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Brazilian Tadpoles: current knowledge and future perspective

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Resumo

Os girinos, a fase larval dos anuros, diferem dos adultos em sua anatomia, fisiologia e ecologia, o que os consolida como um modelo biológico de estudo por si só, existindo pesquisadores dedicados especialmente ao estudo desses semaforontes. Em 2015, a Dra. Denise de Cerqueira Rossa-Feres organizou o primeiro encontro no Brasil dedicado ao tema dos girinos, e desde então alguns outros eventos surgiram com o objetivo de unir pesquisadores para debater e apresentar suas pesquisas sobre esses organismos. Quase 10 anos depois, no workshop "Girinos do Brasil: conhecimento atual e perspectivas futuras", apresentado em 2023 no X Congresso Brasileiro de Herpetologia, atualizamos o estado da arte dos estudos com girinos, especialmente no Brasil. Apresentamos algumas das pesquisas atuais sobre girinos brasileiros, organizadas nos seguintes eixos temáticos: sistemática, anatomia, neurologia, ecotoxicologia, genotoxicidade, ecologia, comportamento e parasitologia. Para cada tópico apresentamos uma breve fundamentação teórica, sintetizamos os principais resultados, as lacunas existentes e sugerimos caminhos para avançar os estudos com girinos no Brasil. Concluímos que os estudos com girinos estão sendo consideravelmente expandidos, com incrementação de conhecimento em áreas consolidadas (como sistemática, anatomia, ecologia, ecotoxicologia, comportamento) e surgimento de áreas novas (parasitologia, neurologia). Esperamos que as pesquisas com girinos no Brasil avancem ainda mais e preencham mais lacunas de conhecimento, tanto nos temas delineados no workshop quanto em outros temas.

Palavras-chave

Conhecimento, Larva de Anuro, Pesquisas.

Abstract

Tadpoles, the larval stage of anurans, are very different from adults in their anatomy, physiology, and ecology, which consolidates them as a biological model of study, with researchers dedicated specifically to the study of these semaphoronts. In 2015, Dr. Denise de Cerqueira Rossa-Feres organized the first meeting in Brazil dedicated to tadpole studies, and since then, several other events have been held with the aim of bringing researchers together to discuss and present their research on these organisms. Almost 10 years later, at the workshop "Tadpoles of Brazil: current knowledge and future perspectives," presented in 2023 at the 10th Brazilian Congress of Herpetology, we updated the state of the art of studies on tadpoles, especially in Brazil. We presented some of the most current research on Brazilian tadpoles, organized in the following thematic axes: systematics, anatomy, neurology, ecotoxicology, genotoxicity, ecology, behavior, and parasitology. For each topic, we present a brief theoretical foundation and summarize the main results, the existing gaps, and suggest ways to advance studies with tadpoles in Brazil. We conclude that the tadpole studies are being considerably expanded, com knowledge increase in established areas (like systematics, anatomy, ecology, ecotoxicology, behavior) and the emergence of new areas (parasitology, neurology). We hope that research with tadpoles in Brazil will advance even further and fill more gaps in knowledge, both on the topics covered in the workshop and on other topics.

Keywords:

Anuran Larvae, Knowledge, Research.

Anurans (frogs and toads) are one of the most intriguing and interesting group of vertebrates due to their biphasic life cycle. Tadpoles, also known as polliwogs, are the (often) aquatic larvae of anurans and are completely different from adults regarding their morphology, ecology, behavior, and physiology (McDiarmid and Altig, 1999; Handrigan and Wassersug, 2007). Natural selection can act decoupled in these distinct semaphoronts, so tadpoles and adults respond to different selective pressures, rendering metamorphosis an adaptive trait of anurans (Wassersug, 1975; Moran, 1994). Available evidence suggests that tadpoles have played an important role in the evolution and diversification of anurans (Altig, 2006). For instance, Roelants et al. (2011) found an expansion of morphospace during larval diversification.

Tadpoles have colonized all freshwater environments worldwide, occupying different ecological niches (Altig and Johnston, 1989; Schiesari et al., 2009; Caut et al., 2013). They are phenotypically and ecologically diverse (e.g., Noble, 1927; Haas, 2003; Dias et al., 2019a; Sabbag et al., 2022; Dias et al., 2024b; Phillips et al., 2024), being, as frequently said by Dr. Richard Wassersug, "the most common amphibian in the planet". Despite their importance in the ecology and evolution of anurans, tadpoles are still poorly studied. This fact is illustrated by the large gaps and shortfalls in our knowledge about them (Altig et al., 2023; Vera Candioti et al., 2023; Nori et al., 2025), and by the fact that novel and astonishing phenotypes are discovered yearly (e.g., Peixoto et al., 2003; Haas et al., 2006; Zachariah et al., 2012; Barej et al., 2015; Gan et al., 2016; Rada et al., 2019; Dias et al., 2021b; Vera Candioti et al., 2021; Dubeux et al., 2023). Brazil is home to the greatest Anura diversity in the world, with 1206 recognized species (Drummond et al., 2026). Worldwide, tadpoles have been described for approximately 41 % of anuran species (Vera Candioti et al., 2023). In Brazil, the last percentage published accounted for around 62 % of tadpoles described (Provete et al., 2012), disregarding those species with direct development. Although many tadpoles have been described since then (e.g., Dias, 2018; Dubeux et al., 2020; Pezzuti et al., 2021; Schiesari et al., 2022; Santos et al., 2023; Menezes et al., 2025), many new species have been described as well, and many of these descriptions did not include the description of their tadpole. Similar argumentation can be made, for example, regarding the ecological aspects of Brazilian tadpoles, since basic information as the type of habitat, use of water column and biological interactions is unknown for most species (Rossa-Feres et al., 2015).

