

## Parallel evolution of behavioral, life-history, and sexual traits in guppies, *Poecilia reticulata* Peters 1859, under variable predation regimes

<sup>1</sup> Tudor Păpuc, <sup>2</sup> Maria Popescu, <sup>1</sup> Cristian-Ovidiu Coroian

<sup>1</sup> Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; <sup>2</sup> Equine Clinic, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania. Corresponding author: C.-O. Coroian, [cristian.coroian@usamvcluj.ro](mailto:cristian.coroian@usamvcluj.ro)

**Abstract.** Research on *Poecilia reticulata* has shown that predation intensity functions as a powerful and repeatable driver of evolutionary change across natural populations. Guppies inhabiting high-predation environments consistently evolve cryptic male coloration, accelerated maturation, increased reproductive output with smaller offspring, and more cautious behavioral profiles, reflecting strong survival pressures. In contrast, low-predation populations exhibit pronounced sexual ornamentation, enhanced courtship displays, delayed maturation, larger offspring, and more exploratory behaviors, driven largely by relaxed predation and intensified sexual selection. Intermediate environments typically display mixed phenotypes that underscore the continuous nature of selection gradients. The recurrence of these patterns across independent river drainages provides compelling evidence for parallel evolution and highlights how ecological conditions shape the interplay between natural and sexual selection. This system remains a key model for dissecting the mechanisms through which predators influence behavioral strategies, reproductive investment, and the evolution of sexual traits in vertebrates.

**Key Words:** behavioral ecology, ecological gradients, guppy, life-history evolution, parallel evolution, *Poecilia reticulata*, predation pressure, sexual selection.

The aim of this work is to concisely review key, repeatedly observed shifts in behavior, life-history traits, and sexual characteristics of guppies, *Poecilia reticulata* Peters 1859, across different predation regimes, highlighting why this species has become a powerful model for understanding how ecological pressures drive evolutionary change in vertebrates.

Guppy populations display remarkably consistent evolutionary and behavioral responses to differences in predation pressure, and these patterns have been documented repeatedly in natural “replicate” environments (Mag & Petrescu 2006; Mag et al 2006; Petrescu & Mag 2006; Jacquin et al 2016; Künstner et al 2016; Reznick & Travis 2019) (Figure 1). Because Trinidad’s river systems create upstream refuges with low predation and downstream stretches with high predation, the species offers a natural experiment for observing how selection shapes phenotype, life history, and mating strategies (Reznick et al 2001; Künstner et al 2016; Reznick & Travis 2019).

In high-predation environments, guppies tend to evolve traits that reduce detectability and enhance survival. Males typically show more cryptic coloration, with reduced saturation and smaller or fewer conspicuous spots (Künstner et al 2016; Reznick & Travis 2019; De Waele et al 2025). This shift reflects a strong survival cost of bright ornamentation when visually oriented predators, such as *Crenicichla* or larger characins, are abundant (Künstner et al 2016; Reznick & Travis 2019; De Waele et al 2025). Females in these populations also tend to invest more heavily in early reproduction: they mature sooner, produce more, but smaller offspring per brood, and allocate energy toward rapid life cycles that compensate for elevated extrinsic mortality (Reznick et al

2001; Zandonà et al 2011; Dowdall et al 2012; Auer et al 2018; Reznick & Travis 2019). Behaviorally, individuals from high-predation areas tend to adopt more cautious foraging and schooling patterns, respond more rapidly to alarm cues, and maintain greater vigilance (Seghers 1974; Zandonà et al 2011; Stephenson et al 2015; Burns et al 2016; Jacquin et al 2016; Earl et al 2024; Fox et al 2025).

