown to be more intense in spring than in autumn (SALVIDIO et al. 2012). Furthermore, the most common prey taxa are the same as in the case of other populations in Romania (COVACIU-MARCOV et al. 2002, CICORT-LUCACIU et al. 2007, FERENȚI et al. 2008, 2010a, 2010b, LEZAU et al. 2010, MAIER et al. 2020). This fact suggests the probable homogeneity of the trophic availability of the habitats populated by *S. salamandra*, at least in Romania. Nevertheless, some taxa like scorpions are absent from the diet of salamanders in the Sirinia Valley, although in other cases they have been consumed even at the beginning of March, also at low temperatures (MAIER et al. 2020). Probably the scorpions enter hibernation before salamanders in autumn, as they are thermophilous and distributed only in some areas in the southern parts of the Romanian Carpathians (e.g. BUNESCU 1959, GHERGHEL et al. 2016). At the same time, the habitat from this study is different to the one in MAIER et al. (2020), as it is flatter and with larger area. Thus, both weather conditions and habitat aspects might have determined the absence of scorpions from the salamanders' food. Although the habitat is situated along a permanent water course, all preys were terrestrial, even if sometimes *S. salamandra* consumes aquatic prey (e.g. COVACIU-MARCOV et al. 2002, FERENȚI et al. 2010a), like other salamanders (ANDREONE et al. 1999). Nevertheless, some prey items are related to water (Plecoptera, Trichoptera), as its life cycle in-

cludes an aquatic phase (RADU & RADU 1967). Most of the prey items were flightless, associated with wet and wooded areas, and generally large-sized (some specimens of Limacidae exceeded 1 cm length). The fire salamanders also consumed small-sized prey like Collembola, even if other salamanders avoid small prey (RONER et al. 2020). Collembola are also consumed by another *S. salamandra* population in Romania (LEZAU et al. 2010).

The feeding of *S. salamandra* in IGNP in mid-autumn was more balanced than in early spring (MAIER et al. 2020). Even if the number of prey taxa, prey items or diversity were similar to the ones registered at the beginning of March (MAIER et al. 2020), the percentage abundances were uniform and the homogeneity index was higher. In spring, Limacidae and Diplopoda together represented more than 60 % of the food (MAIER et al. 2020) but, in autumn, they reached only 36 %. Probably, in autumn, the trophic resources are more evenly distributed or the fire salamanders are more uniformly distributed in their habitats, thus having a uniform access to the food.

Although usually amphibian feeding intensity is reduced in autumn as the weather cools (e.g. COVACIU-MARCOV et al. 2005a, 2005b, MOLLOV et al. 2010, BOGDAN et al. 2012), in this case the decrease was not linear. Thus, even if the lowest values were registered on the last study date in the middle of November, the highest values were not registered on the first date in the middle of October but on the second date, at the end of October. Thus, instead of a slow and constant decrease, there was an increase and then an accentuated decrease. Probably after a relatively dry and warm September, at the beginning of October fire salamanders had not yet increased their activity or did not encounter enough prey. This fact seems confirmed by a previous study, where in September, the fire salamanders feeding intensity was lower than the one registered in October or

even in November in IGNP (FERENȚI et al. 2008). It seems that at least in autumn 2020, in the Danube Gorge, *S. salamandra* had the most intense feeding at the end of October. Because all study days were after rain, with temperatures of about 10°C, the local weather conditions did not modify the feeding. The decrease of feeding intensity in the middle of November might be the consequence of lower night temperatures affecting the prey, as *S. salamandra* could tolerate low temperatures (CATENAZZI 2016). Nevertheless, probably with low trophic availability and higher metabolic rate at lower temperatures (e.g. CATENAZZI 2016), *S. salamandra* prepares for hibernation at the end of November.

In the Sirinia Valley, *S. salamandra* consumed more terrestrial isopods from more species, compared with the situation registered in IGNP in spring (MAIER et al. 2020). Thus, previously only *Ligidium hypnorum* was found in the diet of fire salamanders (MAIER et al. 2020), a species which was not consumed in the autumn. Nevertheless, it is possible that some digested individuals of *Ligidium*, which could not be properly identified, belonged to this species. The isopods consumed by *S. salamandra* in the Sirinia Valley confirm the fact that they have similar habitat requirements like their predators (MAIER et al. 2020). The majority of isopods consumed by the fire salamanders belonged to species related to humid areas (*Ligidium*, *Hyloniscus*) or forests (*Protracheoniscus*, *Trachelipus arcuatus*) (e.g. RADU 1983, 1985, TOMESCU et al. 2011, 2015). This fact is consistent with the studied habitat, which is represented by a wet forested area situated near a watercourse. Beside this, a fire salamander consumed an individual from a species related to dry and open areas, namely *T. nodulosus* (TOMESCU et al. 2015). Nevertheless, *T. nodulosus* has also been recorded in forested areas (IANC & FERENȚI 2014). Probably, just like in other cases (IANC & FERENȚI 2014), *T. nodulosus* had benefited by the deforestations from the past, as in the vicinity of the fire salamanders habitat there was a wood loading platform and a mine (currently closed). In contrast, *Armadillidium banaticum* is an endemic species, present only in southwestern Romania, in the Banat Region (e.g. RADU 1985). Previously, this species has been recorded both under stones and in leaf litter (RADU, 1985, GIURGINCA & ILIE 2003), habitats also used by the fire salamanders. Another endemic species recorded in diet of *S. salamandra* was *Ligidium intermedium*, although this species has a wider distribution range than the previous one (RADU 1983, KONTSCHÁN 2002, SCHMALFUSS 2003, POP et al. 2019). As it is a species related with humidity, *L. intermedium* is

a natural food for the fire salamanders like other species of *Ligidium* (MAIER et al. 2020). The isopod species consumed by *S. salamandra* confirms the prey - predator relation between them (MAIER et al. 2020) but also indicates the use of diverse habitats; according earlier studies, other amphibian species consumed fewer isopod species (TOMESCU et al. 2010, COVACIU-MARCOV et al. 2012).

Data from the present study correlate with those of previous studies (MAIER et al. 2020) and indicate that in IGNP *S. salamandra* is active and feeds normally near the cold season, as it is active at low temperatures (e.g. CATENAZZI 2016). The activity and feeding of salamanders in IGNP should be explored in summer rainy days or during the winter months, because in other areas it is active even in February (PULEV et al. 2016). In IGNP, *S. salamandra*, a protected species with a wide distribution range, and some endemic terrestrial isopod species are in a prey - predator relation. Both are important for the maintenance of the protected area and are threatened by human activities that favour the entrance of other isopod species. *Salamandra salamandra* feed on isopods regardless if they are endemic or not, but the deforestations will affect both predators and preys.

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