Since 2012, although the knowledge gap has not been bridged, Brazilian researchers showed a growing interest in tadpoles, resulting in the development of multiple research areas, such as systematics, anatomy, neurology, ecotoxicology, ecology, behavior, and parasitology, among others (Pezzuti et al., 2015; Sousa et al., 2015; Costa and Nomura, 2016; Espanha et al., 2016; Carvalho et al., 2018; Eterovick et al., 2018; Gontijo et al., 2018; Annibale et al., 2019; Freitas et al., 2019; Moreira et al., 2019; Annibale et al., 2020; Daam et al., 2020; Eterovick et al., 2020; Freitas et al., 2020; Girotto et al., 2020; Melo et al., 2020; Moutinho et al., 2020; Kloh et al., 2021; Mamede and Nomura, 2021; Martins et al., 2021; Nascimento et al., 2021; Barsoumian et al., 2022; de Souza et al., 2022; Dias et al., 2022; Montesinos et al., 2022; Nascimento et al., 2022; Montesinos et al., 2023; Santos et al., 2023; Rosa et al., 2024). In addition to scientific production, Brazilian institutions hosted important scientific events focused on tadpoles. These include the *"First Tadpoles International Workshop"* (2015), organized by Dr. Denise Rossa-Feres and colleagues and hosted by the Universidade Estadual Paulista (São José do Rio Preto municipality, São Paulo state); the first and second editions of the *"International Symposium on Tadpole Evolution"* (2021; 2024), organized by Dr. Pedro H. S. Dias and colleagues; and, more recently, the workshop *"Girinos do Brasil: conhecimento atual e perspectivas futuras"* (2023) organized by us as part of the "X Congresso Brasileiro de Herpetologia" (Porto Seguro municipality, Bahia state). Both the increase in the number of studies on tadpoles, and the increase in the events organized in Brazil or by Brazilian researchers demonstrate the growing interest in the study of tadpo-

les in the country. These events also bring the types of studies that are currently in vogue, and that may inspire researchers to conduct projects involving these animals.

Taking this advance in consideration, herein we discuss the current knowledge and the perspectives in the study of Brazilian tadpoles, based on presentations during the 2023' Workshop. Our review is divided into sections that cover different aspects of tadpole research. Moreover, we echoed the discussion raised by Rossa-Feres et al. (2015) to evaluate the real progress achieved in the last decade. Finally, the perspectives we bring are in the form of suggested topics and aspects of tadpole biology that should be tackled in the near future.

Tadpole research in Brazil: Where did we come from, and where are we going to?

The first tadpole studies around the world were morphological descriptions or developmental descriptions, dating from the 1500's. In Brazil, the scenery was not different, and the first described tadpole from a Brazilian species and specimen was that of *Batrachychthys* (Pizarro, 1876), currently known as *Pseudis platensis* Gallardo, 1961, described by João Joaquim Pizarro (1842–1906; Caramaschi and Pombal Jr., 2023). Following J. J. Pizarro, other prominent Brazilian researchers also described tadpoles during the first half of the last century, being worth highlighting the descriptive works and the comments on tadpole development carried out by Adolpho Lutz (1855–1940; e.g., Lutz, 1930), Alípio de Miranda-Ribeiro (1874–1939; e.g., Miranda-Ribeiro, 1926), Bertha Lutz (1894–1976; e.g., Lutz, 1947), and Antenor Leitão de Carvalho (1910–1985; e.g., de Carvalho, 1949). In the second half of the last century, research on tadpoles in Brazil began to diversify with the contributions of several researchers who trained many of the scientists currently studying tadpoles in the country. Among them, Luiz Dino Vizotto (1930–2025; e.g., Vizotto, 1973), Werner Carlos Augusto Bokermann (1929–1995; e.g., Bokermann, 1957), Eugênio Izecksohn (1932–2013; e.g., Izecksohn and Jim, 1971), Jorge Jim (1942–2011; e.g., Caramaschi and Jim, 1983), and Adão José Cardoso (1951–1997; e.g., Cardoso and Sazima, 1977).

Tadpoles knowledge often requires a morphological description as a first step. This description may include only the external morphology, although the internal morphology characters provide valuable information (e.g., Wassersug, 1980; Haas, 2003). As it is well known among herpetologists, the Brazilian territory harbors the largest number of amphibian species in the world. As previously mentioned, the most recent Brazilian amphibian species list includes 1206 anuran species (Drummond et al., 2026). Of the approximately 723 extant species in Brazil with tadpoles (putatively, according to the percentage for the world in Nori et al., 2025), ca. 62 % had at least their external morphology described (Rossa-Feres et al., 2015). Extrapolating from the current number of anuran species (1206, Drummond et al., 2026) we can estimate around 448 tadpoles described. If we consider the lack of data on the embryos of direct developers, this proportion reduces drastically.

Much of the recent progress in publications includes technological advances and improved accessibility to this technology. Tadpole research is advancing, with the aid of high-quality microscopes and stereomicroscopes (Pezzuti et al., 2021), electron microscopes (Dias et al., 2022), high technology scanning micro-tomographs (Regnet et al., 2023), synchrotron radiation (Fidalgo et al., 2020), and modern professional filming and photography equipment (Phillips et al., 2020; Phillips et al., 2022). In the case of recordings and photographs, advanced cell phone cameras can also be useful, especially for researchers who can't afford expensive imaging equipment (Annibale et al., 2023).

Nowadays, the biggest challenge to tadpole knowledge is the limited availability of human resources. Despite a growing interest in these animals, the number of researchers dedicated to studying tadpoles is insufficient. Tadpole knowledge in Brazil (as in the whole world) needs to continue advancing, so that we can overcome the known shortfalls in this research field, which encompass internal anatomy, character evolution, diet, trophic ecology, and development (Rossa-Feres et al., 2015; Vera Candioti et al., 2023; Nori et al., 2025).

