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Variation of Colors in Amphibians: Adaptive Strategies in Natural Habitats from Mediterranean Climate to a Desert Environment in Israel

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Abstract

Amphibians in Israel display remarkable adaptive strategies in response to the country's diverse climatic zones, ranging from Mediterranean habitats in the north to desert environments in the south. This study reviews variation in coloration, morphology, and ecological traits across representative species, highlighting their significance for camouflage, aposematism, and environmental plasticity. Species such as *Hyla savignyi* exhibit dynamic color variation linked to substrate and climatic conditions, while *Bufotes viridis* (syn. *Pseudepidalea viridis*) demonstrates polymorphic dorsal patterns associated with habitat-specific pressures. The Eastern spadefoot toad (*Pelobates syriacus*) shows subtle but ecologically significant variations in dorsal mosaic patterns that provide camouflage at the southern edge of its range. The Levant water frog (*Pelophylax bedriagae*) exhibits striking morphs ranging from cryptic brown to vivid green-yellow forms, reflecting both habitat conditions and potential reproductive signaling. The rediscovered Hula painted frog (*Latonia nigriventer*), unique to the Hula Valley, combines cryptic dorsal coloration with stable, individual-specific ventral spotting used in conservation monitoring. Among Caudata, the fire salamander (*Salamandra infraimmaculata*) shows high variability in spot patterns and mucus metabolite profiles shaped by environmental stressors, while the banded newt (*Ommatotriton vittatus*) demonstrates dramatic seasonal sexual dimorphism between terrestrial and aquatic phases. Together, these examples emphasize the role of coloration strategies, morphological plasticity, and ecological adaptation in supporting amphibian survival across heterogeneous landscapes. Understanding these adaptive mechanisms is critical for conservation, particularly in the face of habitat fragmentation

and climate change in the Levant.

Keywords

Variation of Colors, Amphibians: Adaptive, Natural Habitats, Climate, Mediterranean, Desert Environment

1. Introduction

In amphibians, various species exhibit distinct adaptations that provide them with advantages in their habitats. This article focuses on the patterns of camouflage, warning coloration against toxic substances, and the ability to change color in response to environmental shifts among amphibians found in Israel, particularly in transitioning from a Mediterranean climate to a desert environment (**Figure 1**).

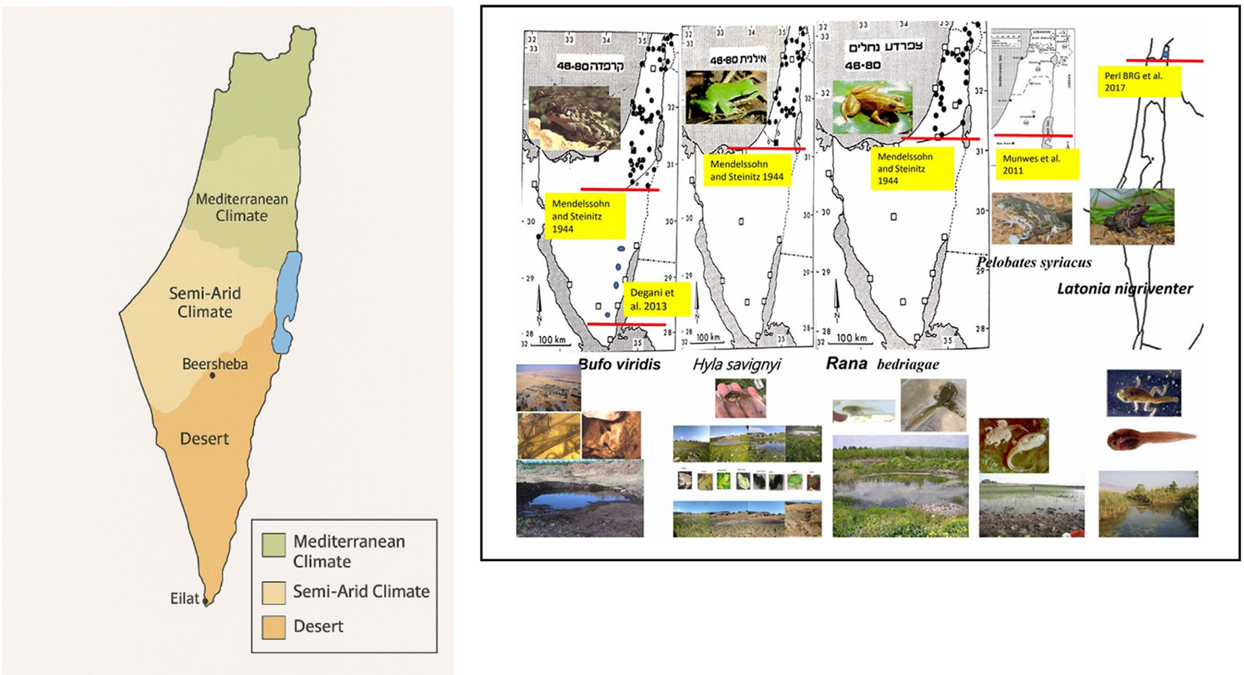

Figure 1. In the Mediterranean climate, all seven amphibian species are found, but they occupy different habitats and sometimes share the same mating populations [1].

Additionally, the ability to change color in response to environmental conditions is a fascinating adaptation. Studies indicate that certain species can alter their skin coloration based on ambient light and substrate colors, which is particularly beneficial in arid environments where visual cues can vary significantly [2].

Understanding these adaptations is vital for conservation efforts, especially as amphibians face increasing threats from habitat loss and climate change. This research highlights the importance of preserving diverse habitats that support these remarkable adaptations.

In Israel, there is a Mediterranean zone in the north, which transitions into a semi-arid zone in the central region and then into a desert area in the south. Within these different environments, there are seven species of amphibians, two of which belong to the order Caudata (tail-bearing amphibians) [3], and four species belong to the order Anura (tailless amphibians) [1].

