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Age structure and body size of Southern Banded Newts, *Ommatotriton vittatus* (Gray, 1835), in a pristine pond in the coastal mountains of Lattakia, Syria

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Abstract. The Southern Banded Newt (*Ommatotriton vittatus*) is widely distributed across Syria, yet its demographic and life-history traits remain largely unexplored. This study provides the first skeletochronological assessment of *Ommatotriton vittatus* in Syria, focusing on age structure, growth, and sexual maturity, using a dataset of thirty-six individuals (15 males, 21 females). Maximum ages reached seven years in males and eight years in females, although the age distribution did not differ significantly between sexes. Mean snout–vent lengths were 62.2 mm and 58.0 mm, for males and females respectively, with males being significantly larger. Both sexes attained sexual maturity at two years, a markedly earlier age than reported for other *Ommatotriton* populations. This accelerated development likely reflects favourable environmental conditions and high habitat quality at the study site. The findings establish the first demographic baseline for *O. vittatus* in Syria and contribute to understanding how local ecological factors shape amphibian life-history strategies in the eastern Mediterranean region.

Keywords. skeletochronology, growth, snout–vent length, sexual maturity, amphibian demography, life-history variation

Introduction

Studying growth in amphibians is crucial as it directly influences age at sexual maturity, timing of reproduction, fecundity, and longevity (Hemelaar, 1988; Smirina, 1994). Hemelaar (1988) investigated growth and age determination in the Common Frog (*Rana temporaria*), providing one of the foundational works on amphibian skeletochronology. Smirina (1994) conducted a comprehensive review of growth and skeletochronological methods across various amphibians, including species from the genera *Rana*, *Triturus*, and *Bufo*. Consequently, understanding population age structure is essential for insights into a species' life history (Altunışık and Özdemir, 2015). The study by Altunışık and Özdemir (2015) focused on the Southern Banded Newt, *Ommatotriton vittatus* (Gray, 1835), in Turkey, providing the first demographic data for this species.

Adult body size in amphibians depends on a variety of factors, such as larval growth rate, the timing and size at metamorphosis, growth rates during juvenile and adult stages, age at maturity, and longevity. The interaction of environmental factors influencing each of these processes can either enhance or constrain the extent of growth in a complex scenario (Özdemir et al., 2012).

For amphibians, which exhibit indeterminate growth, skeletochronology is a widely used and validated method for age determination, its reliability has been confirmed through studies on known-age individuals, and techniques to address its limitations are well-established (Castanet and Smirina, 1990; Castanet et al., 1993; Alcobendas and Castanet, 2000; Rozenblut and Ogielska, 2005). Bone growth is dependent on environmental conditions; favourable periods promote growth, while unfavourable conditions (e.g., cold winters) reduce it, resulting in the formation of distinct Lines of Arrested Growth (LAG)s.

Skeletochronological analysis, based on counting LAGs in bone cross-sections, has become a widely used and validated method for age assessment in amphibians and reptiles (Bionda et al., 2015; Sinsch, 2015; Bülbül et al., 2016; Altunışık et al., 2018). For example, Bionda et al. (2015) applied skeletochronology to *Rhinella arenarum*, Sinsch (2015) reviewed age structure and growth in European amphibians, Altunışık et al. (2018) studied *Ommatotriton vittatus*, and Bülbül et al. (2016) estimated age and growth in the lizard *Darevskia clarkorum*.

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Ommatotriton vittatus is a medium-sized salamander with a total length of 90–110 mm that is widely distributed in the Eastern Mediterranean and Middle Eastern regions, occurring in southern and central Turkey, western and northern Syria, Lebanon, and northern Israel, where it inhabits a variety of aquatic and semi-aquatic environments associated with Mediterranean and sub-Mediterranean climates (Sparreboom, 2014; AmphibiaWeb, 2024). The subspecies that is present in Syria is *O. v. vittatus* (Franzen and Schmidtler, 2000; Borkin et al., 2003), *O. vittatus ciliensis* is restricted to Turkey (van Riemsdijk et al., 2021), while two additional lineages previously treated as subspecies are now recognised as separate species: *Ommatotriton ophryticus* (Berthold, 1846) from northeastern Turkey and the Caucasus, and *Ommatotriton nesterovi* (Litvinchuk et al., 2005) from northern Anatolia in Turkey (van Riemsdijk et al., 2017).