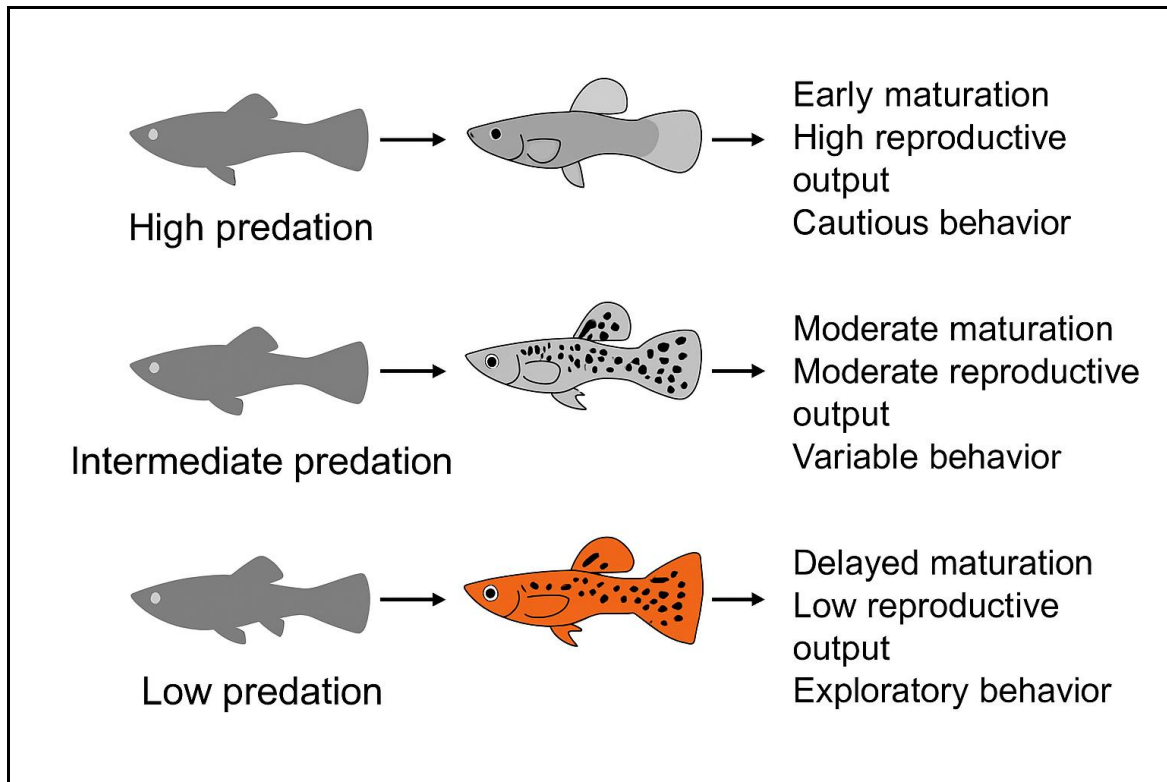


Figure 1. Schematic diagram generated with OpenAI (2025), ChatGPT (DALL·E), illustrating trait variation in guppies under different predation regimes.

In low-predation regions, especially upstream reaches where piscivorous predators are scarce, selective regimes reverse. Males frequently evolve exaggerated, highly variable color patterns because the relaxation of predation allows sexual selection to dominate (Künstner et al 2016; Reznick & Travis 2019; De Waele et al 2025). Female choice operates more strongly, favoring bright, complex ornamentation and more elaborate courtship behaviors, producing some of the most vivid phenotypes in the species (Petrescu-Mag 2008; Petrescu-Mag & Bourne 2008; Künstner et al 2016; Reznick & Travis 2019; De Waele et al 2025). Life-history traits also shift: females mature later, produce fewer, but larger offspring, and invest more resources per reproductive event (Reznick et al 2001; Zandonà et al 2011; Dowdall et al 2012; Auer et al 2018; Reznick & Travis 2019). The overall behavioral profile becomes more exploratory, with reduced wariness and increased foraging in exposed areas (Burns et al 2016; Jacquin et al 2016; Fox et al 2025).

Intermediate predation habitats, where predators are present, but rare or intermittent, often show mixed phenotypes. Here, the trade-off between sexual and natural selection becomes apparent: males may retain moderate ornamentation, and female preferences may vary contextually, reflecting a balance between attraction and survival (Dowdall et al 2012; Jacquin et al 2016; Reznick & Travis 2019; De Waele et al 2025). Such transitional zones provide some of the strongest evidence that guppy traits respond fluidly to quantitative changes in predation risk rather than simply to its presence or absence (Dowdall et al 2012; Jacquin et al 2016; Reznick & Travis 2019).

Because these patterns recur across multiple isolated drainages, they are considered among the clearest demonstrations of parallel evolution in a vertebrate. The

predictability of these shifts reinforces the idea that predation is a dominant, repeatable driver of life-history evolution, morphology, behavior, and sexual trait diversification in *Poecilia reticulata*.

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

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Authors:

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](mailto:tudor.papuc@usamvcluj.ro)

Maria Popescu, Equine Clinic, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: [maria.popescu@usamvcluj.ro](mailto:maria.popescu@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](mailto:cristian.coroian@usamvcluj.ro)

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