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Seasonal Color Plasticity in *Hyla savignyi* as a Potential Adaptation to Mediterranean and Semi-Arid Environments

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Abstract

The Middle East tree frog, *Hyla savignyi*, occupies Mediterranean and semi-arid habitats that change markedly from green during the rainy season to yellow-brown during the dry season. This narrative review evaluates whether seasonal dorsal-color variation may contribute to environmental matching. Evidence was synthesized from field observations in northern Israel, a controlled substrate-use experiment, and comparative studies of physiological color change in amphibians. Field records show green, pale, brown, and dark frogs in seasonally contrasting habitats, whereas experimental observations show nonrandom substrate use and a strong association between frog color and occupied substrate. These findings are consistent with background matching, but they do not establish rapid physiological color change, reduced predator detection, or improved survival. Substrate treatments also differed in vegetation structure and microclimate, preventing color from being isolated as the sole cue. Chromatophore-mediated pigment redistribution provides a plausible reversible mechanism, but this mechanism has not yet been demonstrated directly in H. savignyi. Seasonal color plasticity and microhabitat selection are therefore best regarded as complementary, testable hypotheses for adaptation to Mediterranean seasonality. Controlled experiments using standardized substrates, repeated objective color measurements, and predator-vision models are needed to distinguish color change from background choice and to quantify adaptive value.

Keywords

Hyla savignyi, Phenotypic Plasticity, Background Matching, Chromatophores, Mediterranean Climate, Semi-Arid Habitat, Substrate Selection

1. Introduction

The Middle East tree frog, *Hyla savignyi*, occurs across the eastern Mediterranean and adjacent semi-arid regions, including northern Israel [1] [2]. These landscapes undergo a pronounced annual transition from a cool, rainy, predominantly green winter to a hot, dry summer dominated by yellow, brown, and gray vegetation and exposed substrates (**Figure 1**). Field observations in the Golan Heights, Galilee, and Hula Valley documented frogs with green, white, brown, and black dorsal coloration across ten breeding-site habitats [3].