The natural habitat of *O. vittatus* includes various water bodies within temperate forests and pastures, such as rivers, ponds, canals, and occasionally caves, arable land, and rural gardens (Bogaerts et al., 2013). In Syria, its distribution, ecology, and conservation status were previously studied by Bogaerts et al. (2013). The species is found from sea level up to approximately 1100 meters in elevation in the Taurus Mountains of Turkey (Franzen and Schmidtler, 2000).

Life history traits of *O. vittatus* have been investigated in several populations across its range. Altunışık and Özdemir (2015) studied a Turkish population that showed a relatively long lifespan among newts, with individuals living up to eight years in both males and females. Males were generally larger than females, showing significant sexual size dimorphism. The mean age did not differ significantly between sexes, suggesting similar survival rates and growth trajectories (Altunışık and Özdemir, 2015). A study on a population in Israel showed that the life cycle of *O. vittatus* includes distinct developmental phases: eggs, aquatic larvae, a terrestrial juvenile/adult phase, and a return to the aquatic environment for breeding (Degani and Meerson, 2024). As a carnivorous species, *O. vittatus* primarily feeds on small aquatic and terrestrial invertebrates, including insects, molluscs, and crustaceans (Yıldız et al., 2009). Environmental factors such as temperature, altitude, and habitat moisture likely influence growth rates, age at metamorphosis, and reproductive timing, as observed in related salamandrids (Özdemir et al., 2012).

Growth in *O. vittatus* is characterised by a positive correlation between age and body size, indicating continuous somatic growth throughout the lifespan of both sexes (Altunışık and Özdemir, 2015). In a Turkish population, males were found to reach sexual maturity at approximately three years of age, while females matured around four years, with a maximum recorded longevity of eight years for both sexes (Altunışık and Özdemir, 2015). The study further reported significant sexual size dimorphism, with males exhibiting a greater SVL than females, suggesting sex-specific growth trajectories likely related to reproductive and ecological roles (Altunışık and Özdemir, 2015). Although specific growth rate parameters (e.g., mm/year) were not quantified, the observed increase in SVL with age implies that individuals continue growing after reaching sexual maturity, a pattern common among salamandrids (Özdemir et al., 2012). Environmental factors such as temperature, altitude, and resource availability are also expected to influence growth dynamics, as documented in related newt species (Özdemir et al., 2012).

Several studies have utilised skeletochronology whilst studying *Ommatotriton* species. Altunışık (2018a) studied an *O. vittatus* population in Turkey, where the maximum recorded age was eight years. Female ages ranged between 4–8 years (mean = 5.82), while male ages ranged between 3–8 years (mean = 5.65). The age at sexual maturity for both sexes was between 3 and 4 years. Sexual size dimorphism was male-biased, as males exhibited a larger SVL than females. Additionally, age was positively correlated with body size in both sexes. Özcan and Üzüm (2015) studied age and body size in three populations of *Ommatotriton ophryticus* in Turkey. Males were found to be noticeably larger than females across all populations, while age was similar between sexes, ranging between 9–12 years in males and 9–11 years in females. The SVL index was positively correlated with age in all populations.

Here we report on the first study using skeletochronology on any amphibian species in Syria. We aim to establish a baseline for the age structure and body size of *O. vittatus* in an undisturbed breeding site in the Lattakia governorate.

Materials and Methods

Our study site is a pristine, pond (approx. 30 x 20 m) in the coastal mountains, supporting a large population of newts. This site provides an ideal reference for the species' demography under optimal environmental conditions in Syria. The pond is located in Latakia Governorate, Qardaha area, near the village of Marj Muʿayrban, Syria (35.4870ºN, 36.0454ºE). Sampling was conducted in March 2024 during the breeding season, as evidenced by the presence of eggs, larvae, and juveniles. The sex of each individual was determined based on external secondary sexual characters: males have highly developed crest along the back and tail, brightly coloured sides and a swollen cloaca, whilst females have no dorsal crest, enlarged cloaca and often gravid with visible eggs.

We captured individuals using dip nets and anesthetised each specimen with chloroform. The longest toe was excised and fixed in 10% formalin for subsequent skeletochronological analysis, following the standard protocol established by Castanet and Smirina (1990). This method is a reliable means of assessing individual age, size at maturity, and growth rates (e.g., Castanet and Smirina, 1990; Castanet et al., 1993; Castanet, 1994; Smirina, 1994). In the laboratory, we moved the toe samples to 70% ethanol, decalcified in 5% nitric acid for two hours, washed in water, and stored them in Bouin's solution. After fixation and decalcification, the samples were dehydrated through a graded ethanol series, cleared in xylene, and embedded in paraffin. Transverse sections (10 µm thick) were obtained using a rotary microtome and mounted on glass slides. Sections were stained with hematoxylin and eosin (H&E) following standard histological procedures. The slides were examined under a light microscope at 100–400× magnification, and digital images were taken for documentation (Fig. 1).