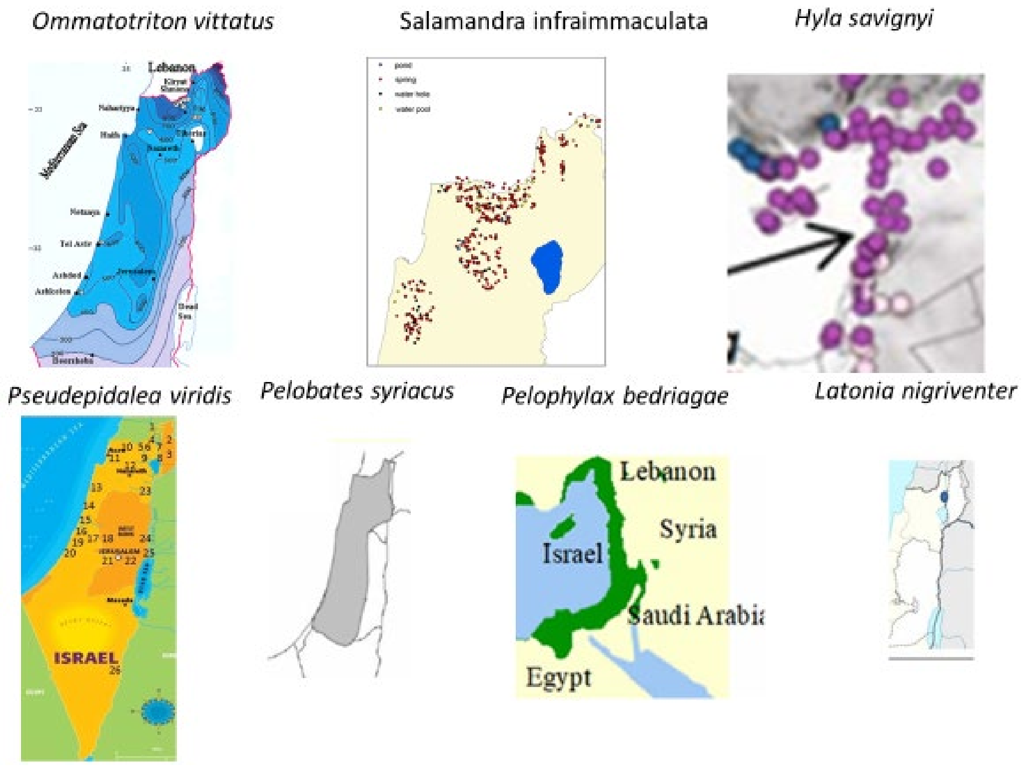

Figure 2. Species distribution of amphibians in Israel.

The two species in the order Caudata are: The Near Eastern fire salamander, *Salamandra infraimmaculata* (family Salamandridae) and the banded newt, *Ommatotriton vittatus* (family Salamandridae) [3]. The four species in the order Anura are [4]: The Middle East tree frog, *Hyla savignyi* (family Hylidae), formerly synonymized as *H. arborea* [5]. This species is found in Yemen, Jordan, southern Syria, and extreme northeastern Israel. The green toad, *Bufo viridis* (family Bufonidae), also known by the synonym *Pseudepidalea viridis* [3] [5]. It is found in many countries across Europe and Israel, in diverse habitats, including mountainous areas, semi-arid and arid regions, as well as urban environments. The Levant water frog, *Pelophylax bedriagae* (family Ranidae), with synonyms *Rana ridibunda* and *Rana bedriagae* [1]. This species is found in Israel, Turkey, and surrounding areas. The eastern spadefoot toad, *Pelobates syriacus* (family Pelobatidae) [6] [7]. This species has a wide distribution across parts of Europe and Asia, including northern Syria, Israel, northern Iraq, Iran, Asia Minor, and the Caucasus. Additionally, there is one species endemic to Israel: The Hula painted frog, *Latonia nigriventer* (family Alytidae) This species is found only in the Hula Reserve in Israel [8].

2. Color Variation and Camouflage in *Hyla savignyi*: Adaptive Significance in Mediterranean to Desert Habitats

Hyla savignyi (Savigny's tree frog, also known as the Middle East tree frog) provides a remarkable example of these adaptations. Distributed across Mediterranean to desert habitats in the Middle East, this species demonstrates dynamic color variation that enhances camouflage and increases survival in diverse ecological niches. This section reviews the ecological, genetic, and evolutionary mechanisms underlying color variation in *H. savignyi*, with a particular emphasis on Israeli populations, where adaptation to contrasting habitats is critical (**Figure 2**) [1].

Figure 3. The ability of the Mediterranean tree frog (*Hyla savignyi*) to change its color according to habitat variation across different climates, ranging from Mediterranean to desert environments [4] [9].

Research shows that camouflage plays a crucial role in predator avoidance, allowing amphibians to blend into their surroundings effectively [10]. For instance, species like the Mediterranean tree frog (*Hyla savignyi*) exhibit coloration that closely resembles the vegetation in their habitat, enhancing their survival [1] [11].

In terms of warning coloration, many amphibians display bright colors as a defense mechanism to signal their toxicity to potential predators [12]. This aposematic coloration can deter predators, which learn to associate specific colors with an unpleasant taste or toxic effect.

Field observations and experimental studies have shown that *H. savignyi* can display dorsal coloration ranging from bright green to brown or gray, often depending on background substrate, humidity, temperature, and light intensity [4] [9]. In Mediterranean habitats, individuals are commonly green and cryptic against vegetation, while in drier, rocky habitats, they frequently exhibit brown or gray coloration, improving concealment (**Figure 3**).

This plasticity in coloration provides camouflage against both avian and reptilian predators. The phenomenon is not solely environmental: genetic and molecular studies suggest that heritable variation also contributes to these differences, producing polymorphism within and between populations [13].

The camouflage strategy of *Hyla savignyi* through dynamic color variation exemplifies how amphibians adapt to heterogeneous and changing environments. In Israel and neighboring regions, where habitats range from Mediterranean forests to desert landscapes, such plasticity provides an evolutionary advantage. Genetic studies confirm that color polymorphism is shaped by an interplay of genetic, environmental, and selective pressures, highlighting this species as a model for studying ecological adaptation in amphibians [1].

