

## Guppies, *Poecilia reticulata* Peters 1859, as a model for sexual trait evolution: Integrating behavioral, genetic, and ecological perspectives

<sup>1</sup>Florin D. Bora, <sup>2</sup>Tudor Papuc, <sup>2</sup>Cristian-Ovidiu Coroian

<sup>1</sup> Viticulture and Oenology Department, Advanced Horticultural Research Institute of Transylvania, Faculty of Horticulture and Business in Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania;

<sup>2</sup> Faculty of Animal Science and Biotechnologies, University of Agricultural Science and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania. Corresponding author: F. Bora, [florin-dumitru.bora@usamvcluj.ro](mailto:florin-dumitru.bora@usamvcluj.ro)

**Abstract.** The guppy (*Poecilia reticulata*) has emerged as a pivotal model for dissecting the evolution of sexual traits due to its marked sexual dimorphism, rapid generation times, and pronounced ecological heterogeneity. Research on this species has revealed how female mate choice, genetic architecture, and environmental pressures interact to shape male ornamentation, courtship behaviors, and reproductive strategies. Studies combining natural variation and experimental manipulation have shown that sexual and natural selection frequently act in opposition, enabling direct quantification of trade-offs between attractiveness and survival. Work on guppies has also illuminated post-copulatory processes, including sperm competition and cryptic female choice, highlighting the multilayered nature of sexual selection. Furthermore, comparisons among ecologically replicated populations demonstrate that predation, resource availability, and social structure consistently drive predictable evolutionary shifts in sexual traits. Collectively, guppy research provides exceptionally detailed empirical evidence for how sexual behaviors and preferences originate, diversify, and respond to ecological change, offering a comprehensive framework for understanding sexual evolution across animal taxa.

**Key words:** ecological variation, evolutionary trade-offs, genetic architecture, guppy, male ornamentation, mate choice, reproductive strategies, sexual selection.

The aim of this work is to provide a concise overview of key findings on guppies that demonstrate why this species has become an exceptional model for investigating how sexual traits originate, diversify, and evolve in vertebrates under varying ecological conditions.

Research on the guppy (*Poecilia reticulata*) has become a cornerstone for understanding sexual behavior and the evolution of sexual traits in animals, largely because this species meets several key criteria rarely found together in a single model system. Guppies show pronounced sexual dimorphism, rapid generation times, strong and measurable sexual selection pressures, and substantial ecological variability across their natural range. These features create a setting in which hypotheses about sexual evolution (often abstract or theoretical in other species) can be directly tested with empirical rigor.

One central contribution of guppy studies lies in clarifying how female choice drives the diversification of male traits (Figure 1) (Petrescu-Mag & Bourne 2008). Male guppies are known for their unusually variable color patterns, ornamentation, and courtship displays (Petrescu & Mag 2006; Petrescu-Mag 2009). These traits are not arbitrary: they evolve under competing selective forces, combining sexual attractiveness with survival constraints (Oroian et al 2019; Petrescu-Mag et al 2019). Females frequently prefer males with more intense coloration or specific patterning, preferences that can generate swift evolutionary responses. At the same time, brightly colored males

experience higher predation risk. Guppies therefore offer a natural experiment where sexual and natural selection act in opposing directions, making it possible to quantify the balance of these pressures (Petrescu-Mag 2023). Many foundational models describing the maintenance of polymorphism, the stability of female preferences, and the emergence of exaggerated sexual traits draw directly from guppy research.

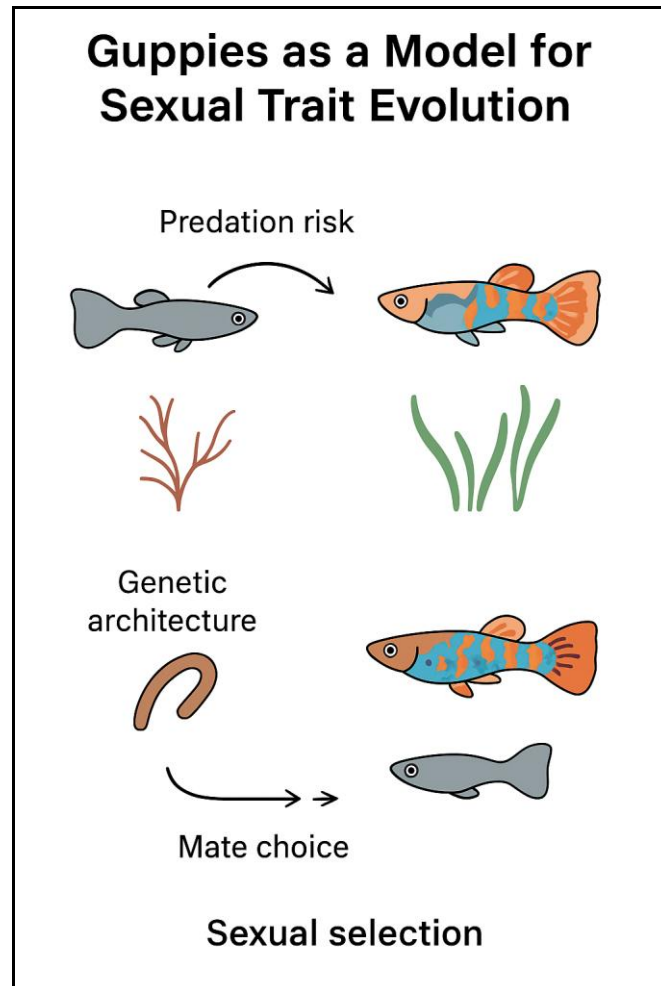


Figure 1. Conceptual diagram generated with OpenAI (2025) (GPT-5.1 with DALL·E), illustrating key mechanisms underlying sexual trait evolution in *Poecilia reticulata*.