We measured SVL (to the nearest 0.1 mm) and body weight (to the nearest 0.01 g) for each individual using digital callipers and an electronic balance, respectively. To assess growth patterns and evaluate the relationship between age and body size, linear regression analyses were conducted separately for males and females using Python (v3.11) with the *pandas* and *scipy.stats* libraries. We calculated Pearson's correlation coefficient (r) and regression equations to describe the strength and direction of the age–size relationship, with significance set at $p < 0.05$.

In the laboratory, we determined total hardness and calcium hardness using standard titrimetric methods with ethylenediaminetetraacetic acid (EDTA) as a chelating agent, following the procedures described by the American Public Health Association (APHA, 2017). These parameters were measured to assess water quality and to evaluate the suitability of the lake environment for the survival and reproductive success of the studied amphibian species.

We measured water temperature and pH, and analysed water samples in the laboratories of Aquatic Animal Ecology at Latakia University to determine total and calcium hardness, as well as to evaluate the suitability of the lake's water for the survival and reproductive success of this species.

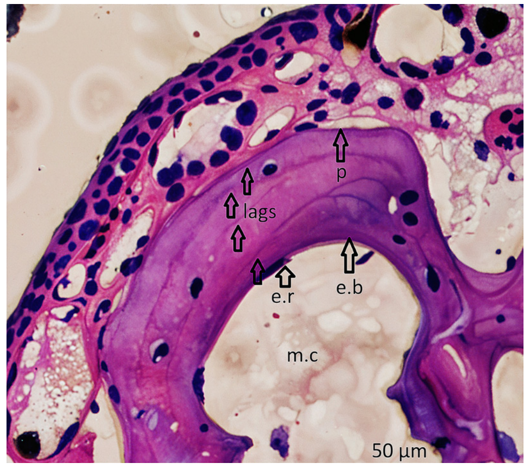

Figure 1. Cross-section of a phalangeal bone of *Ommatotriton vittatus* (H&E stain). Section thickness: 10 µm; scale bar: 50 µm. The medullary cavity (m.c) is surrounded by the endosteal resorption zone (e.r) and endosteal bone (e.b), with the periosteum (p) forming the outer margin. Arrows indicate lines of arrested growth (LAGs) used for age estimation. Photo by Diaa Alkhayer.

Results

A total of 36 specimens (15 males, 21 females) of *Ommatotriton vittatus* were collected at the study site (Fig. 2). Age determination based on

Figure 2. The Marj pond, Latakia Governorate, Qardaha area, near the village of Marj Muʿayrban, Syria (35.4870ºN, 36.0454ºE). This pristine freshwater habitat supports a population of *Ommatotriton vittatus*. Photo by Diaa Alkhayer.

skeletochronological analysis revealed that *O. vittatus* individuals ranged between 2–8 years of age. Female ages varied between 2–8 years (mean ± SD = 3.55 ± 2.16, $n = 20$), in contrast to males, 2–7 years (mean ± SD = 3.33 ± 1.72, $n = 15$). Sexual maturity was estimated to occur at approximately two years of age in both sexes. The population exhibited a predominantly young age structure, with most individuals belonging to the 2–3-year age classes, and a marked decline in the frequency of older individuals (≥ 7 years). This pattern suggests a population characterised by high recruitment and relatively low survival rates among older cohorts.

A significant positive relationship was detected between age and snout–vent length (SVL) in females ($r = 0.63$, $p < 0.01$), described by the regression equation SVL = 5.41 + 0.11 × Age, indicating an average annual growth of approximately 1.1 mm per year. In males, the relationship between age and SVL was positive but not statistically significant ($r = 0.41$, $p = 0.13$), described by SVL = 5.85 + 0.11 × Age, suggesting greater individual variation in male growth patterns (Fig. 3).

Males exhibited a larger average body size (mean SVL = 62.2 mm) (range 50–68 mm) than females (mean SVL = 58.0 mm) (range 50–62 mm). Although both sexes reached similar maximum ages, males showed a tendency toward higher growth rates across age classes.

