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Differences in Ecological and Genetic Adaptations between *Salamandra infraimmaculata* and *Ommatotriton vittatus*

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Abstract

Israel is home to two species of amphibians belonging to distinct genera: *Salamandra* and *Ommatotriton*. They inhabit various regions, sometimes co-existing and in other instances dwelling separately across different areas, making their segregation challenging. This study compares the biological, ecological, and genetic traits of two species, the Near Eastern fire salamander *Salamandra infraimmaculata* and the southern banded newt *Ommatotriton vittatus*, to determine why *O. vittatus* thrives in a wider range of semi-arid habitats in central and southern Israel, whereas *S. infraimmaculata* predominantly occupies the coastal Mediterranean region in the north. Salamander larvae are typically found in streams, freshwater springs, and cave pools, whereas newt larvae inhabit winter pools and ponds exclusively. The developmental phase of salamander tadpoles extends over several months, whereas newt tadpoles spend a comparatively brief period in the water, from 1 to a few months. Notably, genetic disparities in the cytochrome b sequence in Israeli populations are more pronounced among newts than salamanders.

Keywords

Ommatotriton vittatus, Salamandra infraimmaculata, Biological, Ecological, Genetic, Israel

1. Introduction

Two genera of Urodela—*Salamandra* and *Ommatotriton*—are found in Israel. They are distributed together in some areas, and scattered separately in others, making them difficult to segregate [1] [2]. Salamander species are prevalent throughout Europe, extending from North Africa, where *Salamandra algira* thrives, to the Near East, with *Salamandra infraimmaculata* [1]-[3]. Studies have extensively documented the characteristics and behaviors of this latter yellow-spotted black *Salamandra* species, found in Europe and Israel [4]. Degani *et al.* [4] delved into the diverse color-pattern manifestations of the yellow markings on the dorsal surface of *S. infraimmaculata* across different habitats along the southern edge of its distribution in Israel. At Tel Dan, 454 salamanders were documented thriving in moist environments with perennial water flow, and their images were captured. From this group, 100 individuals were sampled to assess the proportion of yellow and black pigmentation on their backs, as well as the number of spots on their heads. Similarly, at Kibbutz Sasa, 201 salamanders were photographed, and measurements were conducted on 62 of them. In Kibbutz Yehiam, another 200 salamanders were documented, and measurements were conducted on 60 of them [4]. Skin mucus metabolites in *S. infraimmaculata* and *S. salamandra* from Europe and Israel have been described in several studies [5] [6].

The banded newt, scientifically known as *Ommatotriton vittatus* (formerly *Triturus vittatus*), is among the trio of *Ommatotriton* species, which also includes *O. nesterovi* and *O. ophryticus* [7], that inhabit regions spanning Türkiye, Syria and Israel, showcasing their remarkable adaptability to highly unpredictable environmental conditions [8]. Notably, *O. ophryticus* and *O. vittatus* display distinct traits, such as in the number of vertebrae in their trunk, genome size and allozyme composition [9]. Furthermore, *O. ophryticus*, the northernmost species, exhibits a geographical division into two segments: the "western group" residing in western Anatolia Türkiye, and the "eastern group" scattered across the remainder of Türkiye and Western Caucasus. *O. vittatus*, which inhabits Israel [2], marks the southernmost extent of the genus' distribution. Israel's environment exhibits notable seasonal fluctuations and extreme changes. For instance, one study site for *O. vittatus*, Nahalit pool in the upper Galilee [10]-[12], is aquatic for only about a month annually. This pattern is typical of newt habitats in Israel, whereas northern habitats tend to remain partially aquatic for most of the year. This environmental context underscores newt species' remarkable adaptability, which is crucial to their survival, particularly in coping with such drastic changes. This adaptability likely faces stronger selective pressures in arid climates such as in Israel compared to regions farther north with milder climates [2]. The present study compares biological, ecological, and genetic variables between two species—*S. infraimmaculata* and *O. vittatus*—to understand the characteristics enabling the broader distribution of *O. vittatus* in semi-arid regions in central and southern Israel as compared to the more limited distribution of *S. infraimmaculata* in the Mediterranean coastal area of northern Israel (**Figure 1**).

2. Material and Methods

2.1. Study Area

The study was carried out over consecutive years (1976-2023) all over Israel, and focused on the larvae of amphibian species *O. vittatus* and *S. infraimmaculata*.