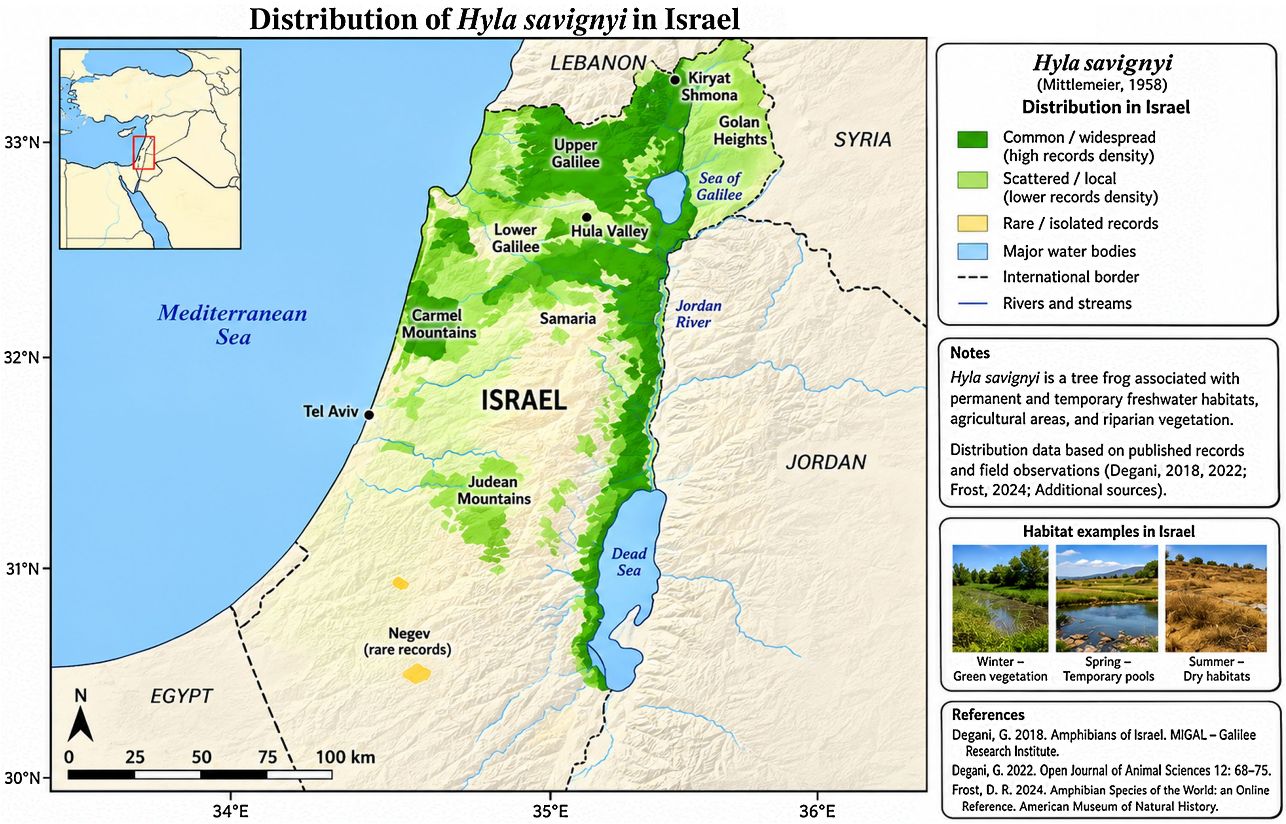

Figure 1. Distribution and representative habitats of *Hyla savignyi* in Israel. The map illustrates the Mediterranean-to-semi-arid environmental gradient considered in this review, based on Degani [1] and Surizon *et al.* [2].

Seasonal environmental change simultaneously alters background color, temperature, humidity, solar radiation, vegetation structure, and water availability (**Figure 2**). Consequently, an observed association between frog color and season cannot by itself identify the causal environmental cue or demonstrate an adaptive outcome.

Color change is an important form of phenotypic plasticity in many ectothermic vertebrates and can contribute to camouflage, thermoregulation, physiological homeostasis, or communication [4]-[6]. In amphibians, reversible physiological color change commonly involves chromatophore activity and intracellular redistribution of pigment-containing organelles [4] [5]. The present review evaluates the evidence that seasonal color variation in H. savignyi reflects background