Water temperature, pH, and hardness values indicated stable and high-quality conditions throughout the sampling period. Water temperature ranged between 15.1–16.2 °C (mean ± SD = 15.72 ± 0.43 °C), reflecting a cool and thermally stable aquatic environment suitable for newt activity and larval development. The pH was nearly neutral, ranging between 7.3–7.5 (mean ± SD = 7.42 ± 0.08), indicative of a chemically balanced and biologically supportive habitat. Total hardness (GH) varied between 3–4°dH (mean ± SD = 3.2 ± 0.45 °dH), while calcium hardness (KH) showed the same mean and variability (3.2 ± 0.45 °dH). These low-to-moderate hardness values reflect soft, unpolluted water typical of undisturbed freshwater ecosystems.

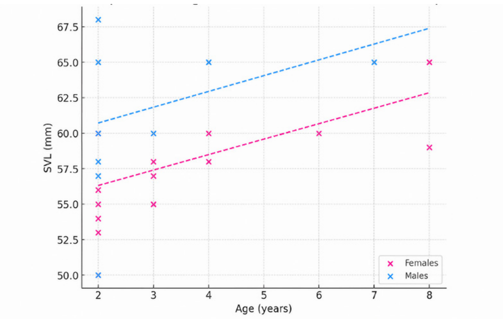

Figure 3. Relationship between age and snout–vent length (SVL, mm) in *Ommatotriton vittatus*. Linear regression lines indicate a positive relationship between age and body size in both sexes.

Discussion

Here we determined the age at sexual maturity for both male and female *Ommatotriton vittatus* in a Syrian coastal mountain population to be two years. This early maturation is likely facilitated by optimal conditions at the study site, including favourable weather, clean water, abundant nutrition, and low competition. All captured specimens displayed external signs of sexual maturity (e.g., well-developed crests in males, robust bodies, and enlarged cloacae in females). Histological analysis revealed that many of these sexually mature individuals possessed only one Line of Arrested Growth (LAG). Given that the first LAG is deposited after the first winter, the presence of a single LAG indicates these individuals were in their second year of life, having not yet undergone a second winter dormancy period (Hemelaar, 1985). Therefore, their biological age was accurately estimated as two years. This finding is consistent with reports of captive *O. vittatus cilicensis* reaching maturity within one year (Fahrbach and Gerlach, 2024).

The finding that both male and female *O. vittatus* in this Syrian population reach sexual maturity at only two years of age represents a remarkable deviation from the life-history patterns reported in other *Ommatotriton* species and populations. This accelerated maturation—approximately two years earlier than the 4–6 years typically observed in *O. nesterovi* and *O. ophryticus* populations from Turkey (Çiçek and Üzüm, 2015) and 3–5 years in Caucasian populations (Altunışık, 2018a, citing Kuzmin, 1999; Tarkhnishvili and Gokhelashvili, 1999)—suggests strong local environmental and evolutionary influences shaping the demographic structure of this population.

Collectively, the demographic and morphometric patterns suggest that the studied *O. vittatus* population is dynamically young, with strong juvenile recruitment and limited representation of older individuals. Such a pattern is consistent with amphibian populations inhabiting variable environments, where growth and survival are influenced by ecological factors such as temperature, habitat stability, and resource availability. Such early onset of maturity is commonly associated with favourable ecological conditions, including stable temperature regimes, abundant food resources, and minimal interspecific competition or predation pressure (Miaud et al., 2000). The pristine nature of the study pond—characterised by cool, thermally stable water (15–16° C), near-neutral pH, and low hardness—likely minimises physiological stress and promotes continuous foraging and growth, enabling individuals to attain reproductive size earlier than conspecifics inhabiting harsher environments. In contrast, populations living in colder, high-altitude, or resource-limited habitats often experience shorter growing seasons, slower metabolism, and consequently delayed maturity (Morrison and Hero, 2003; Esteban and Sanchiz, 2000).

The physicochemical characteristics of the study pond support its classification as a pristine and ecologically stable habitat. The cool, narrow-range water temperature (15–16 °C) and near-neutral pH (7.3–7.5) fall within the optimal physiological range for *Ommatotriton vittatus* and other temperate newts, promoting efficient metabolism, oxygen solubility, and embryonic development (Navas, 2006; Wells, 2007). Similarly, the low total and calcium hardness values (≈ 3 °dH) recorded in the present study fall within the range reported for natural habitats of *Ommatotriton vittatus*, where water chemistry parameters (including pH, GH, and KH) were characteristic of relatively unpolluted freshwater systems (Altunışık, 2018b). Such favourable abiotic conditions likely explain the early sexual maturity and high juvenile abundance observed in this population.