Tadpoles of Brazil and their contribution to the anuran systematics: A brief review

Larval traits have been crucial in systematics, aiding in species descriptions, identification of cryptic lineages (sometimes indistinguishable in adult form), and in supporting the monophyly of clades (e.g., Araujo-Vieira et al., 2023; Dias et al., 2024b). The taxonomic studies of tadpoles began in the second half of the 19th century, with the characterization of the external morphology of some species (Van Bambeke, 1863). From then on, the observation of differences in the oral disc and the position of the spiracle were useful in the classification of species into morphological groups (Mediogyrinidae and Laevogyrinidae) and in the proposition of identification keys (Lataste, 1879; Boulenger, 1892). In addition to including larval characters in systematics, the 20th century was also marked by evolutionary studies, in which the anatomical form and morphological structures of tadpoles were directly related to the lifestyle and habitat of the species (e.g., Noble, 1926, 1927; Orton, 1953; Sokol, 1975, 1977). Such observations were essential for the species classification into ecomorphological groups or functional guilds, a system originally proposed by Altig and Johnston (1989) and still in use today. During the same period, studies highlighted the importance of tadpoles internal morphology (buccopharyngeal morphology, chondrocranium elements, and hyobranchial apparatus, as well as the associated musculature, among others) to elucidate unresolved taxonomic and phylogenetic questions (e.g., Wassersug, 1980; Maglia et al., 2001; Haas, 2003; Pugener et al., 2003; Vera Candioti, 2007).

External and internal larval characters have been increasingly utilized in phylogenetic and evolutionary studies, both independently and in combination with adult and molecular data (e.g., Grant et al., 2017; Orrico et al., 2021; Araujo-Vieira et al., 2023; Dias et al., 2024b). In Brazil, however, until the end of the 1990's, research on tadpoles had only a descriptive nature. There were several contributions to the description of Brazilian tadpoles, from the characterization of external morphology to internal morphology (e.g., Bokermann, 1965b, a; Cruz, 1982; Hero, 1990; Carvalho-e-Silva and Carvalho-e-Silva, 1994, 1998). Few Brazilian species were included in some of the first cladistic analyses using larval characters (e.g., Haas, 1996; Larson and de Sá, 1998), but taxonomic sampling was far from being representative of taxonomic diversity in Brazil. Despite recent progress (e.g. Colaço et al., 2024; Araújo et al., 2025; Dias et al., 2025; Marcondes et al., 2025), internal morphology remains insufficiently studied in many species groups (e.g., Ferreira et al., 2023; Costa et al., 2024; Dias et al., 2024b; Vera Candioti et al., 2024). However, in the past decades, there has been a notable rise in studies using larval characters in systematic and taxonomic studies (e.g., Grosjean et al., 2015; Dias et al., 2019b; Dias et al., 2020; Dias et al., 2021b; Nascimento et al., 2021; Nascimento et al., 2022; Ferreira et al., 2023; Costa et al., 2024; Dias et al., 2024a). For instance, external and internal oral morphology data bolster the phylogeny of Leiuperinae, with the presence of a dextral ventral tube considered a synapomorphy for the *Edalorhina* + *Engystomops* + *Physalaemus* clade (see Nascimento et al., 2021), while the shape of the median lateral papilla distinguishes *Engystomops* Jiménez de la Espada, 1872 from Physalaemus Fitzinger, 1826, being flap-like in the former and chela-shaped in the latter (see Nascimento et al., 2022).

Additionally, new synapomorphies have been proposed for various species groups based on larval internal oral morphology, including Allophrynidae (Dias et al., 2024a), Centrolenidae (Dias et al., 2020), Cycloramphidae (Dias et al., 2021b), Bufonidae (Dias and Anganoy-Criollo, 2024), Dendrobatidae (Dias et al., 2021a), Leptodactylidae (Nascimento et al., 2021; Nascimento et al., 2022; Ferreira et al., 2023), Pelodryadidae (Dias, 2023), Dendropsophini (Dias et al., 2019c; Dias et al., 2022; Costa et al., 2024; Marcondes et al., 2025), Phyllomedusidae (Dias et al., 2018; Araújo et al., 2025), and Sphaenorhinchini (Dias et al., 2025).

Notwithstanding, despite the increase in studies with tadpoles in Brazil, guided by the growing interest of young herpetologists and the settlement of researchers in different regions of the country, some challenges can be highlighted and grouped into historical, methodolo-

gical, human-resource, and structural issues. Methodological challenges: (i) a limited number of descriptions, especially regarding internal morphology (internal oral cavity, chondrocranium, and musculature); (ii) brief, omissive or incomplete descriptions, lacking details that are important to taxonomy and systematics; (iii) lack of nomenclatural standardization especially for characters of external morphology; (iv) reduced knowledge of intraspecific and ontogenetic variations. Human-resource challenges: (v) the lack of human resources and of researchers specialized in comparative anatomy; (vi) lack of formal training (e.g., graduate level courses dedicated to tadpoles). Structural and historical challenges: (vii) insufficient funding; (viii) the limited representation of tadpoles in scientific collections and the lack of specific curatorial practices for their preservation; (ix) lack of an organized network of collaboration within the Brazilian research groups and with international collaborators.

Tadpole brain: A promising frontier for future research

The general structure and functional organization of the amphibian brain includes several apparently primitive features (e.g., small size) as well as the standard major brain areas and basic connection patterns found in all vertebrates (Wilczynski, 1992). Studies regarding anurans nervous system have increased in the last years, and anurans have played a prominent role as experimental animals in brain research for comparative studies (González et al., 2020). However, most studies have focused on a few anuran species, such as *Xenopus laevis* (Daudin, 1802) and *Rana temporaria* Linnaeus, 1758 (e.g., Eagleson and Harris, 1990; Muñoz et al., 2015).