3. Green Toad (*Pseudepidalea viridis*, Synonym *Bufotes viridis*)—Exhibits Diverse Patterns and Color Variations within Populations, Adapted to a Range of Terrestrial Habitats with Different Background Shades

Figure 4. Color and habitat variation in the green toad.

The green toad, following metamorphosis, exhibits a remarkable range of color patterns that adapt to diverse Mediterranean and arid environments. This article examines how its coloration—ranging from vivid green to brownish tones—correlates with different habitat types, supported by scientific literature (**Figure 4**) [1].

3.1. Geographic Distribution & Habitat Diversity

Bufotes viridis inhabits a broad geographic range across the Palearctic, spanning Eastern France and Denmark through the Balkans, Western Russia, the Middle East, and into Central Asia, North Africa, and parts of the Arabian Peninsula. It thrives in steppes, mountain slopes, semi-deserts, urban areas, and even arid or semi-arid environments. In forested zones, they typically occupy open, shrubby areas often distant from water, whereas in drier southern regions, they are bound to moist microhabitats like oases, irrigation ditches, or the margins of lakes and ponds [1].

3.2. Color Patterns & Morphological Plasticity

The dorsal coloration of *B. viridis* is notably variable: Base colors: pale to olive, cream, greyish, or brownish. Spot patterns: typically, irregular green or greenish-olive spots that may merge into dense patches or marbled patterns. In some individuals, the spots coalesce so densely that the toad appears uniformly greenish or olive; some males, in particular, display near-uniform coloration. Under certain conditions, spots can even appear blackish, brown, or tinged with red in preserved specimens [1].

3.3. Environmental Influence on Color Polymorphism

Recent empirical studies suggest that coloration in *B. viridis* is not just genetic—it is significantly influenced by habitat characteristics: A study conducted in urban areas of Plovdiv, Bulgaria documented four distinct morphs: light-background with individual spots (A/B morphs) and dark-background with merged spots (C/D morphs). Toads in one site ("Mladezhki hulm") were predominantly dark-morph individuals, whereas those in another site ("Hulm Bunardzhik") were mainly light-morphs—highlighting a strong habitat-based distribution. This provides clear evidence that environmental factors—perhaps substrate, light, temperature, or predation pressure—drive morph prevalence across habitats, supporting adaptive coloration [14]-[17].

3.4. Implications and Adaptive Significance

The variation in dorsal coloration likely serves camouflage and thermoregulatory roles, enhancing survival across diverse ecosystems. Darker morphs may be better suited to shaded or volcanic soils, while lighter or green-spotted individuals blend effectively in open, grassy, or rocky environments typical of Mediterranean or steppes. This adaptive polymorphism underscores the toad's ecological resilience—its ability to thrive in both natural and anthropogenic environments reflects strong plasticity and evolutionary adaptability [14] [15] [17].

3.5. Future Directions

Further comparative studies across wider geographic and ecological gradients, integrating genetic, environmental, and behavioral data, would deepen understanding of the drivers behind this polymorphism. Insights could advance conservation strategies, especially in regions facing habitat fragmentation or climate change [14]-[17].

4. Morphological Variations of the Eastern Spadefoot Toad (*Pelobates syriacus*) at the Southern Edge of Its Distribution

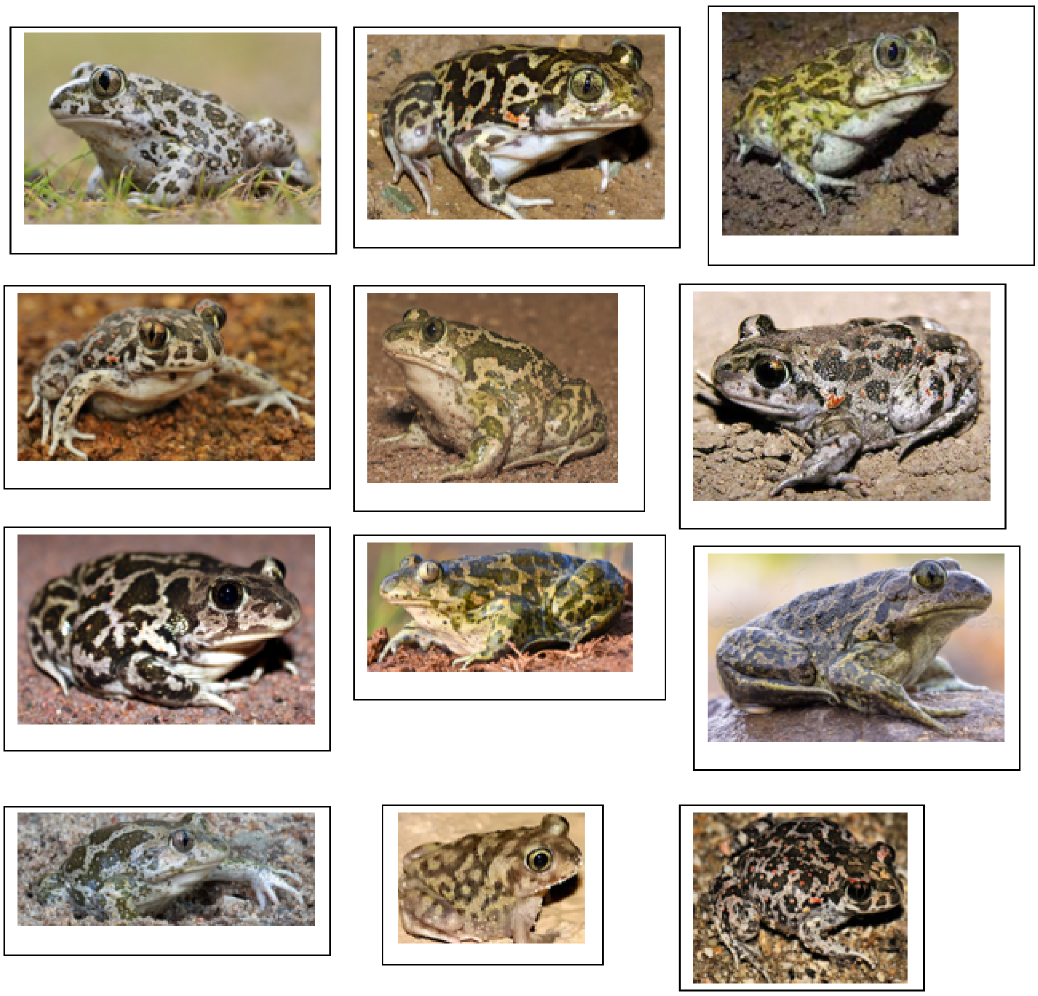

Figure 5. Variation in the terrestrial phase of the Eastern spadefoot toad (*Pelobates syriacus*) [1].