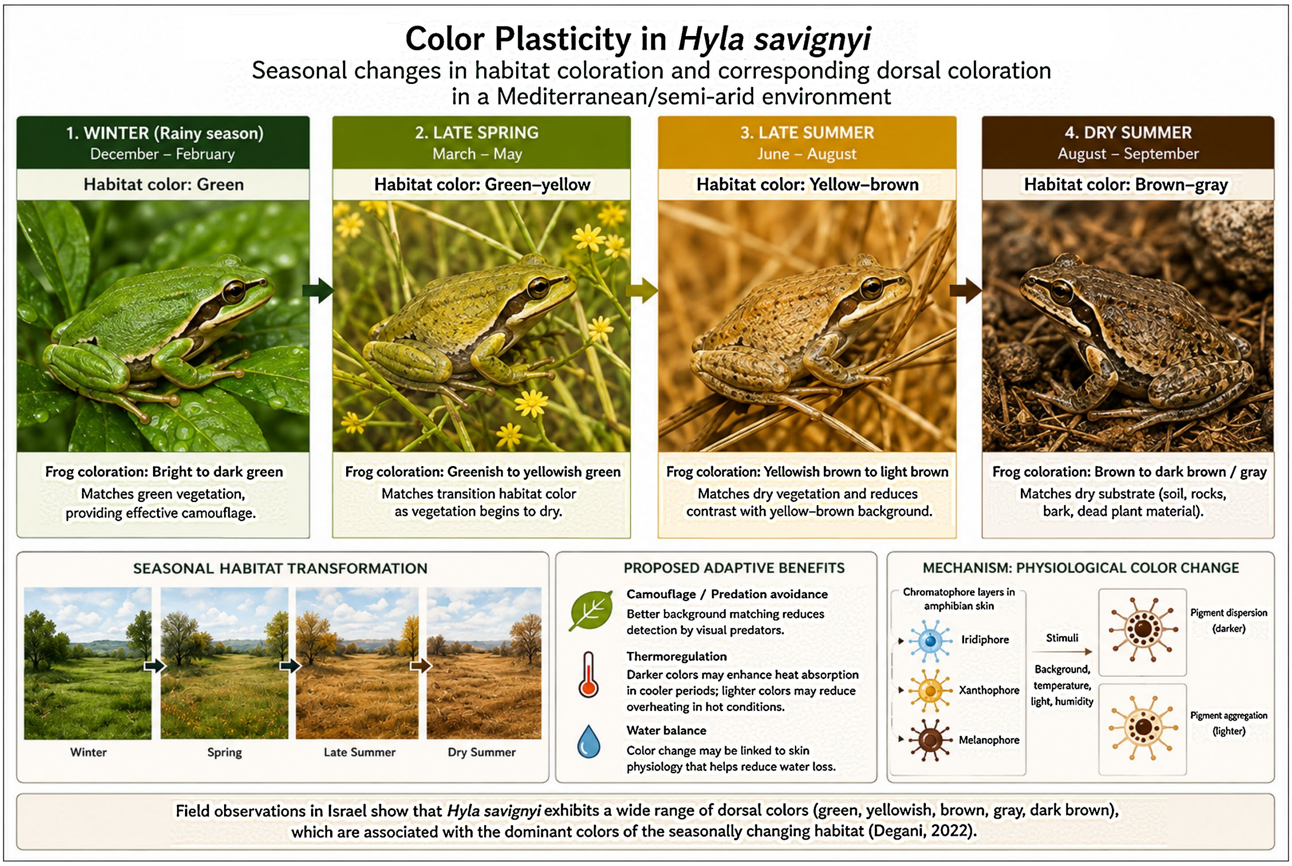

Figure 2. Seasonal changes in habitat color and representative dorsal coloration of *Hyla savignyi* near the southern limit of its distribution.

matching and develops explicit, testable predictions while separating demonstrated associations from proposed mechanisms and adaptive functions.

2. Review Approach

A targeted narrative search was conducted through August 2026 using Google Scholar, PubMed, Crossref, and publisher websites. Search combinations included "*Hyla savignyi* color", "tree frog substrate preference", "amphibian physiological color change", "chromatophore background matching", "Mediterranean seasonality frog coloration", and related terms. Priority was given to studies directly addressing H. savignyi, followed by mechanistic reviews and controlled experiments in other hylid frogs. Evidence was included when it addressed at least one of four questions: seasonal field association, substrate selection, cellular mechanism, or adaptive function. The synthesis distinguishes direct observations in H. savignyi from mechanistic or functional inferences based on other species. Because this is a focused narrative review rather than a systematic review, no meta-analysis was attempted.

3. Seasonal Habitat Change and Field Evidence

During winter, rainfall stimulates herbaceous vegetation and produces predominantly green backgrounds. As rainfall declines during spring, vegetation senesces and shifts through green-yellow to yellow-brown. By late summer, prolonged drought exposes dry vegetation, soil, rocks, bark, and other brown or dark substrates. Thus, a frog remaining within one geographical region encounters very different visual and microclimatic environments over the annual cycle.

Degani [3] surveyed ten localities around water bodies in the Golan Heights, Galilee, and Hula Valley. Frogs and habitats were photographed, and mitochondrial cytochrome-b and one nuclear marker were examined in the associated population analysis. The report documented seasonal and spatial associations between frog coloration and habitat color (Figure 3), but it did not provide a complete count of photographed adult frogs or a standardized, blinded, instrument-based method for classifying color. Its observations should therefore be interpreted as field evidence of association rather than as a quantitative demonstration that individual frogs changed color.