The habitats included springs and a stream which were stable water bodies with water year-round, rock pool holes which were filled by rainwater and their hydroperiods were long (about 200 days per year), and ponds which were flooded during the autumn, when rainfall begins, and gradually dried out between the late winter months and early summer (**Figure 1** and **Figure 2**). All of the waterways were tested at least twice, and most more than that, over the study years. The water bodies were sorted into three categories: those in which salamanders and newts were found, those in which there was only one of the species, and those in which there were tadpoles of both species (**Figure 1** and **Figure 2**).

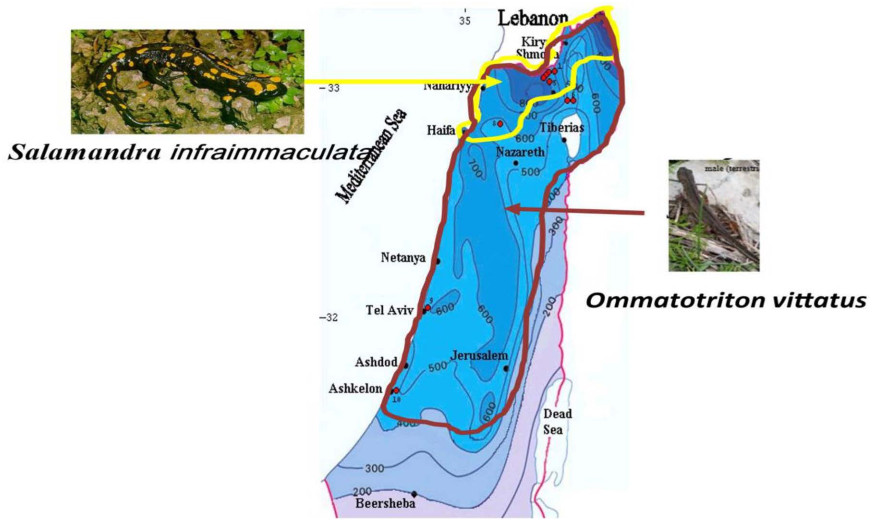


Figure 1. Breeding habitats for *S. infraimmaculata* and *O. vittatus* based on a government-issued map spanning Israel's distribution zones from 1941 to 2024. It categorizes water bodies into four types: winter reservoirs shown in blue, springs and streams, water holes, and winter pools.

2.2. Larval Samples

The breeding periods of *O. vittatus* and *S. infraimmaculata* in rain pools, *i.e.*, ponds and rock pools, streams and springs in Israel were studied during the years 1976 to 2023. Breeding sites in different locations were selected (**Figure 2** and **Figure 3**). We examined the pond areas from the beginning of October, as previously described [4] [8] [10], showing that *O. vittatus* and *S. infraimmaculata* larvae metamorphose and migrate to the breeding areas year-round. These habitats ranged in elevation from 0 - 740 m above sea level (asl), with extreme ecological and physical conditions, such as temperature and hydroperiod [12] [13]. At the onset of the rainy season (autumn and winter in Israel), when natural pools fill up for the first time, and until the pools dry up, during the migration periods, we monitored the mature newts and salamanders and recorded the water parameters every 2 weeks.

2.3. Measuring Water Quality at Breeding Sites

On-site measurements were conducted to assess water temperature, pH, dissolved oxygen concentration and electrical conductivity (EC). These measurements were performed using portable instruments: a pH meter equipped with a digital thermometer (WTW, pH315i, Germany), an oxygen meter (WTW, Oxi330 set) and an EC meter (WTW, Multiline P4). Water samples of 0.5 L were collected from each breeding site for further analysis. In the laboratory, we conducted additional tests for NH_4 and NO_2 levels, as well as for turbidity. The NH_4 and NO_2 tests were carried out using specific cell tests (Merck 1.14739 and 1.14547, Germany, respectively) and analyzed with a Spectroquant Photometer NOVA 60 (Merck). Turbidity measurements were performed using a turbidimeter (Hach, USA) as described previously [13].

2.4. Larva Sampling

Ten larvae of *O. vittatus* and *S. infraimmaculata* were sampled from each breeding site using a dipnet, following the methodology outlined by [14]. The sampling sites included eight different locations in Galilee, northern Israel, as depicted in **Figure 2** and **Figure 3**. The sampling sites included both ephemeral ponds: Manof Pond (located 340 m asl in Gush Segev), Dovev Pond (740 m asl), Matityahu Pond (682 m asl), and the Maalot Pit (a 2-m deep pit on a hill at 596 m asl), which are available from March to July; and permanent water bodies: Al Balad Spring (a perennial spring on Mount Carmel), Navuraya Spring (663 m asl), Humema Spring (900 m, a spring in a cave on Mount Meron), and the Tel Dan Stream (150 m, with water year-round at 16˚C), as shown in **Figure 2** [1] [14].