The terrestrial phase of the Eastern spadefoot toad (*Pelobates syriacus*) exhibits a dorsal coloration pattern that, in principle, resembles that of the green toad (*Bufotes viridis* species complex). Although the inter-individual variation is relatively small, the dorsal pattern is composed of a complex mosaic of brown and green blotches in varying shades, providing both camouflage and species-specific recognition (**Figure 5**). Such coloration patterns in *Pelobates* are considered adaptive for concealment in heterogeneous Mediterranean and semi-arid habitats, where background matching plays a key role in predator avoidance. Similar patterns of chromatic variability have been reported in *Bufotes* species, emphasizing the ecological significance of dorsal patterning in anurans inhabiting transitional environments between mesic and xeric regions.

These observations are consistent with previous studies documenting dorsal coloration variability and ecological adaptations in both *Pelobates* and *Bufotes* species across the Eastern Mediterranean [5] [15].

The figure (**Figure 5**) presents a comprehensive view of dorsal color and pattern variation in the Eastern spadefoot toad (*Pelobates syriacus*). Instead of describing each specimen separately, here is a detailed synthesis of the main morphological and chromatic patterns that appear across the individuals shown [1] [5]:

Background Coloration Light Gray to Sandy Forms: Several toads exhibit pale gray, beige, or sandy backgrounds, often blending with loess or sandy soils typical of arid habitats. Olive-Green Forms: Others have greenish or olive dorsal tones, usually interspersed with dark blotches; this morph is more cryptic in vegetated environments. Dark Brown to Blackish Forms: Some individuals show a dominant dark brown background with contrasting lighter margins, effective for camouflage on darker soils. Dorsal Patterning Large. Dark Blotches: Common across many individuals, irregular black or dark brown blotches cover much of the dorsum. These blotches can be oval, circular, or fused into larger patches. Reticulated or Mosaic Patterns: In several specimens, blotches connect to form net-like reticulations, producing a marbled appearance. Small and Dense Spots: Some morphs display finer, more numerous dark speckles scattered across the dorsum, creating a more uniform, speckled look [1] [5].

Secondary Markings. Green Patches or Irregular Bands: Certain individuals possess distinct bright green patches or irregular green bands, often standing out against a lighter background. Reddish-Orange Accents: A few morphs include small reddish or orange markings embedded in the dark blotches—likely a population-specific feature observed in Israeli habitats. Vertebral Striping: Although not as prominent as in other anurans, some individuals hint at faint lighter vertebral zones where blotches are reduced.

Ecological and Adaptive Significance. Camouflage on Substrate: Pale sandy morphs suit loess plains and dunes. Olive-green forms are cryptic in vegetated habitats or seasonal wetlands. Darker morphs blend with rocky or basaltic soils. Predator Avoidance: Variability in blotch size and arrangement disrupts the body outline, reducing detectability. Population Plasticity: This spectrum of dorsal designs reflects the phenotypic plasticity of *P. syriacus*, enabling it to persist across the ecological mosaic of northern Israel to semi-arid southern zones [1] [5].

The figure demonstrates that the Eastern spadefoot toad is not uniform in appearance but instead shows a continuum of dorsal phenotypes ranging from pale sandy with sparse markings to dark heavily blotched forms, with intermediate olive and reticulated morphs. This diversity illustrates the species' adaptation to different microhabitats and substrates within its distributional range.

The body is robust and somewhat flattened, with a broad head and large, protruding eyes that have vertical pupils—an adaptation typical of spadefoot toads, linked to their largely nocturnal activity [5]. The skin texture is relatively smooth compared to *Bufotes* species, though fine granulations may be present.

A distinctive feature of *P. syriacus* is the keratinized black metatarsal tubercle ("spade") on the hind feet, which is used for burrowing into sandy or loose soils. This burrowing adaptation allows the species to avoid desiccation during hot, dry conditions of Mediterranean and semi-arid habitats [5].

The terrestrial phase of the Eastern spadefoot toad (*Pelobates syriacus*) demonstrates a relatively narrow but ecologically significant range of dorsal color variation. The combination of green and brown blotches provides effective camouflage in Mediterranean and semi-arid habitats, supporting survival at the southern edge of its distribution. This adaptive coloration, together with morphological traits such as the keratinized metatarsal "spade" for burrowing, highlights the species' evolutionary specialization for coping with heterogeneous and arid environments [5] [15].

5. Morphological and Ecological Variations of the Levant Water Frog (*Rana bedriagae*) at the Southern Edge of Its Distribution in Israel

5.1. Introduction

The Levant Water Frog (Pelophylax bedriagae, formerly Rana bedriagae) has been subject to taxonomic and morphometric assessments across the Middle East. In Israel, [18] performed multivariate analyses—such as principal component and discriminant analyses—on frogs from multiple localities in Israel, Türkiye, Syria, and Jordan, comparing them to R. ridibunda populations elsewhere. Their results confirmed that populations from Israel and neighboring countries are conspecific (*P. bedriagae*), distinguishable from *R. ridibunda* by size and shape. AmphibiaWeb provides additional morphological detail: adult male snout–vent lengths (SVL) range between 42.5 - 89.5 mm, with females slightly larger. Diagnostic features include a pointed snout, large dorsally placed eyes with horizontal pupils, a tympanum about 10% smaller than the eye, a supratympanic fold, dorsolateral folds, extensive toe webbing, and presence of nuptial pads on males during the breeding season.