Among the knowledge gaps discussed during *"First Tadpoles International Workshop"* (2015) the evaluation of the relationship between the anatomical structures of larvae and their respective functions (Rossa-Feres et al., 2015) stands out. When it comes to the nervous system, for example, the information is scarce and fragmented (Quinzio and Fabrezi, 2018) . In tadpoles, most studies involving the brain are largely associated with regeneration (Aztekin et al., 2019), genetics (Ledón-Rettig and Ragsdale, 2021), toxicology (Yost et al., 2016; Rutkoski et al., 2020; McClelland and Woodley, 2022; Spirhanzlova et al., 2023), while ecological studies were restricted to responses to populational density (Gonda et al., 2010), and the carry-over effects of the larval environment on brain size after metamorphosis (Trokovic et al., 2011).

In a seminal contribution, Uray et al. (1987) described changes in the nervous system during amphibian metamorphosis. Lanoo (1999) detailed the organization of the tadpole brain and the organization and function of the spinal cord and discussed how the various sensory systems of tadpoles are related to the nervous system morphology. Moreover, Lanoo (1999) summarized the organization of the tadpole nervous system with a brief consideration of the changes that it undergoes during metamorphosis. Research conducted with species *Rana* Linnaeus, 1758, *Xenopus* Wagler, 1827, *Rhinella* Fitzinger, 1826 (previously as *Bufo*), and *Boana* Gray, 1825 (previously as *Hyla*) genus are, in many cases, the only source of information for tadpole brain anatomy, being a starting point for understanding the brain of tadpoles.

In addition to the scarcity and fragmentation of information about the nervous system, the functional and evolutionary significance of interspecific variation in tadpole brains remains unexplored (Altig and McDiarmid, 1999), probably because the nervous system appears as an invariant anatomical system (see key literature in Quinzio and Fabrezi, 2018). However, the brains of tadpoles differ among species (Lanoo, 1999) and our understanding of the organization and functioning of the nervous system remains limited, particularly regarding how development is integrated with nervous system differentiation and how the nervous system adapts to the demands imposed by different environments (Quinzio and Fabrezi, 2018).

The use of new techniques, such as three-dimensional reconstruction and computed tomography, provides a valuable opportunity to study a broad range of species and individuals (Fidalgo et al., 2020; Ishii et al., 2023). These tools can be applied broadly to answer questions regarding brain variation and evolution. The aforemen-

tioned resources and methodologies not only allow for further investigation of crucial questions about similarities and differences between species but, together with experimental studies, also enable a deeper exploration of how evolutionary variations in the brain are related to behavioral and ecological adaptations, and how this may reflect the evolution of the nervous system.

The use of tadpoles as biological models for addressing ecological questions

The use of tadpoles as model organisms to address ecological questions, employing both experimental and empirical approaches, is almost historical, particularly in the Global North where studies began in the 80's (Wibur, 1987; Petranka, 1989; Kupferberg, 1997; Wilbur, 1997). To study ecological processes, firstly is needed knowing the biology, autecology, and ecological interactions of tadpoles. Unfortunately, these data comprise a knowledge gap in South America, especially in Brazil. Despite significant advances over the past 20 years, several gaps remain in ecological knowledge of tadpoles across different ecological hierarchies (i.e., organismal, population, community, and ecosystem ecology). In 2015, during the *"First International Workshop on Tadpoles"*, seven major knowledge gaps in tadpole ecology were identified as constraining further progress in the field (Rossa-Feres et al., 2015). One of these gaps concerns the recognition of distinct community-structuring processes across locations, biogeographical regions, and spatial scales.

In ecology, spatial scale is associated with the processes that generate and maintain patterns of diversity (Menge and Olson, 1990; Levin, 1992; Rapacciuolo and Blois, 2019). Spatial scales are composed of two components: grain and extent. Grain refers to the sampling unit, that is, the location where the variables are collected, while extent refers to the geographic scope of the study considering all sampling units. In this way, the components of spatial scale (i.e., grain and extent) should be defined according to the ecological phenomenon and the organism in question, but variations in grain size and extent may weaken comparisons across studies (Wiens, 1989). Thus, variation in the spatial patterns observed in various studies concerning the ecological processes and patterns of tadpole communities (e.g., Kopp and Eterovick, 2006; Both et al., 2008; Vasconcelos et al., 2011; Provete et al., 2014) is due, at least partially, to the restrict spatial grain of studies (e.g., usually ponds where tadpoles develop) within different geographic coverage (spatial extent), including different biogeographical regions, hindering the identification of the possible synthetic link connecting community ecology to evolutionary biology and ecosystem processes.

Studies developed in different locations within and among biogeographical regions (e.g., Melchior et al., 2017; Garey et al., 2023) implies variation in several aspects relevant to the biodiversity distribution, such as vegetation, climate, topography, soil, evolutionary history, and species pool. These differences not only affect the biodiversity distribution but also the dynamics of ecosystems including productivity, stability, and nutrient cycling (Tilman et al., 2014; van der Plas, 2019). In this way, the evaluation of the different factors that affect the biodiversity distribution in studies that control or manipulate grain and extent across biogeographical areas provides robust evidence for advancing ecological theory and recognizing the role of scale in these patterns.

One of the results of the *"First International Workshop on Tadpoles"* indicate a way to advance the knowledge of tadpole community ecology by implementing a program to gather data on community-structuring processes across multiple spatial scales, using a standardized sampling protocol developed across different biomes (Rossa-Feres et al., 2015). Data from the "SISBIOTA Tadpoles of Brazil" project, as well as publications using standardized databases, have advanced the understanding of the effects of scale on ecological patterns and processes in anuran communities.