2.5. DNA Analysis

DNA was extracted from whole larvae or their clipped tails using the QIAamp DNA Mini Kit. This method entails breaking down the proteins with proteinase K and then binding the DNA specifically to a silica-gel membrane in the kit, which allows impurities to be separated out. Two sets of primers were utilized for amplification and sequencing. The first set, comprised of L Pro ML and H 12S1 ML [3], was employed to amplify an 807-bp segment of the D loop in the control region. The second set, consisting of L14841 and modified primer cyt b B2 [15], was used to amplify a 361-bp segment of cytochrome b (Cyt b); details are provided in [16] [17].

PCR amplification was conducted in a 50 μL solution comprising 10 mM Tris HCl, 50 mM KCl, 2.5 mM $MgCl_2$, 0.5 mM of each dNTP, 0.5 μM of each primer, 10 to 500 ng genomic DNA, and 2.5 units of Taq DNA polymerase from Promega (USA). The PCR procedure was executed using a PTC 150 MiniCycler from MJ Research (USA) with the following steps: initial denaturation at 94˚C for 3 min, followed by 32 cycles of denaturation at 94˚C for 1 min, annealing at 52˚C for 1 min, elongation at 72˚C for 1 min, and a final elongation period of 10 min at 72˚C. The amplified products were electrophoresed on a 1.3% agarose gel, stained with ethidium bromide, and DNA was extracted using the Jet Quick

Gel Extracting Spin Kit from Genomed (Germany). The recovered DNA was dissolved in deionized water. Purified DNA was sequenced bidirectionally using an ABI PRISM 3100 Genetic Analyzer from PE Biosystems (USA). The genetic relatedness among samples was assessed using the neighbor-joining method proposed by [18]. Genetic distances were calculated using the maximum composite likelihood method introduced by [19] and expressed as the number of base substitutions per site.

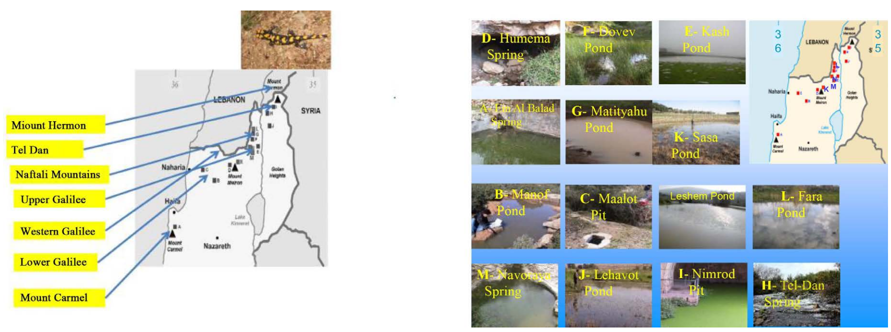
3. Results

Significant distinctions were observed in the distribution patterns of the two urodeles, *O. vittatus* and *S. infraimmaculata*, within Israel. While both species were present in the northern regions characterized by a Mediterranean climate, *O. vittatus* was also found in the central parts of the country and in the southern areas, limited to the border with arid regions extending into the desert (**Figure 1**).

Water bodies could be categorized into three types based on the presence of breeding tadpoles of the two distinct species. The first type was characterized by the exclusive breeding of salamanders, while in the other type, only newts were bred. Nevertheless, there were bodies of water where both salamanders and newts coexisted and bred (**Figure 2** and **Figure 3**).

Salamander tadpoles inhabit streams, freshwater springs, and pits in caves without newt tadpoles. Only newt tadpoles were found in winter pools and ponds, not salamander tadpoles. Both species of tadpole were found together in relatively large ponds where the water is stagnant from winter to summer (**Figure 2** and **Figure 3**). In northern Israel, only the larvae of newts were discovered in the small and fluctuating aquatic habitats (**Figure 3**).

Testing the water quality in habitats where both species have adapted, it was discovered that newt tadpoles thrive in warmer temperatures, reaching up to 30˚C., whereas salamander tadpoles prefer cooler waters, typically below 22˚C. No differences in other water-quality parameters were detected among the breeding sites (**Figure 4**).



