

## **Growing in the darkness: predation ability and cannibalism in cave-born larvae of fire salamander, *Salamandra salamandra* (Linnaeus, 1758)**

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**Riassunto.** *Crescere al buio: abilità predatoria e cannibalismo in larve di salamandra pezzata, Salamandra salamandra nate in grotta.* La salamandra pezzata in diverse aree carsiche del proprio areale può deporre le larve anche in ambienti ipogei come grotte naturali e artificiali. Lo scopo di questo studio è valutare se le popolazioni che utilizzano tali, inusuali, siti riproduttivi, abbiano sviluppato degli adattamenti specifici. Per tale scopo abbiamo effettuato alcuni esperimenti comportamentali sulla capacità di predazione e sul cannibalismo. Da 20 grotte e da 20 ruscelli adiacenti abbiamo raccolto delle larve che abbiamo allevato in due differenti condizioni: in ambiente ipogeo ed in ambiente epigeo. Sia le larve da grotta che da ruscello sono state in grado di catturare prede in condizioni di buio totale. Le larve nate in grotta hanno però mostrato una maggiore efficienza. Per quanto riguarda il cannibalismo esso è ridotto alla nascita e molto più accentuato dopo un mese di vita delle larve. Il grado di digiuno e la taglia delle larve influenzano l'aggressività. Non sono però risultati evidenti effetti della provenienza delle larve o delle condizioni di allevamento.

**Keywords.** Cave, *Salamandra salamandra*, underground, ecology, predation performance, biospeleology.

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The study of underground environments can provide challenging scientific insights for the study of the biological, ecological and evolutionary processes facing with an habitat with such peculiar dominating features. Underground environments are very different from the epigean ones for several features, such as light scarcity, limited food availability, and stability of microclimatic conditions (Culver et al., 2004). These features determine strong selective pressure, thus the colonization of underground habitats can induce a number of drastic phenotypic changes and genetic adaptations such as the improvement of features increasing individual development, survival and fitness (Friedrich et al., 2011). Most of studies on amphibians occurrence in caves focus on obligate cavernicoles, while the active use of subterranean habitats by epigean taxa is less studied. The latter can be useful to focus

on the ecological and evolutionary phenomena connected with cave colonization and to the adaptation processes for the hypogean environment in general. We focused on the fire salamander, *Salamandra salamandra*: it usually breeds in epigeal streams, but in karstic areas underground springs are often used as breeding habitat (Manenti et al., 2011). Although there is evidence that the species achieves metamorphosis in underground environments, there are not detailed studies on behaviour and breeding success in these habitats. Lack of light and limited availability of preys are major differences between underground and epigeal habitats. The aim of this study was assessing whether larvae laid in caves have better predation ability in underground conditions and whether they show differences in the cannibalistic behavior.

We studied 20 salamander populations breeding in underground and epigeal streams in Northern Italy. First, we performed a behavioural experiment about prey detection and capture. We collected newborn larvae from 20 different underground springs and from 20 neighbouring epigeal streams. Larvae were reared under two different conditions: 10 from caves and 10 from streams were raised in underground conditions (an ancient draining gallery provided by the Monte Barro Regional Park), while 10 from caves and 10 from streams were raised under outdoor conditions. Larvae were fed with living chironomid larvae. For each larva, at the collection moment and after a month of raising, we recorded under total darkness two measures of predation performance: time of the first head turning toward the prey and frequency of prey capturing. Second, we performed an experiment on the cannibalistic behaviour on 9 larvae from caves and 9 from the nearest stream of each cave. We kept the larvae in the same conditions as above. Under light conditions we recorded, both at the catching and after one month of rearing, the number of bites that each larva caused to other larvae under conditions of increasing density, and when another larva was eating. We repeated the trials both when larvae were replete and after 3 days of starvation. For each condition we performed 3 trials.

Both epigeal and hypogean larvae were able to detect and capture preys in the darkness; most of larvae used an active widely foraging mode. In the darkness, larvae born in underground springs captured preys with higher success than those born in outdoor conditions, while we did not detect differences for the time of head movements. Acclimatization to underground conditions did not improve predation performance. Attempts of cannibalism was very low at hatch, and increased after one month. Starvation increased aggressiveness towards conspecifics, as the presence of other larvae is feeding. We did not detect a clear effect of being born in caves or in streams.

The plasticity of *S. salamandra* larvae allows to successfully prey and grow in caves. The higher foraging performance of larvae born in underground conditions suggests that also behavioural adaptations to the cave environments are possible. We are currently investigating also genetic features of the populations in order to highlight the possible differences. Cannibalism seems to become more important during larvae growth, and may impact larval survival in underground habitats.

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