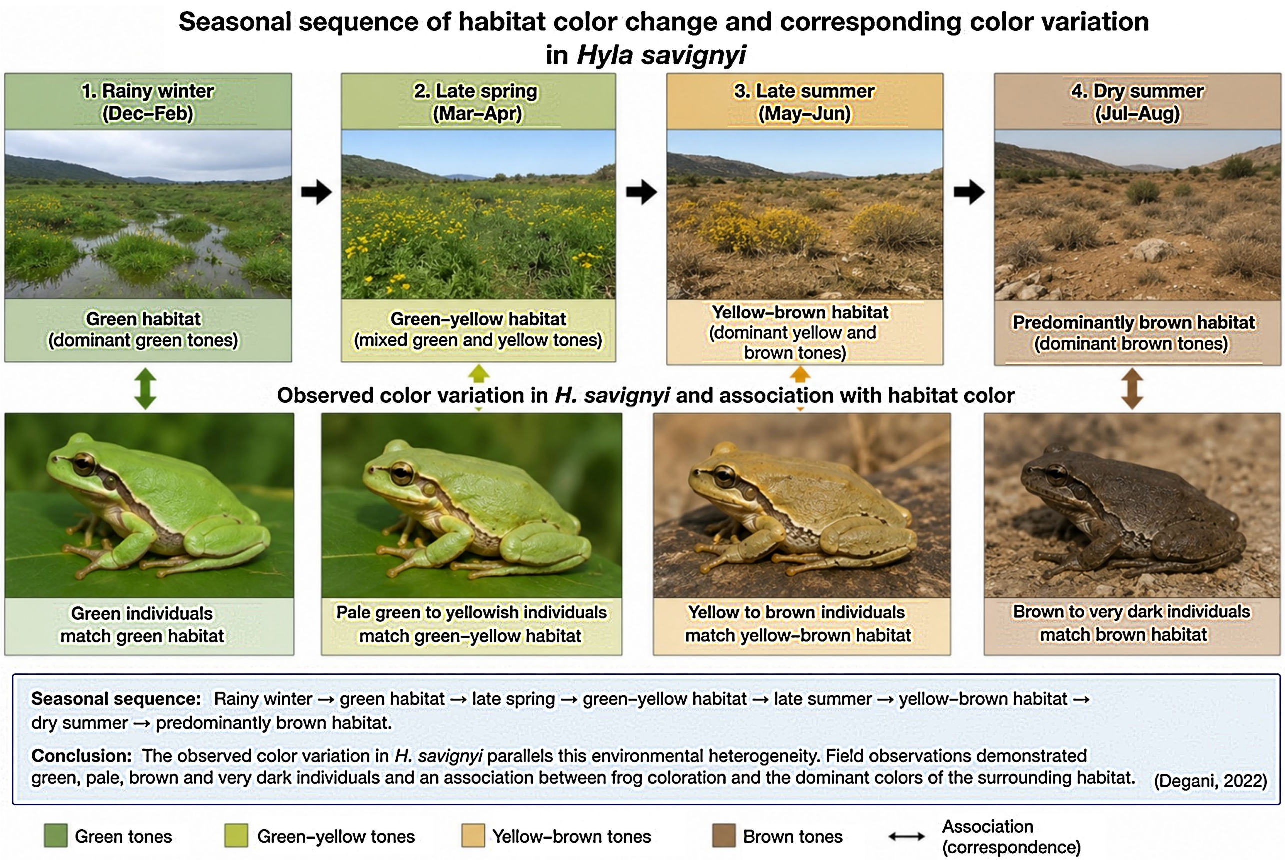

Figure 3. Association between seasonal habitat-color change and dorsal-color variation in *Hyla savignyi* in northern Israel, based on field observations reported by Degani [3].

No examined marker was diagnostic of the observed color phenotypes [3]. This result does not exclude a genetic contribution: a small marker set cannot test genome-wide or regulatory variation, and the field study did not follow identified individuals through color transitions. The evidence instead supports further study of environmental, physiological, and genetic contributions.

4. Physiological Basis of Reversible Color Change

Amphibian skin color is produced by interactions among xanthophores, iridophores, and melanophores organized within the dermal chromatophore unit [7] [8]. Xanthophores contain yellow-orange pigments, iridophores reflect incident light, and melanophores contain melanin. Dispersion or aggregation of pigment organelles changes optical properties without requiring rapid synthesis of new pigment [4] [5]. Environmental cues, including light, background brightness, and temperature, can modulate these responses in some amphibians (**Figure 4**).