5.2. Ecological Variation, Distribution, Life History

In northern Israel, [6] [19] Degani & Kaplan (1999) explored the breeding habitats and life cycle of *P. bedriagae*. The species breeds in diverse aquatic environments, including winter ponds, rock pools, springs, and streams. Breeding typically occurs during May and June, though tadpoles can persist and metamorphose later in the summer or into winter.

Goldberg *et al.* [20] provided additional notes on reproduction in Israel, documenting aspects of breeding behavior and timing MDPI. Degani investigated larval growth across various aquatic habitats [5]. His findings highlight variations in growth rates tied to habitat conditions, such as oxygen levels and water chemistry (e.g., pH, ammonium). Larval development displayed notable differences in duration and size across different environments.

Figure 5 is a detailed description of the variation shown in the attached images of the Levant Water Frog (*Pelophylax bedriagae*), illustrating the remarkable range of color morphs and patterns within this species at the southern edge of its distribution in Israel:

A. Top Left—Brown Morph with Dark Spots. This frog displays a light to medium brown background coloration, overlaid with dark brown to black irregular spots across the dorsum and flanks. The dorsolateral folds are clearly visible and darker in tone. This morph blends well with dry soil, leaf litter, and terrestrial substrates, providing camouflage during periods of terrestrial activity.

B. Top Middle—Bright Green Morph. This individual exhibits a vivid green dorsal coloration, particularly concentrated in the mid-dorsal region, with dark patches and reticulations along the flanks. The green is mottled with black and brown spots, especially on the limbs. This morph is strongly associated with lush, vegetated aquatic habitats, such as reed beds or grassy pond margins, where the green enhances camouflage.

C. Top Right—Light Brown Morph with Yellow Vertebral Stripe. This morph is characterized by an overall light brown coloration with a distinct yellow vertebral stripe running from snout to vent. The limbs and dorsum are patterned with subtle dark mottling. The vertebral stripe is a common feature in many ranid frogs and is thought to serve as a disruptive visual signal in aquatic environments, breaking up the body outline. This morph is often found in shallow pools and muddy wetlands, where light reflection enhances its camouflage.

D. Bottom Left—Bright Green-Yellow Morph with Heavy Black Spottling. This frog exhibits a striking bright green to yellow-green dorsal coloration, overlaid with dense, irregular black spots. The coloration is especially vibrant on the head and back, fading slightly towards the hind limbs. Such frogs are well camouflaged among floating vegetation and sunlit water margins, where green reflections dominate. This morph is often more conspicuous but may signal health and sexual fitness, playing a role in mate attraction during the breeding season. Overall Variation as described in **Figure 6**. The images highlight the phenotypic plasticity of *Pelophylax bedriagae* in Israel: Brown morphs provide camouflage in drier or muddy habitats. Green morphs blend into aquatic vegetation. Yellow-striped morphs may use disruptive coloration for predator avoidance. Bright green-yellow with heavy spotting may be adaptive in vegetated aquatic zones and possibly linked to sexual signaling.

This variation reflects the species' broad ecological adaptability, allowing survival across Mediterranean, semi-arid, and aquatic environments at the southern limit of its range. Such plasticity has been described in Israeli populations [6] [19] [20].

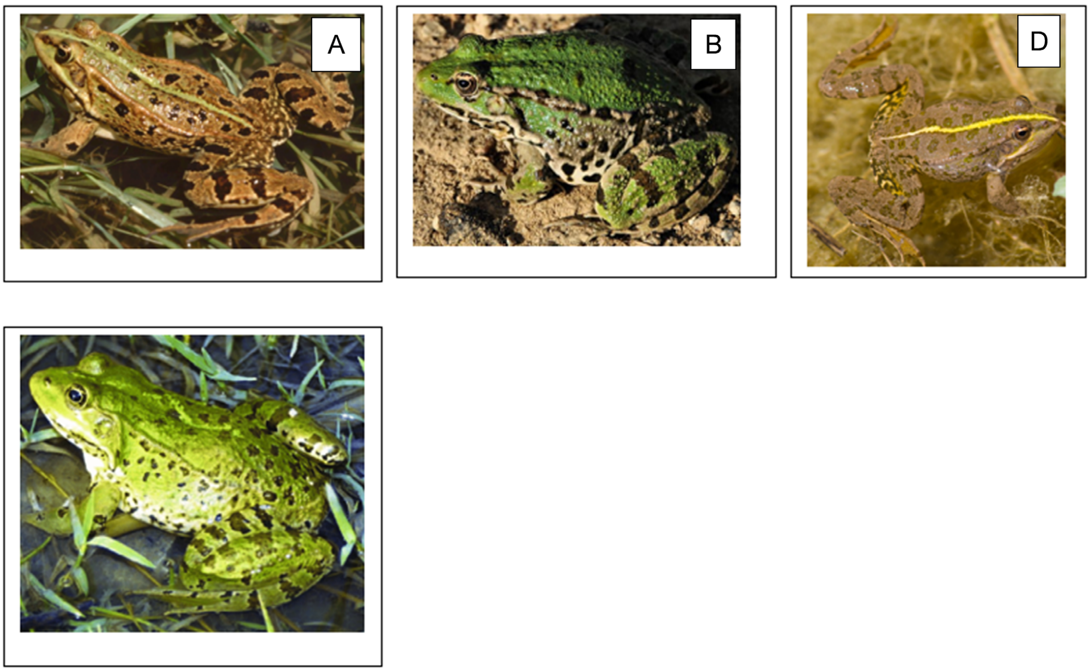

Figure 6. The Levant water frog (*Pelophylax bedriagae*) exhibiting various color morphs [1].

6. The Coloration of the Hula Painted Frog (*Latonia nigriventer*) after Metamorphosis

The Hula painted frog (*Latonia nigriventer*) is an enigmatic amphibian species endemic to northern Israel and the sole living representative of the genus Latonia, a lineage otherwise known only from fossils spanning the Oligocene to Pleistocene epochs [21] [22]. Once thought to have gone extinct following the extensive drainage of Lake Hula in the 1950s, the species was remarkably rediscovered in 2011, igniting renewed conservation and research interest [7] [21].