Another major insight from this species concerns the genetic architecture of sexually selected traits. Guppy studies have revealed complex polygenic influences on coloration, as well as sex-linked inheritance patterns that promote rapid trait turnover (Sharma et al 2014; Wright et al 2017; Bergero et al 2019; Fraser et al 2020; Van Der Bijl et al 2025). Because guppies can be bred and tracked across multiple generations with relative ease, researchers have demonstrated how sexual traits can shift in real time under experimental manipulation (Kemp et al 2009; Kunstner et al 2016). This has allowed tests of hypotheses that would otherwise remain speculative, such as whether female preferences themselves evolve under predation regimes (Godin & Briggs 1996; Kemp et al 2009; Valvo et al 2019), whether male ornamentation can be constrained by pleiotropy (Rahman et al 2013; Sharma et al 2014; Evans et al 2015), and how environmental heterogeneity maintains sexual diversity within populations (Blows et al 2003; Hughes et al 2013; Evans et al 2015; Valvo et al 2019).

Guppies have also clarified the adaptive nature of mate choice. For a long time, the intuitive assumption was that female preferences for particular male traits must always reflect direct or indirect fitness benefits. Work on guppies has shown that these relationships are not consistently straightforward (Rodd et al 2002; Blows et al 2003;

Hughes et al 2013; Valvo et al 2019). In some cases, female guppies obtain offspring with higher survival or greater mating success when choosing more ornamented males; in others, the benefits appear minimal or context-dependent (Hughes et al 2013; Rahman et al 2013; Evans et al 2015; Valvo et al 2019). This variability has been scientifically valuable because it illustrates that sexual selection does not require consistent advantages to persist; stochastic effects, sensory biases, ecological constraints, and population structure can all modulate the strength and direction of mate choice (Rodd et al 2002; Valvo et al 2019; Gomes-Silva et al 2020; Prazdnikov 2021; Herdegen-Radwan 2022; Earl et al 2024).

Behavioral studies in guppies have further transformed understanding of sexual coercion, sperm competition, and post-copulatory processes. Males employ both courtship and sneaking tactics, creating a natural scenario for studying how alternative mating strategies coexist (Evans et al 2003; Head & Brooks 2006; Evans 2010; Cattelan et al 2016). Female guppies can store sperm from multiple males simultaneously, making it possible to disentangle pre- and post-copulatory components of sexual selection (Devigili et al 2016; Devigili et al 2018; Gasparini et al 2018; Cardozo et al 2020). Research has shown that cryptic female choice, sperm precedence patterns, and differential allocation can influence reproductive success as strongly as visible courtship traits (Evans et al 2003; Devigili et al 2016; Devigili et al 2018; Gasparini et al 2018; Cardozo et al 2020; Morbiato et al 2023). This has provided some of the clearest demonstrations that sexual selection extends far beyond mating encounters and operates at multiple biological levels (Evans et al 2003; Evans 2010; Devigili et al 2016; Devigili et al 2018; Gasparini et al 2018; Cardozo et al 2020; Morbiato et al 2023).

Finally, guppies have proven essential for understanding how ecology shapes the evolution of sexuality. Populations inhabiting different predation environments, resource conditions, or social structures often diverge markedly in their sexual traits (Hendry et al 2006; Kemp et al 2018; Gomes-Silva et al 2020; Yong et al 2021; Rahman et al 2021; Van Der Zee et al 2021). Such ecological replicates, multiple river systems with similar gradients in selection pressures, allow robust comparisons that are rarely possible in other vertebrates (Hendry et al 2006; Kemp et al 2018; Gomes-Silva et al 2020; Yong et al 2021; Van Der Zee et al 2021). The repeated evolution of specific sexual phenotypes in independent guppy populations has offered unusually strong evidence for predictable evolutionary responses, as well as insights into how ecological change can rapidly remodel sexual systems (Hendry et al 2006; Kemp et al 2018; Gomes-Silva et al 2020; Yong et al 2021; Van Der Zee et al 2021).

In sum, the scientific importance of guppy research stems from the species' capacity to reveal the mechanisms by which sexual traits arise, persist, and diversify. Their combination of high variability, tractable genetics, behavioral complexity, and ecologically diverse habitats has made them indispensable for testing theories of sexual selection that apply broadly across the animal kingdom. Through work on *Poecilia reticulata*, the field has gained some of its most precise empirical evidence for how sexual behaviors and preferences evolve, illustrating both their flexibility and their constraints within natural environments.

**Conflict of Interest.** The authors declare that there is no conflict of interest.

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Authors:

Florin Dumitru Bora, Viticulture and Oenology Department, Advanced Horticultural Research Institute of Transylvania, Faculty of Horticulture and Business in Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: florindumitru.bora@usamvcluj.ro

Tudor Păpuc, Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Cluj, Romania, e-mail: tudor.papuc@usamvcluj.ro

Cristian-Ovidiu Coroian, Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Cluj, Romania, e-mail: cristian.coroian@usamvcluj.ro

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