(a) (b)

Figure 2. (a) Map of various regions in Israel colonized by *Salamandra infraimmaculata*. (b) In the northern region of Israel, salamander tadpoles were discovered inhabiting various aquatic environments, including swiftly flowing streams, natural springs, seasonal water sources and man-made wells.

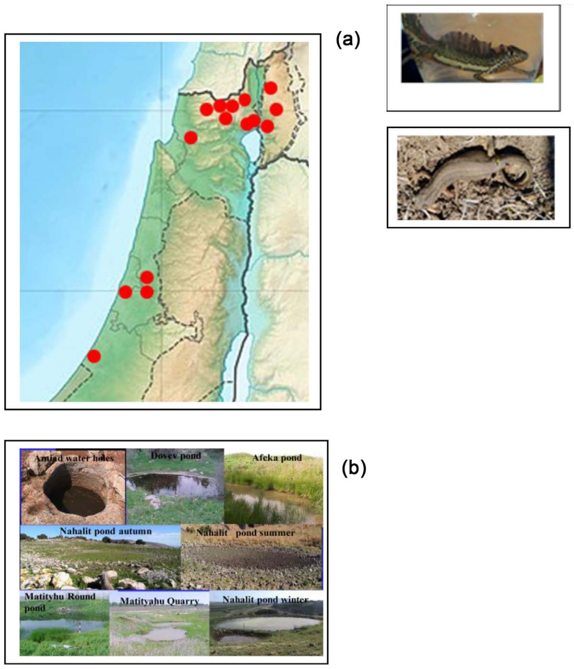


Figure 3. (a) Illustration depicting the assorted territories across Israel inhabited by *O. vittatus*. (b) Bodies of water making up breeding sites for *O. vittatus*.

In comparing the water quality in the water bodies where salamander and newt tadpoles grew, one clear difference was found. The growth curves of newt (**Figure 5(a)**) and salamander (**Figure 5(b)**) tadpoles in different bodies of water from the time of hatching to the completion of metamorphosis are shown in **Figure 5**. The growth period of newt tadpoles was significantly shorter (**Figure 5(a)**), by 100 days, compared to salamander tadpoles, the latter taking 250 days and sometimes more (**Figure 5(b)**). In all stages of growth until the completion of metamorphosis, the newt tadpoles (**Figure 5(a)**) were significantly smaller than the salamander tadpoles (**Figure 5(b)**).

The phylogenetic tree of *O. vittatus* and *S. infraimmaculata* from various breeding places in Israel based on the Cyt b sequence is presented in **Figure 6**. The differences between different populations in Israel were greater between newt populations than between salamander populations.

4. Discussion

We examined the ecological, biological and genetic differences between two urodele species. *S. infraimmaculata* is found in the Mediterranean region of northern Israel, whereas *O. vittatus* inhabits dry, semi-desert areas in central and southern Israel [1] [2]. By comparing these two amphibian species, the study aimed to shed light on how they adapt to dry environmental conditions.

The ability of amphibians to adapt to the various water environments in which they breed is crucial for their survival during droughts. We found that *O. vittatus* survives in temporary water bodies, such as temporary ponds and pools,