Despite increasing attention to its conservation status, knowledge of the species' ontogenetic development, particularly coloration after metamorphosis, remains limited. Adult frogs are generally described as having ochre dorsal coloration with rusty tones grading into dark olive-grey or greyish-black on the sides, and a distinctive black belly densely spotted with white [22]. The ventral spotting has particular significance: researchers have used these unique patterns for individual recognition in non-invasive mark-recapture monitoring, which is especially important given the species' critically endangered status and small population size [23].

Recent work by Perl *et al.* [23] examined how these ventral spot patterns develop post-metamorphosis and whether individuals maintain recognizable and stable patterns into adulthood. Their study revealed that although juveniles (SVL

< 35 mm) possess fewer ventral spots than adults (SVL > 100 mm), the overall configuration of spot patterns remains sufficiently stable over time to enable reliable re-identification of individuals—even across a two-year span.

However, gaps remain in our understanding of external coloration and its ontogenetic trajectory beyond ventral spotting. Can dorsal and lateral color patterns similarly support individual recognition? How consistent are post-metamorphic coloration features—such as dorsal ground coloration and lateral hues—through juvenile development into adulthood? These questions are particularly pressing in light of the species' conservation: understanding coloration stability may inform more effective, non-invasive monitoring and identification protocols.

This paper seeks to address these knowledge gaps by characterizing the post-metamorphic coloration patterns of Latonia nigriventer, focusing on changes in dorsal, lateral, and ventral attributes and assessing their constancy over time. By enhancing our understanding of color pattern ontogeny, this study aims to support improved field identification methods, with implications for monitoring elusive, critically endangered amphibian species.

7. Description of the Hula Painted Frog (*Latonia nigriventer*) in Figure 7

The Hula painted frog (*Latonia nigriventer*) is a stocky, robust amphibian characterized by relatively short limbs and a broad head, reflecting its adaptation to a burrowing and sedentary lifestyle. The dorsal surface is dominated by a dark background ranging from brown to nearly black (**Figure 7**). Superimposed on this base coloration are irregular ochre to rusty markings scattered across the dorsum. These markings may appear as distinct blotches or diffuse patches, providing effective camouflage in the muddy habitats of the Hula Valley. The sides are typically shaded darker, in tones of greyish-black or olive-grey, which further enhances the cryptic appearance. In some individuals, lighter mottling or faint striping is present along the flanks, adding to the variation in patterning.

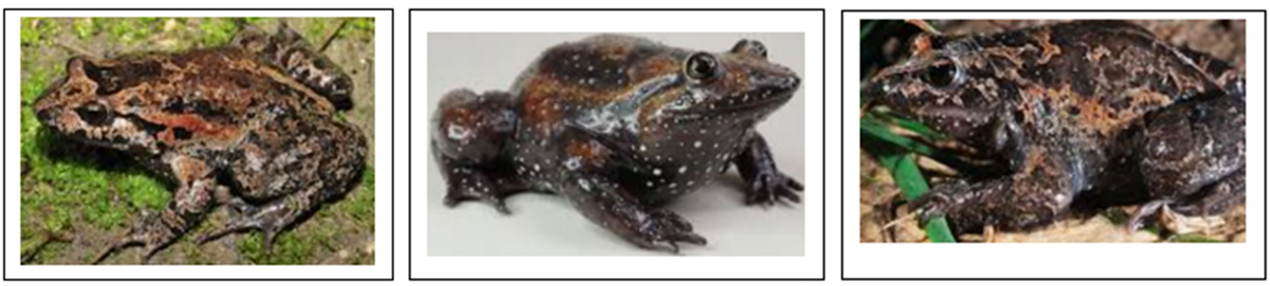

Figure 7. The hula painted frog (*Latonia nigriventer*) [1].

A diagnostic feature of the species is its ventral coloration: a black belly covered with numerous small, contrasting white spots. This pattern is unique to each individual and has been successfully employed for non-invasive identification in mark–recapture studies [23]. The dorsal skin is granular, covered with fine warts and ridges, giving it a rougher texture compared with the smoother skin of true ranid frogs. This rugose surface may provide additional camouflage by breaking up the frog's outline. The eyes are large and prominent, with irises ranging from golden to copper in color. Their position and size indicate an adaptation to semi-aquatic activity, allowing efficient vision both above and below the water surface. Adults of the Hula painted frog generally range between 6 and 12 cm in snout–vent length, making it a medium-sized amphibian within the Israeli fauna [21].

The genus *Salamandra* (Garsault, 1764) is a terrestrial urodele distributed across Europe, extending to North Africa and the Middle East. Its taxonomy has shifted over time, with current consensus recognizing six species: *S. salamandra, S. infraimmaculata, S. corsica, S. atra, S. lanzai,* and *S. algira*. Distinguishing species and subspecies is often difficult due to broad variation in coloration and spot patterns. In Israel, *S. infraimmaculata* occurs at the southern edge of the genus' range, forming isolated northern populations. These populations show notable morphological, physiological, developmental, and genetic differences, shaped by diverse habitats. *Salamandra infraimmaculata* in Israel occurs in fragmented northern habitats (130 - 1000+ m). Its polymorphic coloration and varied reproduction complicate classification (**Figure 8**) [24] [25]. Genetic studies mostly examined tadpoles; adult samples are few, making morphology-genetics links unclear. Body size differs among populations (e.g., Tel Dan smaller), while color-spot patterns show high variability but no clear regional distinction. Environmental conditions strongly influence morphology and physiology.

Figure 8. Different patterns of spot distribution in the fire salamander (*Salamandra infraimmaculata*) as observed within a single population in northern Israel [25].