The results from studies developed in Brazil by (Melchior et al., 2017), Pelinson et al. (2022), and Garey et al. (2023) allow us to present the following initial synthesis regarding the role of scale in the structuring of

tadpole communities. In general, spatial scale plays a central role in understanding niche-based and dispersal processes that generate beta diversity patterns (Viana and Chase, 2018). At small spatial scales, spatial processes tend to be weaker than niche processes (e.g., environmental filtering), as dispersal is usually not limited. However, there is significant variability across locations, highlighting the dependence on local context. This results in varied patterns and lower predictability implying that results obtained in one location cannot be generalized to others, even within the same ecoregion. On the other hand, at large spatial scales, the impact of spatial processes increases, along with the influence of broader environmental filters (e.g., climate) on beta diversity. This impact can be spatially structured through environmental variation, while reducing the effect of purely niche-based processes associated with local environmental factors (e.g., structural variables of water bodies). Therefore, at broader scales, patterns are more congruent, even when compared with other taxonomic groups (Cottenie, 2005; Soininen, 2014, 2015), resulting in greater predictability of the processes that generate and maintain diversity patterns. On the other hand, data obtained from studies conducted in small spatial scale are crucial, as it is at the local (i.e., community) scale that interactions occur, regulating species diversity and coexistence at both local and regional levels (Brooker et al., 2009).

Despite recent advances, much work remains to be done in understanding the processes and mechanisms that generate and maintain diversity patterns in tadpole communities. A deeper understanding requires several actions, but we highlight four that seem most beneficial at this time: (i) refining information on dispersal (e.g., obtaining empirical data on the dispersal of individuals from different species), as we use spatial vectors to infer dispersal limitations between communities; (ii) including additional metrics of community structure, as most studies rely on species composition and richness, whereas evaluating other metrics such as functional and phylogenetic diversity will enhance understanding of the role of spatial scales and detecting the processes in diversity patterns; (iii) incorporating interspecific interactions into niche-based processes, as studies often focus only on environmental gradients, neglecting the central role of competition, predation, parasitism, and mutualism; (iv) examining the impacts of metacommunity (i.e., a set of local communities linked by organism dispersal) dynamics on metaecosystems (i.e., a set of local ecosystems connected by spatial flows of energy and materials across their boundaries) as understanding community patterns (i.e., the assessment of local communities without considering the role of dispersal, which may influence the observed patterns) does little to inform ecosystem processes, which are central to maintaining biodiversity and ecosystem services. In conclusion, despite the progress observed in recent years, more efforts should be devoted to understanding not only the processes but also the mechanisms that generate and maintain diversity patterns, to increase our predictive power and support management and conservation actions for amphibian biodiversity.

Diving in water bodies: Knowing anuran tadpoles' behaviors

The behavioral repertoire of tadpoles reflects the challenges they face throughout development (Hoff et al., 1999). During this period, tadpoles encounter multiple pressures, including competition (Smith, 2005), predation (Buskirk and Arioli, 2002), pathogens (Blaustein et al., 2005), water pollution (Relyea et al., 2005), and climatic changes (Kohl and Yahn, 2016). These factors can shape behavior in diverse ways. For instance, *Pseudopaludicola* aff. *falcipes* tadpoles jump out of small puddles and traverse moist soil to escape predation by Odonata naiads (Sousa et al., 2011). This example illustrates how behavioral strategies emerge from the interaction between environmental challenges and developmental processes, resulting in a broad and adaptive repertoire. Given these challenges, empirical studies are particularly needed for Neotropical tadpoles, which remain poorly studied despite their high taxonomic diversity (Rossa-Feres et al., 2015).

In recent years, experimental studies have examined tadpoles from different ecomorphological guilds (benthic, nektonic, and neustonic) across laboratory, mesocosm, and field settings. These studies have focused mainly on defensive behaviors (Lima et al., 2015; Espanha et al., 2016; Eterovick et al., 2018; Gontijo et al., 2018; Eterovick et al., 2020; Melo et al., 2020; Mamede and Nomura, 2021; Martins et al., 2021; Souza et al., 2024; Souza et al., 2025a), foraging behaviors (Sousa et al., 2015; Annibale et al., 2019; Annibale et al., 2020; Kloh et al., 2021), and responses to chemical contaminants (Costa and Nomura, 2016; Amaral et al., 2018; Wrubleswski et al., 2018; Almeida et al., 2019; Silva et al., 2020; Barsoumian et al., 2022). Overall, this growing body of work suggests that Neotropical tadpoles exhibit marked behavioral plasticity, with responses varying according to ecological guild, predator identity, resource availability, and anthropogenic stressors. However, despite recent progress, we are still far from identifying broad behavioral patterns across taxa, as most studies focus on a limited number of species and use distinct methodologies that hinder cross-study comparisons.

The current scenario of behavioral research on Neotropical tadpoles is promising. Many Brazilian researchers are actively addressing gaps highlighted in the *"First Tadpoles International Workshop"* (Rossa-Feres et al., 2015) while contributing to the training of new professionals. Consequently, the community of behavioral researchers is growing, yet numerous questions remain regarding the behavioral ecology of these organisms. For example: (i) Are there differences in feeding kinematics among benthic, nektonic, and neustonic tadpoles? and (ii) What defensive strategies do neustonic tadpoles employ to avoid predators? Addressing these and other questions in the coming decade will be crucial to deepening our understanding of Neotropical tadpoles' natural history.

Assessing genotoxicity and mutagenicity of amphibian species inhabiting the agroecosystem environment

Pesticides are chemical, physical, or biological substances used to control organisms considered harmful in various contexts, such as agricultural pests, etiological agents of diseases in animals, and infestations in urban environments (Mei et al., 2022). These compounds can be classified according to their chemical composition or the target organisms they are designed to combat. Regarding chemical structure, the main groups include organochlorines (e.g., Aldrin), organophosphates (e.g., Glyphosate), carbamates (e.g., Carbofuran), pyrethroids (e.g., Fipronil), triazines (e.g., Atrazine), and triazoles (e.g., Tebuconazole). In terms of biological targets, pesticides are categorized as insecticides, nematicides, fungicides, bactericides, herbicides, and rodenticides (Liang et al., 2022).