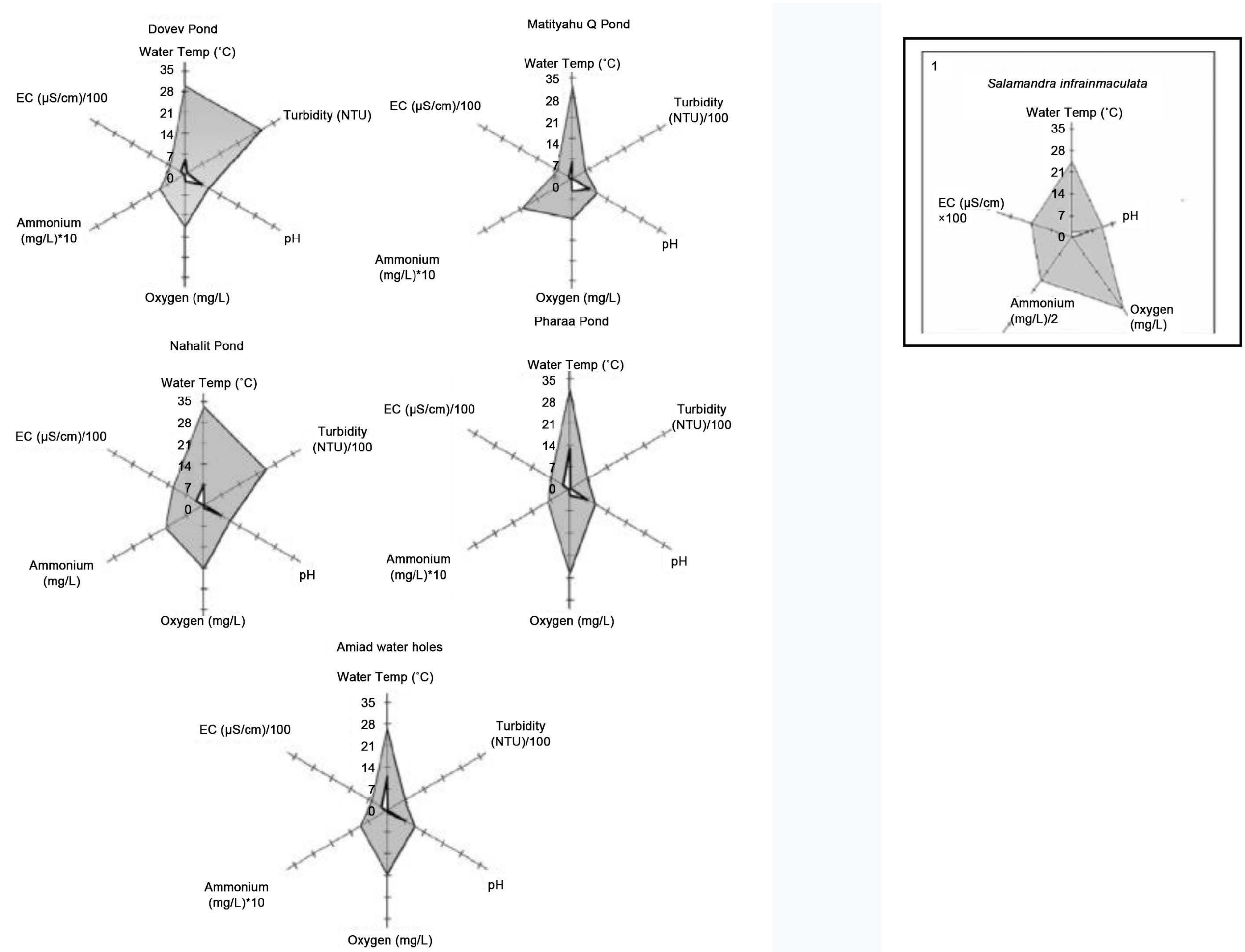
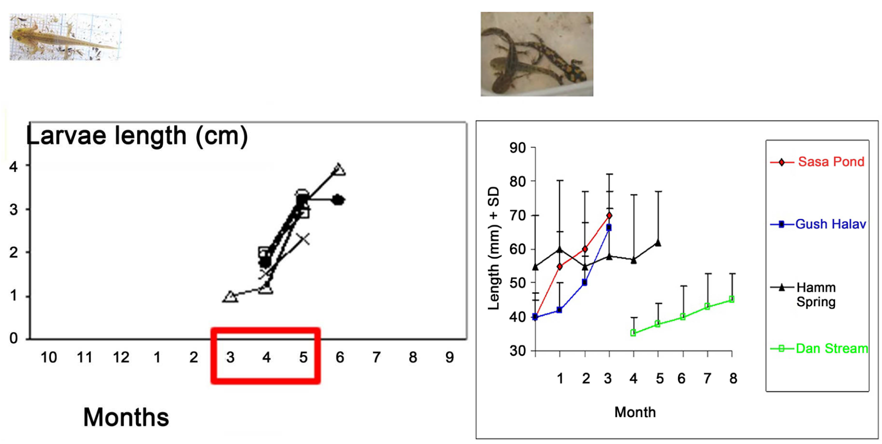


Figure 4. (a) Ecological conditions of *O. vittatus* larval habitats in northern Israel: oxygen levels (measured in mg/L), ammonium concentration (measured in mg/L), temperature (measured in ˚C), conductivity (measured in μS/cm), and pH. Each axis on the graph represents one of the ecological variables. (b) *S. infraimmaculata* larval habitats in northern Israel.



(a) (b)

Figure 5. Graphs depicting the development of larvae of *O. vittatus* (a) and *S. infraimmaculata* (b). These curves represent the Von Bertalanffy growth model. On the vertical axis, larval size is measured in centimeters, while the horizontal axis represents the duration, in days, of larval habitation of the aquatic environment until metamorphosis.