Degani *et al.* [26] performed an untargeted metabolomic profiling of skin mucus in the Near Eastern fire salamander (*Salamandra infraimmaculata*) using LC-MS/MS. Mucus samples were obtained from individuals inhabiting three locations at the southern edge of the species' range in Israel: Kibbutz Sasa in the Upper Galilee and Manof in the Lower Galilee—both semi-arid mountainous sites—and the Dan River, characterized by a continuous water supply and stable year-round temperature. In total, 10 metabolites were consistently detected in the mucus of salamanders from all three habitats. These compounds represent diverse chemical classes, and we describe their molecular structures and secretion levels. Salamanders from the Dan River exhibited elevated concentrations in half of these metabolites (5 out of 10) compared with the Sasa and Manof populations. Moreover, six mucus metabolites varied between the two mountainous populations. Overall, the results support the hypothesis that the harsh environmental conditions in the southern distribution range shape both the quantity and chemical composition of salamander mucus secretions. The genus *Salamandra* exhibits considerable coloration diversity and occupies a broad spectrum of habitats. Compared to *S. salamandra* [27], *S. infraimmaculata* displays more limited variation in the distribution of speckles and the arrangement of its black-and-yellow pattern. A study of 25 populations examined color diversity, habitat traits, and food availability among adults [21]. Although specific information on dietary differences of *S. infraimmaculata* across habitats is lacking, the marked contrasts between these environments suggest potential variation in the food resources accessible to the species [2].

8. Marked Color Differences in the Banded Newt (*Ommatotriton vittatus*) across the Life Cycle: Contrasts between Terrestrial and Aquatic Phases and between Sexes

8.1. Introduction

The banded newt (*Ommatotriton vittatus*), belonging to the family Salamandridae, is one of the most characteristic amphibians of the eastern Mediterranean region. Its range extends from southern Türkiye through Syria and Lebanon into northern Israel, where it reaches the southernmost border of its distribution [11] [28]. In Israel, populations are mainly restricted to the Upper Galilee and Golan Heights, areas characterized by relatively high precipitation and the presence of temporary ponds and springs [3]. This narrow distribution illustrates the species' sensitivity to climatic gradients and habitat availability in the southern Levant.

The life cycle of *O. vittatus* in Israel is strongly synchronized with Mediterranean seasonality. Breeding takes place in winter and early spring, when rainfall fills temporary aquatic habitats [3] [4]. During this period, males undergo striking morphological transformations, including the development of a dorsal crest, a tail filament, and bright nuptial coloration that play an important role in sexual signaling and courtship [4] [28]. Females deposit eggs singly on aquatic vegetation, ensuring protection and aeration [3] [29]. Larvae develop in these water bodies and maintain external gills for aquatic respiration until metamorphosis in late spring or early summer. After metamorphosis, juveniles disperse to terrestrial habitats, where they spend the dry summer months in shelters such as crevices, under stones, or in leaf litter [3] [29]. Adults return annually to water bodies for reproduction, demonstrating an alternation between aquatic and terrestrial phases typical of salamandrids.

The habitats of *O. vittatus* in Israel are closely associated with montane and hilly Mediterranean environments. Breeding occurs in small ponds, springs, and slow-flowing streams rich in aquatic vegetation, which provide both oviposition sites and refuge for larvae [3]. Outside the reproductive season, newts occupy moist terrestrial microhabitats in oak woodlands and scrublands, where they remain inactive during the hot and dry summer. However, habitat destruction, anthropogenic water extraction, and climate-driven reductions in pond hydroperiods pose severe threats to the long-term survival of *O. vittatus* in Israel [3].

8.2. Morphology and Coloration of *Ommatotriton vittatus* in Israel (Figure 9)

Figure 9. Morphology and color variation of *Ommatotriton vittatus* in Israel: (A) male in aquatic breeding phase, (B) male in terrestrial phase, (C) female in terrestrial phase Israel [4].

Males (Aquatic Phase):

During the breeding season, males develop distinctive secondary sexual traits. Their body color becomes brighter, showing an olive to greenish-brown back with dark spots and a clear light stripe along the side. The most striking feature is the tall, jagged dorsal crest that runs from the head to the tail, often marked with black. The tail flattens from side to side and shows blue and black bands near the end. These features make males highly visible in water and are important for courtship and mate choice.

Males (Terrestrial Phase):

When the breeding season ends, males lose most of these features. The dorsal crest shrinks, their bright colors fade, and the body takes on a dull brown-gray tone, sometimes with faint stripes. This camouflage helps them hide in dry land habitats such as under rocks, leaf litter, and in cracks during the summer.

Females (Aquatic Phase):

In water, females are less colorful than males. Their bodies are olive-brown with scattered dark spots, and the side stripe is less clear. They do not develop a tall dorsal crest, though a small ridge may appear on the tail. Their shape is more streamlined, which helps with laying eggs and staying hidden rather than attracting mates.

Females (Terrestrial Phase):

On land, females look similar to terrestrial males but are usually a bit larger and more robust. Their colors are mostly earthy browns and grays, with a pale belly. This camouflage helps them blend into their surroundings, such as under wet logs, stones, or soil, where they often stay inactive during the dry season.

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9. Summary of Amphibian Coloration Strategies in Israel

9.1. Introduction

In the Mediterranean region of northern Israel, as well as in the semi-arid Mediterranean foothills and relatively dry habitats, all ecological niches are present. Consequently, the adaptation of coloration strategies in their various forms—such as warning coloration, camouflage with the ability for color change, concealment, and burrowing—exists and enables the survival of all species. Alongside camouflage, there are many other mechanisms that are equally important, including behavioral, physiological, and ecological adaptations. See **Figure 10** [1] [3].

9.2. Description of the Model Linking Amphibian Species and Habitats in Israel

The model presents the geographic distribution of amphibian species in Israel and their ecological connection to regional climate zones and breeding habitats. The central map is divided into three main climatic regions: Mediterranean climate (north and west), semi-arid climate (center and transitional zones), and desert climate (south).