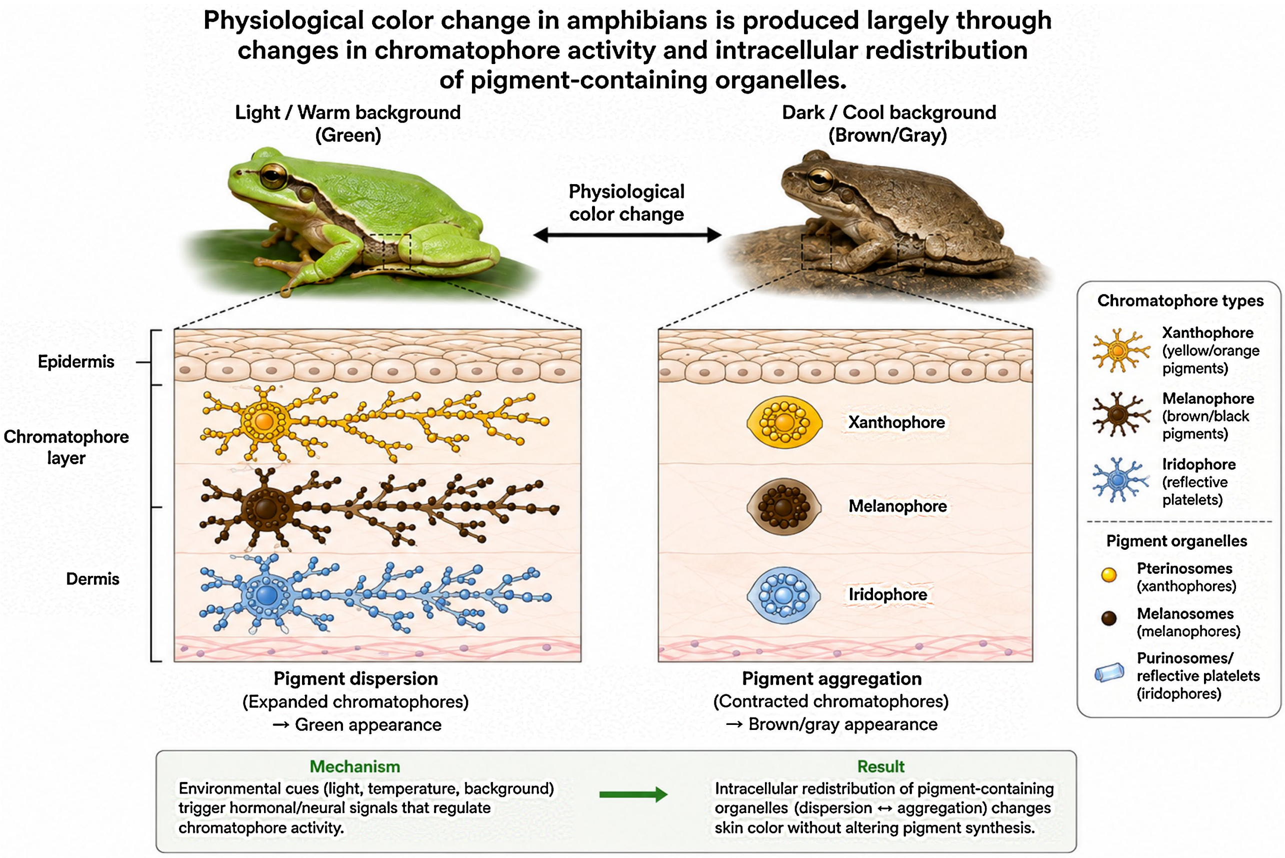

Figure 4. Conceptual cellular mechanism of physiological color change in amphibians. Environmental cues can alter pigment-organelle distribution within xanthophores, iridophores, and melanophores, thereby changing visible skin coloration [4] [5] [7] [8]. This mechanism is plausible for H. savignyi but has not yet been tested directly in the species.

In Hyla cinerea, background brightness and temperature influence physiological color change [9]. However, comparative evidence should not be treated as direct proof for H. savignyi. Species-specific experiments are required to determine response rate, reversibility, sensory cues, endocrine control, and the relative contributions of chromatophore movement and longer-term morphological change.