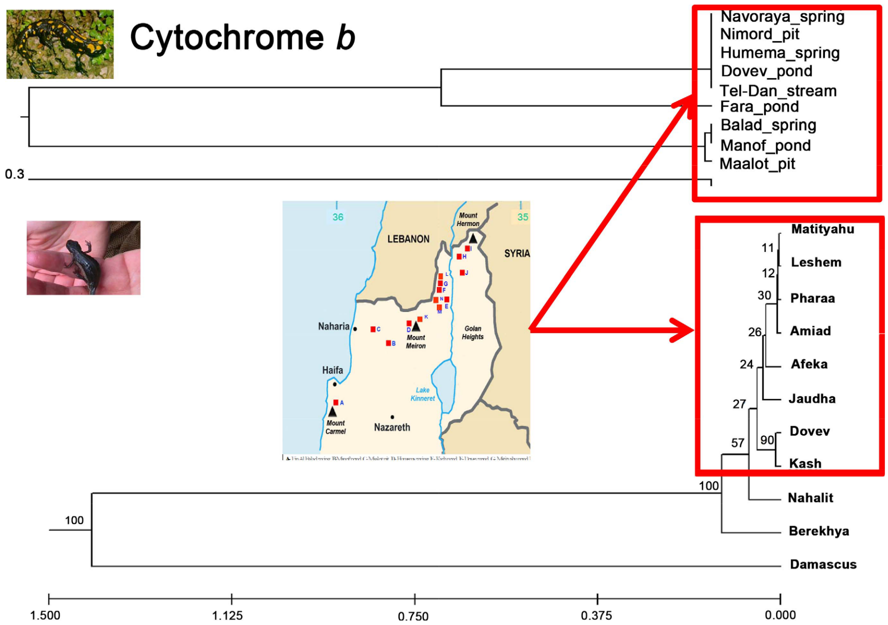


Figure 6. Evolutionary relationships among *O. vittatus* and *S. infraimmaculata* in Israel by comparisons of genetic sequences, specifically focusing on the nucleotide sequences of the Cyt b gene obtained from specimens collected at various locations in Israel.

which are more commonly found in semi-continental regions, compared to *S. infraimmaculata* that breed in permanent bodies of water with relatively low temperatures.

Newts are well-suited to temporary water bodies such as ponds, where water is present for shorter durations, typically 1 to 3 months [1] [2] [10] [13] [20]. Conversely, salamanders require more permanent water sources. These findings align with earlier research and can be attributed to the rapid growth and efficient molting process observed in newt tadpoles [21]-[23].

The results of this study suggest that *O. vittatus*, adapted to semi-arid habitats with dry climates, exhibits greater genetic diversity compared to *S. infraimmaculata*, which resides in environments that are less arid.

The genetic profiles of aquatic larvae, male and female terrestrial adults, and male and female aquatic adults have been examined [8], with a focus on life in water versus on land during adulthood, and the distinct genetic expressions associated with different adult phenotypes. In addition, we investigated how shifts in gene expression during the metamorphosis from larvae to adults contribute to these adaptations.

Understanding the functions of these pathways and specific genes is crucial for investigations into habitat transitions, particularly those impacted by climate fluctuations. Moreover, the adaptability of the newt's physical traits and the mechanisms governing gene expression provide valuable insights into the evolutionary processes of land-dwelling vertebrates [8].

Previous studies have detailed the life cycle, behavior, and genetic diversity within *O. vittatus* populations across various habitats in northern Israel, extending to the central coastal plains and near desert regions (see Degani [11] for review). Recent studies have identified transcriptomic distinctions not only between aquatic larvae and adult newts, but also between the terrestrial and aquatic adult stages characteristic of the *Ommatotriton* genus [7]. Historically, most "omics" investigations of *Ommatotriton* species have concentrated on population variance and phylogenetic aspects. Our study presents the first examination of changes in developmental gene expression within an *Ommatotriton* species.

There have been many studies on *S. infraimmaculata* genetic variation among larvae at various breeding sites compared to *O. vittatus*, but they are difficult to compare because they used various methods, e.g., amplified fragment length polymorphism [24], microsatellite loci and the mitochondrial D-loop [25], to analyze the gene expression [26].