From an evolutionary perspective, the early sexual maturity observed in this population may represent a life-history strategy favouring rapid turnover and population persistence in small, temporally stable aquatic systems. Amphibians are well known for their remarkable plasticity in growth and maturation timing in response to environmental conditions (Wilbur and Collins, 1973; Semlitsch and Reyer, 1992). Under favourable conditions, individuals may accelerate metamorphosis and early reproduction to maximise lifetime reproductive success, whereas in less favourable or unpredictable environments, delayed maturity allows for the accumulation of larger body size and higher fecundity. The observed pattern in *O. vittatus* thus exemplifies a "fast" life-history strategy, optimising early reproduction at the expense of maximum size or longevity—an adaptive response that ensures reproductive success in environments with low ecological stress.

Comparable examples of early maturity have been reported in other amphibians occupying benign or thermally stable habitats, such as *Triturus carnifex* in Italy (Bruni et al., 2018). Equally, comparable examples of life-history plasticity have also been documented in other amphibians living in relatively favourable or stable habitats. For instance, *Salamandra salamandra* populations in certain low-stress environments show variation in age at maturity and adult body size in response to local habitat quality (Sinsch, 2024). Sinsch (2024) studied of four neighbouring *S. salamandra* populations in Germany and reported age at sexual maturity of 2–3 years, with demographic and size variation linked to local terrestrial habitat quality and metabolic growth carryover from the larval stage. Adult body size plasticity was especially influenced by environmental stressors during juvenile growth (Sinsch, 2024). Among anurans, *Rana temporaria* populations in colder or highelevation habitats often show delayed maturity, while *Pelophylax ridibundus* demonstrates variation in age structure linked to habitat conditions (Miaud et al., 1999; Sheremetyev et al., 2022). Taken together, these patterns indicate that the two-year maturation observed in Syrian *O. vittatus* is not an anomaly but a context-dependent ecological adaptation. The combination of stable aquatic conditions, sufficient food availability, and lack of anthropogenic disturbance has likely favoured individuals with faster growth trajectories and earlier reproductive onset.

Males exhibited a larger average body size (mean SVL = 62.2 mm) than females (mean SVL = 58.0 mm), indicating male-biased sexual size dimorphism (SSD). Maximum SVL values were 68 mm for males and 65 mm for females. Although both sexes reached similar maximum ages, males tended to maintain higher growth rates. The observed sexual dimorphism likely reflects differing energy allocation strategies between the sexes, with males investing more in somatic growth potentially linked to mate competition, whereas females allocate energy to reproductive output.

A positive correlation was found between age and snout–vent length, though the strength and significance of this relationship differed between sexes. In females, the correlation was statistically significant, indicating that body size increased consistently with age, with an estimated annual growth of approximately 1.1 mm. In males, the relationship was positive but not statistically significant, reflecting greater inter-individual variation in growth trajectories and possibly differing energetic allocation patterns between individuals. The stronger correlation in females suggests a more uniform investment in somatic growth linked to reproductive capacity, whereas males may exhibit variable growth due to the energetic costs of territoriality and mating behaviour (Halliday and Verrell, 1988).

In conclusion, while both sexes of *O. vittatus* in the studied pristine Syrian pond exhibit similar ages at maturity and longevity, males are significantly larger in body size. The combination of early maturity, positive age–size relationship, and favourable environmental conditions supports the interpretation of this population as a demographically young and ecologically stable system. This study provides crucial baseline data on the demography of this species and underscores the impact of optimal habitat conditions on its life-history trajectory and population dynamics.

This Syrian population of *Ommatotriton vittatus* represents an important biogeographic and ecological outlier at the southern margin of the species' range. Its persistence in a pristine, undisturbed aquatic system highlights the role of such habitats as critical refugia for maintaining amphibian genetic diversity and adaptive potential in the Levant. The observed combination of early maturity, stable demographic structure, and favourable water chemistry reflects a finely balanced ecosystem largely free from anthropogenic pressure. Given the increasing threats of habitat degradation, water pollution, and climatic variability across the Eastern Mediterranean, these results underscore the urgent need to preserve small, spring-fed ponds and forest-edge wetlands that sustain amphibian populations of high ecological integrity. Long-term monitoring of this site could provide valuable insights into how environmental stability and climatic fluctuations influence life-history plasticity in Middle Eastern newt populations.

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