5. Substrate Use and Color-Background Association

Degani and Biton [10] studied 30 mature H. savignyi collected at Haspin in the southern Golan Heights. Frogs were maintained for approximately five weeks in a 180 × 60 × 60 cm enclosure containing green living vegetation, white stones, brown clay stones, basalt or other dark material, black soil, and a narrow water channel. Locations were recorded twice daily, at 10:00 and 22:00, and the enclosure orientation was changed to reduce directional bias. The published analysis included 1447 observations. The difference between expected equal use and observed substrate use was evaluated using a chi-square test ($P < 0.001$); temporal changes were analyzed by ANOVA, and day-night comparisons by an F-test [10].

The total of 1447 observations is lower than the number of sampling opportunities implied by 30 frogs observed twice daily for approximately five weeks. The original report does not explain the discrepancy, so missing or excluded observations cannot be reconstructed. Moreover, repeated observations of the same frogs were treated as independent in the published tests. This potential pseudoreplication means that the reported P values may overstate precision and should be interpreted cautiously.

Across all observations, approximately 57.36% occurred on green substrate, 31.09% on white, 7.27% on dark or black substrate, and 4.28% on brown substrate [10]. Green-substrate use reportedly increased from about 39% in week 1 to 68% in week 5, while white-substrate use declined from about 43% to 18%. Weekly percentages reproduced in the figure are rounded and do not always sum exactly to 100%; therefore, the original counts—not the displayed percentages—would be required for reanalysis.

Frog color was strongly associated with the substrate occupied: approximately 95% matching for green, approximately 90% for white, 83% for brown, and 82% for black frogs [10] (**Figure 5**). This association is consistent with two nonexclusive processes: frogs may choose backgrounds that already match their coloration, or their coloration may change after they occupy a background. The experimental design did not distinguish these alternatives.

6. Ecological Interpretation and Limitations

Background matching is a plausible explanation for seasonal color-habitat associations because reduced visual contrast can lower detectability in many animals [6]. Green coloration may match living winter and spring vegetation, whereas pale, brown, gray, or dark coloration may match dry vegetation, bark, soil, and stones during summer. Nevertheless, no predator-vision model, detection experiment, predation assay, or survival analysis has yet demonstrated a camouflage benefit for H. savignyi. Adaptive value therefore remains a hypothesis.

Substrate color was also confounded with material, structure, and microclimate in the enclosure experiment. Living vegetation may provide climbing surfaces, concealment, shade, lower temperature, and higher humidity compared with stones or exposed soil. Preference for vegetation cannot consequently be attributed to green color alone. This distinction is particularly important for a small amphibian exposed to dehydration in a Mediterranean summer.