Findings similar to ours have been observed not only in Urodela but also in Anura. For instance, the green toad, which displays high adaptation to arid conditions among anuran species in Israel, exhibits more genetic variation than other species in the region [1] [27].

In conclusion, this study sheds light on the adaptations of *O. vittatus* to semi-arid and nearly desert environments. These adaptations include their ability to survive in fluctuating and unpredictable ponds, *i.e.*, water sources that are transient and short-lived, a short tadpole phase, and rapid completion of metamorphosis. In addition, there is notable genetic diversity among *O. vittatus* populations compared to *S. infraimmaculata*, further contributing to their resilience and adaptability in these challenging habitats.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Degani, G. (2019) Ecological and Genetic Variation of the Distribution of Various Species of Amphibians at the Southern Border of their Distribution. *International Journal of Plant, Animal and Environmental Sciences*, **9**, 21-41.

[2] Degani, G. (2019) The Fire *Salamandra* (*Salamandra infraimmaculata*) and the Banded Newt (*Triturus vittatus*) along the Southern Border of Their. Scientific Research Publishing Inc.

[3] Steinfartz, S., Veith, M. and Tautz, D. (2000) Mitochondrial Sequence Analysis of *Salamandra* Taxa Suggests Old Splits of Major Lineages and Postglacial Recolonizations of Central Europe from Distinct Source Populations of *Salamandra salamandra*. *Molecular Ecology*, **9**, 397-410. https://doi.org/10.1046/j.1365-294x.2000.00870.x

[4] Degani, G., Am, G.I., Ish Am, A.B., Yatom, N., Marshansky, A., Margalit, S., *et al.* (2023) The Yellow Spot Pattern of Salamander (*Salamandra infraimmaculata*) in Various Habitats at the Southern Border of Its Distribution in Israel. *Open Journal of Animal Sciences*, **13**, 114-125. https://doi.org/10.4236/ojas.2023.131008

[5] Barzaghi, B., Melotto, A., Cogliati, P., Manenti, R. and Ficetola, G.F. (2022) Factors

Determining the Dorsal Coloration Pattern of Aposematic Salamanders. *Scientific Reports*, **12**, Article No. 17090. https://doi.org/10.1038/s41598-022-19466-0

[6] Degani, G., Peretz, E. and Musa, S. (2023) Skin Mucus Metabolites in *Salamandra infraimmaculata* from Various Habitats. *Endocrinology, Metabolism and Nutrition*, **2**, 1-9. https://doi.org/10.33425/2833-0307.1014

[7] van Riemsdijk, I., Arntzen, J.W., Babik, W., Bogaerts, S., Franzen, M., Kalaentzis, K., *et al.* (2022) Next-Generation Phylogeography of the Banded Newts (*Ommatotriton*): A Phylogenetic Hypothesis for Three Ancient Species with Geographically Restricted Interspecific Gene Flow and Deep Intraspecific Genetic Structure. *Molecular Phylogenetics and Evolution*, **167**, Article 107361. https://doi.org/10.1016/j.ympev.2021.107361

[8] Degani, G. and Meerson, A. (2024) Transcriptome Variation in Banded Newt (*Ommatotriton vittatus*) during Its Life Cycle and Habitat Transition. *Comparative Biochemistry and Physiology Part D: Genomics and Proteomics*, **50**, Article 101203. https://doi.org/10.1016/j.cbd.2024.101203

[9] Litvinchuk, S.N., Zuiderwijk, A., Borkin, L.J. and Rosanov, J.M. (2005) Taxonomic Status of *Triturus vittatus* (Amphibia: Salamandridae) in Western Turkey: Trunk Vertebrae Count, Genome Size and Allozyme Data. *Amphibia-Reptilia*, **26**, 305-323. https://doi.org/10.1163/156853805774408685

[10] G, D. (2021) Ecological and Biological Adaptations of *Triturus vittatus vittatus* (Urodela) to an Unstable Habitat. *International Journal of Zoology and Animal Biology*, **4**, Article 000306. https://doi.org/10.23880/izab-16000306

[11] Degani, G. (2017) Ecological, Biological, Behavioral and Genetic Adaptation to Xeric Habitats of *Triturus vittatus vittatus* (Urodela) on the Southern Border of Its Distribution. *Journal of Marine Science: Research & Development*, **7**, Article 226. https://doi.org/10.4172/2155-9910.1000226

[12] Degani, G., Pearlson, O. and Goldberg, T. (2013) Impermanent Breeding Site Selection-Fitness of Gonadal Cycle and Larval Growth of *Triturus vittatus vittatus* (Urodela) from the Southern Limit of Its Distribution. *American Open Animal Science Journal*, **1**, 16-30.