9.3. Species Represented

Salamandra infraimmaculata (Fire Salamander)—distributed mainly in the northern Mediterranean region, particularly associated with permanent streams and shaded aquatic habitats. *Latonia nigriventer* (Hula Painted Frog)—restricted to the Hula Valley in the north, a unique and localized habitat in permanent water bodies. *Pelophylax bedriagae* (Levant Water Frog)—widespread in northern and central aquatic habitats, especially in streams, rivers, and ponds. *Ommatotriton vittatus* (Banded Newt)—confined to northern Israel, occupying winter ponds and temporary pools during the breeding season. *Hyla savignyi* (Savigny's Tree Frog)—present in various Mediterranean and semi-arid habitats, utilizing vegetation around ponds and seasonal water bodies. *Pelobates syriacus* (Eastern Spadefoot Toad)—found mainly in northern and central regions, reproducing in temporary ponds that form during the rainy season. *Pseudepidalea viridis* (Green Toad, Bufotes sitibundus)—widely distributed from Mediterranean to desert zones, highly adaptable to different ecological habitats [1].

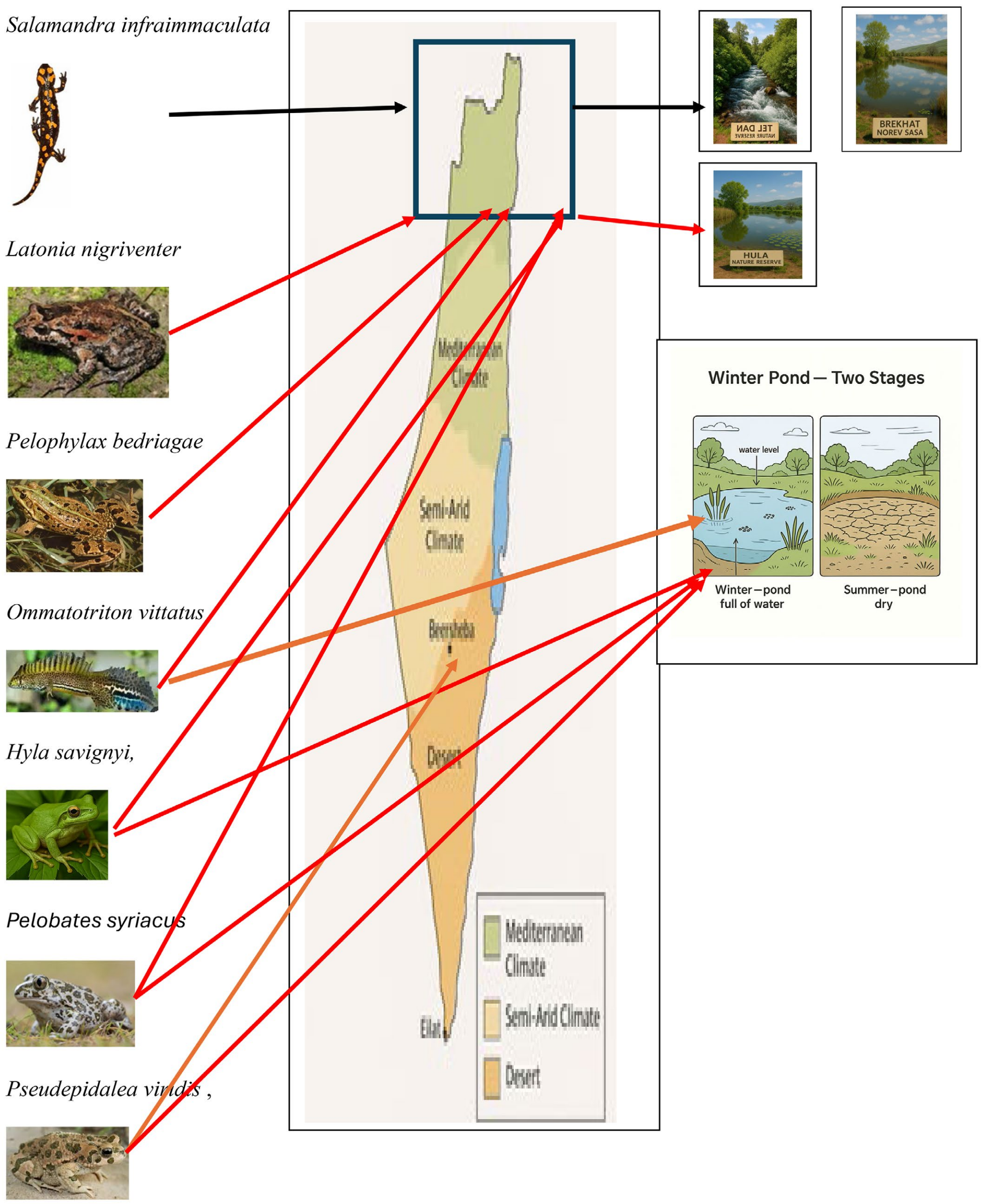

Figure 10. Connections between amphibian species, climatic zones, and habitats in Israel: distribution patterns across diverse regions [1] [3].

9.4. Habitat Representation

On the right side, the model highlights the importance of winter ponds as breeding sites. These are depicted in two stages: Winter stage—ponds are filled with rainwater, providing essential breeding sites for species such as *Ommatotriton vittatus*, *Pelobates syriacus*, and *Hyla savignyi*. Summer stage—ponds dry up, demonstrating the strong seasonal dependency of these species on temporary aquatic habitats.

9.5. Ecological Connection

The arrows linking each amphibian species to specific regions of the map illustrate the spatial distribution of amphibians in relation to climate zones and water availability. Species restricted to the Mediterranean climate (e.g., *Salamandra infraimmaculata*, *Latonia nigriventer*) contrast with widespread and highly adaptable species such as *Pseudepidalea viridis*. This model therefore emphasizes the relationship between species' ecological requirements, breeding habitats (especially temporary ponds), and the climatic gradient of Israel. Description of the Model Linking Amphibian Species and Habitats in Israel [1] [3].

The model presents the geographic distribution of amphibian species in Israel and their ecological connection to regional climate zones and breeding habitats. The central map is divided into three main climatic regions: Mediterranean climate (north and west), semi-arid climate (center and transitional zones), and desert climate (south).

Conflicts of Interest

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

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