The available evidence supports a cautious integrative model: seasonal climate

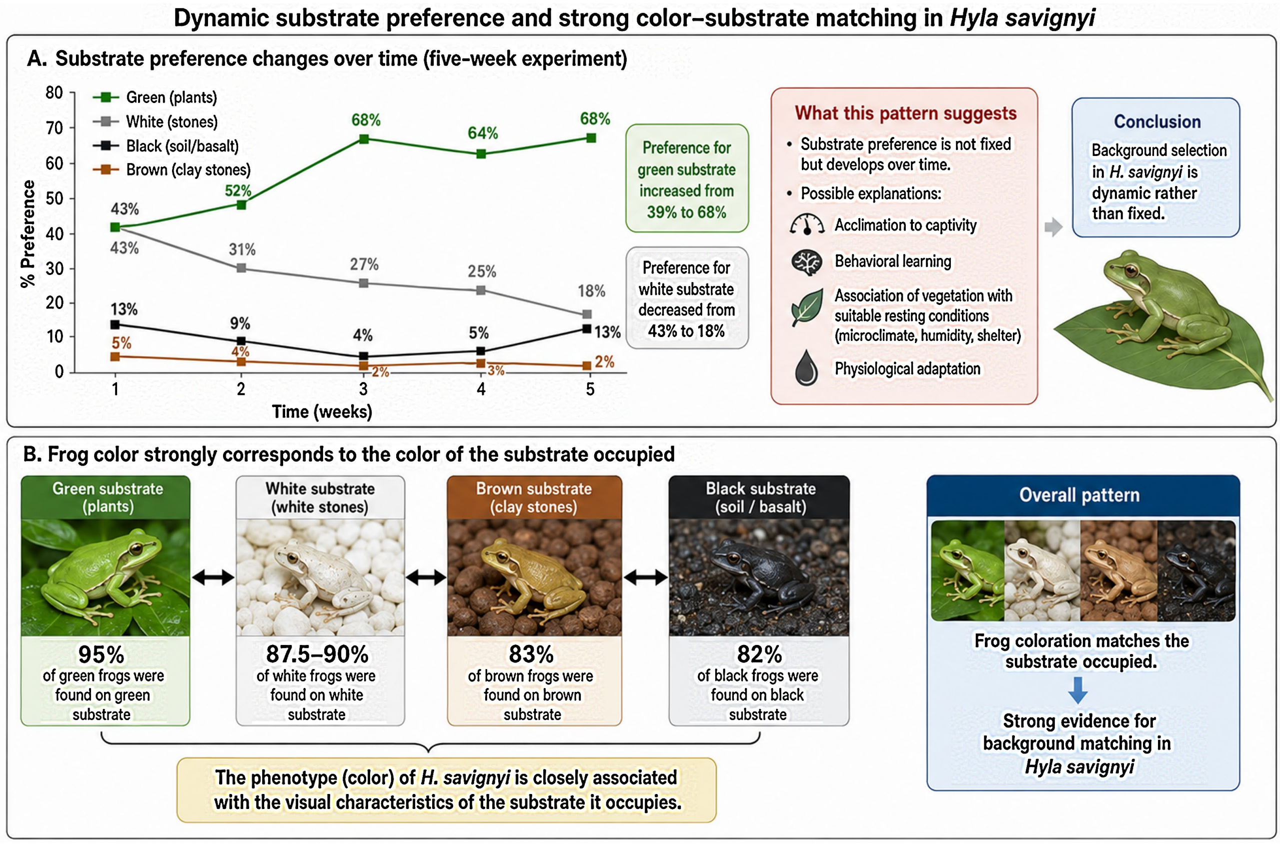

Figure 5. Reported association between *Hyla savignyi* dorsal color and occupied substrate color in the enclosure experiment of Degani and Biton [10]. The association does not, by itself, distinguish background selection from physiological color change.

alters vegetation, substrate color, temperature, humidity, and illumination; frogs may select favorable microhabitats; sensory and neuroendocrine pathways may then regulate chromatophore responses; and the resulting phenotype may reduce contrast with the occupied background. Each link requires separate experimental testing.

7. Research Priorities

Future experiments should use substrates identical in material, temperature, moisture, texture, and structure but differing only in calibrated color. Individually marked frogs should be photographed repeatedly before and after randomized transfers among backgrounds. Reflectance spectrophotometry and standardized illumination should quantify hue, brightness, saturation, response rate, and reversibility. Mixed-effects models should treat frog identity as a repeated-measures factor. Thermal and humidity treatments should be crossed with background color to separate visual from microclimatic cues. Finally, predator-vision modeling or controlled detection trials are needed before camouflage or survival benefits can be claimed. Skin histology, hormone assays, transcriptomics, and genome-wide analyses could then test the cellular and molecular basis of variation.

8. Conclusion

Hyla savignyi displays substantial dorsal-color variation in strongly seasonal Mediterranean and semi-arid environments. Field observations and an enclosure study demonstrate associations among season, occupied substrate, and frog color. These data are consistent with background matching and with a role for reversible color plasticity, but they do not establish individual color transitions, identify the causal cue, or demonstrate reduced predation. Chromatophore-mediated pigment redistribution offers a plausible mechanism based on comparative amphibian research. The most defensible current interpretation is that microhabitat selection and physiological color plasticity are complementary hypotheses whose relative contributions remain unresolved. Standardized repeated-measures experiments can now test these hypotheses directly.

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Conflicts of Interest

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

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