[13] Pearlson, O. and Degani, G. (2011) Water and Ecological Conditions of Striped Newt, *Triturus v. vittatus* (Urodela), Breeding Sites at Various Altitudes Near the Southern Limit of Its Distribution. *Herpetologica Romanica*, **5**, 27-42.

[14] Goldberg, T., Pearlson, O., Nevo, E. and Degani, G. (2009) Sequence Analysis of Mitochondrial DNA In*salamandra infraimmaculata* Larvae from Populations in Northern Israel. *South American Journal of Herpetology*, **4**, 268-274. https://doi.org/10.2994/057.004.0310

[15] Kocher, T.D., Thomas, W.K., Meyer, A., Edwards, S.V., Pääbo, S., Villablanca, F.X., *et al.* (1989) Dynamics of Mitochondrial DNA Evolution in Animals: Amplification and Sequencing with Conserved Primers. *Proceedings of the National Academy of Sciences*, **86**, 6196-6200. https://doi.org/10.1073/pnas.86.16.6196

[16] Degani, G., Goldberg, T. and Yom-Din, S. (2013) The Ecology and Variation in DNA of *Rana Bedreagae* from Various Breeding Site in North Israel. *Research Open Journal of Animal Sciences*, **1**, 1-14.

[17] Goebel, A.M., Donnelly, J.M. and Atz, M.E. (1999) PCR Primers and Amplification Methods for 12S Ribosomal DNA, the Control Region, Cytochrome Oxidase I, and Cytochromebin Bufonids and Other Frogs, and an Overview of PCR Primers Which Have Amplified DNA in Amphibians Successfully. *Molecular Phylogenetics and Evolution*, **11**, 163-199. https://doi.org/10.1006/mpev.1998.0538

[18] Saitou, N. and Nei, M. (1987) The Neighbor-Joining Method: A New Method for Reconstructing Phylogenetic Trees. *Molecular Biology and Evolution*, **4**, 406-425.

[19] Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M. and Kumar, S. (2011) MEGA5: Molecular Evolutionary Genetics Analysis Using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony Methods. *Molecular Biology and Evolution*, **28**, 2731-2739. https://doi.org/10.1093/molbev/msr121

[20] Pearlson, O. and Degani, G. (2008) The Life History of *Triturus v. vittatus* (Urodela) in Various Habitats. *Asiatic Herpetological Research*, **11**, 91-95.

[21] Goldberg, T., Nevo, E. and Degani, G. (2012) Amphibian Larval in Various Water Bodies in the Semi-Arid Zone. *Zoological Studies*, **51**, 345-361.

[22] Degani, G. (1982) Amphibian Tadpole Interaction in a Winter Pond. *Hydrobiologia*, **96**, 3-7. https://doi.org/10.1007/bf00006274

[23] Degani, G. (1986) Growth and Behaviour of Six Species of Amphibian Larvae in a Winter Pond in Israel. *Hydrobiologia*, **140**, 5-10. https://doi.org/10.1007/bf00006723

[24] Degani, G., Goldberg, T. and Nevo, E. (2014) Genetic Variation in *Salamandra infraimmaculata* from Different Habitats Using Amplified Fragment Length Polymorphism. *Journal of Biophysical Chemistry*, **5**, 54-66. https://doi.org/10.4236/jbpc.2014.52007

[25] Preißler, K., Küpfer, E., Löffler, F., Hinckley, A., Blaustein, L. and Steinfartz, S. (2020) Genetic Diversity and Gene Flow Decline with Elevation in the Near Eastern Fire Salamander (*Salamandra infraimmaculata*) at Mount Hermon, Golan Heights. *Amphibia-Reptilia*, **42**, 241-247. https://doi.org/10.1163/15685381-bja10038

[26] Goedbloed, D.J., Czypionka, T., Altmüller, J., Rodriguez, A., Küpfer, E., Segev, O., *et al*. (2017) Parallel Habitat Acclimatization Is Realized by the Expression of Different Genes in Two Closely Related Salamander Species (Genus *Salamandra*). *Heredity*, **119**, 429-437. https://doi.org/10.1038/hdy.2017.55

[27] Degani, G. (2024) Biological Adaptations of Anuran Species across Diverse Habitats, Spanning Mediterranean to Desert Climates. Scientific Research Publishing, 1-92.