One of the most toxic compounds is carbofuran (CB), a carbamate insecticide banned in Brazil in 2022 due to its recognized neurotoxicity in humans. Nevertheless, CB residues are still detected in water bodies within agricultural areas adjacent to forest fragments, posing a relevant risk to non-target fauna, including amphibians (Rocha et al., 2020; Silveira et al., 2023; Virote et al., 2025; Virote, 2025). In this context, the use of biomarkers is essential for ecotoxicological assessment in sentinel organisms. Oxidative stress is one of the earliest cellular responses to toxicity and is associated with increased levels of reactive oxygen species (ROS) and dysregulation of the endogenous antioxidant defense system (Čermak et al., 2018). Genetic biomarkers, such as the comet assay (for genotoxicity) and micronucleus test (for mutagenicity), provide key data on DNA integrity and chromosomal stability (Gonçalves et al., 2019). Histopathological analysis further enables visualization of direct effects on the morphology and function of key tissues such as the liver (Fanali et al., 2021; Lopes et al., 2021).

In Brazil, up until the mid-20th century, agribusiness was primarily concentrated in the Southeast and South regions. The transfer of the capital to Brasília in 1960,

along with government policies that encouraged settlement of the Central-West through low-cost land acquisition, significantly boosted agricultural expansion in that region (Ribeiro et al., 2017). Currently, the Central-West, Southeast, and South regions account for the highest rates of pesticide application and deforestation (Egger et al., 2021).

Among vertebrates, anuran amphibians are among the most affected by anthropogenic pressures, such as climate change, habitat loss, the introduction of invasive species, and environmental contamination by xenobiotics (Falaschi et al., 2019). Moreover, they also are highly vulnerable to environmental changes induced by intensive pesticide use. These features make anurans excellent bioindicators of environmental quality (Pérez-Iglesias et al., 2014). Most species depend on aquatic environments for reproduction and larval development, making them highly sensitive to water contamination.

Even generalist species are affected by pesticides. An example is *Dendropsophus minutus* (Peters, 1872), a generalist species widely distributed across South America and present in all regions of Brazil (Gehara et al., 2014). A recent study conducted in Goiás (Virote, 2025) assessed the acute effects of carbofuran on *Dendropsophus minutus* tadpoles exposed for 96 hours. The results revealed significant biochemical changes, including increased glutathione S-transferase (GST) activity, reduced superoxide dismutase (SOD) and catalase (CAT) activity, and intense lipid peroxidation. Genomic instability was also observed, with increased frequencies of micronuclei and nuclear abnormalities including apoptotic and binucleated cells. Histological analysis revealed notable alterations, including hepatocyte vacuolization, liver fibrosis, and an increased frequency of melanomacrophage centers. Despite the known inhibitory effect of CB on acetylcholinesterase (AChE), no significant alterations in AChE activity were observed in the tadpoles, which may be due to species-specific responses or the concentrations used, since a similar outcome was find to tadpoles of *Rhinella arenarum* (Hensel, 1867) (Peluso et al., 2023).

Taken together, the findings reinforce the high toxicity of carbofuran, even at concentrations close to the Brazilian legal limit for drinking water (7 μg/L). This threshold is considerably higher than the values established by countries such as Australia (0.06 μg/L) and those within the European Union (0.1 μg/L). Given the intense anthropogenic pressure affecting nearly all Brazilian biomes, these findings emphasize the urgent need to revise water quality regulations and strengthen biodiversity conservation strategies. Significant gaps remain in understanding the mutagenic and genotoxic impacts of contaminants on anurans. Future studies should expand contaminant coverage to include fungicides, neonicotinoids, nanopesticides, inert co-formulants, and chronic low-dose residues. Testing mixtures and real formulations rather than single active ingredients will improve ecological relevance. Standardizing comet assay endpoints, adopting automated image analysis, and pairing residue chemistry with biomarker responses are immediate priorities to strengthen causal inference and comparability across studies.

Tadpole ecotoxicology: Current scenario and future perspectives in the context of pesticide contamination

Brazil faces a significant paradox in amphibian conservation, especially considering the known consequences caused by pesticides contamination for Neotropical species. The paradox arises because Brazil is not only the country with the largest number of amphibian species in the world, but it is also one of the world's largest consumers of pesticides. Currently, there is limited knowledge about ecotoxicological effects caused by increased agricultural activity on amphibians in the country, although there are sufficient reasons and an urgent need to produce and make this data available to the scientific community. Therefore, studies that propose integrating the processes related to the Environmental Risk Assessment (ERA) of pesticides on native amphibians are crucial for the conservation of Brazil's rich amphibian diversity.

Environmental pollution resulting from excessive pesticide use has been identified as one of the main cau-

ses of the decline of many amphibian species around the world (Hayes et al., 2010; Sparling et al., 2010; Polo-Cavia et al., 2016). Some of the basic physiological characteristics of these animals, such as low mobility rate and high skin permeability, especially during their larval and aquatic life stages, make amphibians very susceptible to environmental contaminants (Greulich and Pflugmacher, 2003; Yan et al., 2008).

Pesticides act by causing direct effects on mortality or inducing physiological disorders of individuals, such as gonadal malformation, abnormalities, developmental delays, neurotoxicity, behavioral changes, among others (Sparling et al., 2001; Blaustein et al., 2005; McCoy et al., 2008; Freitas et al., 2016; Freitas et al., 2019; Grott et al., 2021; Freitas et al., 2022; Girotto et al., 2023). For example, herbicide bentazone, insecticide and fungicide tebuconazole, isolated or mixed induced oxidative stress in tadpoles of *Boana faber* (Wied-Neuwied, 1821) (Bitschinski et al., 2024), as well as sulfentrazone and clomazone in *Rhinella diptycha* (Cope, 1862) and *Physalaemus nattereri* (Steindachner, 1863) (Freitas et al., 2017a; Freitas et al., 2017b). *Dendropsophus minutus* exposed to 2,4-D showed genotoxic and mutagenic damage, in addition to histological liver alterations, even at the concentrations permitted in drinking water. In a study comparing genotoxicity and mutagenicity data from amphibians inhabiting agricultural and non-agricultural areas, the agroecosystem environment was found to negatively affect individuals of *Dendropsophus minutus, Boana albopunctata* (Spix, 1824), and *Physalaemus cuvieri* Fitzinger, 1826 (Gonçalves et al., 2019). Tadpoles of *Leptodactylus luctator* (Hudson, 1892) and *P. cuvieri* presented oral and intestinal malformations, micronuclei formation, and other erythrocyte nuclearabnormalities after exposure to environmentally relevant concentrations of the insecticide imidaclopride. The active ingredient also impaired swimming activity in *L. luctator*, indicating behavorial toxicity (Samojeden et al., 2022). In general, pesticides induce a wide range of effects in tadpoles, which may vary depending on the active ingredient, species, and study conditions (laboratory or field-based experiments). The problem is that the continuous expansion of agriculture and the consequent conversion of habitats have increasingly brought resident amphibians from open areas into fields within agricultural areas (Freitas et al., 2016; Freitas et al., 2022).

Establishing a comprehensive risk assessment for amphibians is a current challenge because there is a great gap in the environmental concentrations of pesticides that would be safe for native species at a national level. Among other problems involving amphibian ecotoxicology, there is a clear predominance of studies conducted with common species widely distributed in temperate environments (Schiesari et al., 2007; Schiesari and Corrêa, 2016), which are usually more resistant than native species (Freitas et al., 2019). Current legislation also uses the assumption that contaminant concentration limits established for fish must also protect amphibian species. However, there is no evidence that the threshold values established for fish are also safe for amphibians. A recent survey conducted for Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) revealed that approximately 65 % of the active ingredients registered in Brazil still lack data on toxicity to amphibians. Furthermore, the toxicity of pesticides is known for only about 1 % of Brazilian species. Understanding how pesticides affect the physiological mechanisms of amphibians, as well as how environmental factors modulate these processes, is essential for estimating the long-term impacts of environmentally relevant pollutants on biodiversity.

Considering these reasons, the importance of developing specific methodologies for an environmental risk assessment (ERA) of pesticides for amphibians in Brazil was recently highlighted. However, one of the initial difficulties faced by Brazilian environmental legislation is the huge gap regarding the current panorama on the toxicity of widely used pesticides on amphibians, especially considering their aquatic and terrestrial life stages. Thus, the question and challenge that we must face in the coming years is: Are the agricultural technologies currently being used in Brazil really aligned with the protection of Brazilian amphibians?

Trematodes and the parasitism in tadpoles

Helminthological studies related to anurans in Brazil began just over a century ago and focused predominantly on adult forms, particularly gastrointestinal nematodes and trematodes (Travassos, 1920). The parasitic fauna of anurans in Brazil is extensive (Campiao et al., 2014; Fernandes and Kohn, 2014). Approximately 500 trematode species are known in Brazil that parasitize vertebrate hosts, of which 150 species use anurans and reptiles as definitive or intermediate hosts (Fernandes and Kohn, 2014). However, when analyzing the larval stages of anurans, such as tadpoles, parasitological knowledge of this developmental phase remains scarce compared to the number of studies focused on helminths in adult anurans.

Amphibian species that utilize aquatic environments at some stage in their life cycle, whether for reproduction or feeding, are more susceptible to infection by digenetic trematodes, whose larval forms, known as cercariae, infect tadpoles. Aspects of anuran reproduction, as well as tadpole biology, ecology, and habitat, are closely related to the trematode fauna (Esch et al., 2002; Kehr and Hamann, 2003; Bolek et al., 2009; Hamann and Gonzalez, 2009; Hamann et al., 2020; Queiroz et al., 2021). These characteristics make tadpoles a key link between aquatic and terrestrial environments for trematodes, whose presence reveals predator activity and trophic interactions within the ecosystem (Combes et al., 2002; Queiroz et al., 2019).

Recent studies have demonstrated that parasitism, a key ecological interaction, particularly in tadpoles, can trigger both lethal and sublethal effects, directly affecting host development, physiology, and survival. For example, trematode infections may cause severe morphological deformities, including polymelia, limb reduction, and other structural abnormalities that impair locomotion and increase susceptibility to predation (Johnson et al., 2024). Behavioral changes, such as reduced locomotor activity, shifts in microhabitat use, and increased exposure to predators, are also frequently observed in parasitized tadpoles, reflecting parasite manipulation strategies that enhance the transmission success and life cycle completion of helminths (Hernandez-Caballero et al., 2022). Furthermore, physiological alterations and reductions in individual performance, including adverse effects on body condition and a range of stress responses, reinforce that the larval stage represents a critical period for host–parasite interactions and amphibian population dynamics. Infections acquired during this stage may compromise growth, survival, and metamorphic success, ultimately influencing population persistence (Herczeg et al., 2021; Delgado et al., 2026).

Rossa-Feres et al. (2015) emphasized the need for greater scientific effort in research focusing on metazoan parasites associated with tadpoles. A decade after the *"First Tadpoles International Workshop"* (2015), there remains a notable deficiency in studies, scientific publications, and research groups dedicated to this theme. Nevertheless, there has been an increase in undergraduate and graduate research, as well as collaborations among national and international research groups, addressing the biological, ecological, and evolutionary aspects of the host–parasite interactions between digenetic trematodes and tadpoles (Queiroz et al., 2019; Anjos et al., 2021; Queiroz et al., 2021; Rosa et al., 2024). However, these studies are still restricted to a few research groups.

To reduce the existing knowledge gap regarding diversity, interactions, and evolutionary relationships between parasites and their tadpole hosts, it is essential to increase the number of researchers, research groups, and undergraduate and graduate students working in this field. As discussed throughout this article, advancing research and knowledge on the biological, behavioral, ecological, and evolutionary aspects of tadpoles will benefit greatly from enhanced scientific exchange and collaboration among research groups, which offer a viable pathway to advancing studies on metazoan parasites in tadpoles in Brazil.

Toward Standardized Protocols for Research, Conservation, and Ecotoxicology in Neotropical Tadpoles

Although the lack of standard protocols was identified as one of the main gaps during the *"First Tadpoles International Workshop"* (see Rossa-Feres et al., 2015), we still do not have protocols for the maintenance of Neotropical tadpoles in captivity and *ex situ* programs are still few in Brazil (see Jorgewich-Cohen et al., 2019). The lack of standard protocols can hinder the progress in comparative studies on biology, ecology, and behavior of Neotropical tadpoles. Having standardized protocols would allow researchers to conduct more systematic and comparable studies, leading to a better understanding of the ecological patterns and processes and of the needs of species in captivity and in their natural environments. Furthermore, many amphibian species are threatened with extinction, for example due to habitat loss (e.g., Cushman, 2006; Gallant et al., 2007). Having standardized protocols for captive maintenance can be crucial for the conservation of these species, allowing, for example, the creation of captive breeding programs to increase populations and potentially reintroduce them into their natural habitats.

In addition to the lack of protocols for captive maintenance, standardized guidelines for the preservation and curation of tadpoles in biological collections are also largely absent. Because tadpoles possess soft bodies, specimens are particularly prone to degradation in collections when specific curatorial procedures are not applied. The experience accumulated by different researchers indicates that tadpoles should be preserved in buffered 10% formalin, and that the volume of specimens per lot should not exceed one-third of the total volume of preservative. Nevertheless, the original coloration is lost when tadpoles are fixed and preserved in 10 % formalin. To solve this, it is recommended to use a 1:1 solution of 70 % ethanol and 5 % formalin (Souza et al., 2025b), better preserving the coloration and without drying the tadpoles Furthermore, tissue samples should be collected for each lot to enable future DNA-based analyses. Additional techniques for long-term preservation still need to be developed.

Standardized procedures are essential not only for conservation programs of threatened species (Cushman, 2006; Gallant et al., 2007) but also for advancing research in several areas. For example, understanding the mutagenic and genotoxic effects of contaminants on anurans requires expanding contaminant coverage to include fungicides, neonicotinoids, nanopesticides, and inert co-formulants, testing real formulations and mixtures, and standardizing comet assay endpoints with automated image analysis. Integrating residue chemistry with biomarker responses remains an immediate priority to improve causal inference and strengthen environmental risk assessments.

Final comments

It becomes evident that the study of tadpoles in Brazil has evolved significantly, with increase knowledge in established topics (e.g., ecology, morphology, systematics, ecotoxicology, behavior), with thematic expansion (e.g., parasitology, genotoxicity, neurobiolgy), new methodological approaches (e.g., filming equipment, high technology scanning micro-tomographs, synchrotron radiation), and greater integration among research areas. Nevertheless, structural challenges persist, especially the need for standardized protocols (Souza et al., 2025b), the expansion of specialized human resources, and further investigation of aspects of larval biology that remain poorly understood. Moreover, there is an urgent need for compiled and integrated databases of morphology, natural history and taxonomy (Denise C. Rossa-Feres, personal communication). These databases are systematic knowledge storage, and they enable the access to information and the understanding of patterns and processes in many knowledge areas where tadpoles are model organisms (Denise C. Rossa-Feres, personal communication). Thus, the advances observed over the last decade not only reinforce the potential of tadpoles as model systems for investigating various aspects of amphibian biology but also highlight the need for integrative research efforts, which are fundamental for consolidating knowledge and filling existing gaps.

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REFERENCES

Almeida P.R., Rodrigues M.V. & Imperador A.M. 2019. Toxicidade aguda (LC50) e efeitos comportamentais e morfológicos de formulado comercial com princípio ativo glifosato em girinos de *Physalaemus cuvieri* (Anura, Leptodactylidae) e *Rhinella icterica* (Anura, Bufonidae). *Engenharia Sanitaria e Ambiental* 24:1115–1125. doi:10.1590/s1413-41522019166886.

Altig R. 2006. Tadpoles evolved and frogs are the default. *Herpetologica* 62:1–36.

Altig R. & Johnston G.F. 1989. Guilds of anuran larvae: relationships among developmental modes, morphologies, and habitats. *Herpetological Monographs* 3:81–109.

Altig R. & McDiarmid R.W. 1999. Body plan: Development and morphology. Pp. 24–51. in: McDiarmid R.W. &R. Altig (Eds.), Tadpoles: The biology of anuran larvae. University of Chicago Press, Chicago and London.

Altig R., McDiarmid R.W. & Dias P.H.d.S. 2023. Bibliography for the identification, morphology, and development of amphibian gametes and larvae. In: Mueller-Hill H. &J.R. Mendelson III (eds.). Society for the Study of Amphibians and Reptiles, USA.

Amaral D.F.d., Montalvão M.F., Mendes B.d.O., Castro A.L.d.S. & Malafaia G. 2018. Behavioral and mutagenic biomarkers in tadpoles exposed to different abamectin concentrations. *Environmental Science and Pollution Research* 25:12932–12946. doi:10.1007/s11356-018-1562-9.

Anjos C.S.d., Souza F.C.d., Costa G.N., Malta J.C.d.O. & Zuanon J.A.S. 2021. Tadpoles of *Boana geographica* (Spix, 1824) (Anura: Hylidae) parasitised by *Argulus* sp. (Branchiura: Argulidae) in a Central Amazonia forest stream. *Herpetology Notes* 14:335–339.

Annibale F.S., de Sousa V.T.T., de Sousa C.E., Venesky M.D., Rossa-Feres D.C., Nomura F. . . . Wassersug R.J. 2019. Influence of substrate orientation on tadpoles' feeding efficiency. *Biology Open* 8:1–11. doi:10.1242/bio.037598.

Annibale F.S., de Sousa V.T.T., de Sousa C.E., Venesky M.D., Rossa-Feres D.d.C., Wassersug R.J. . . . Nomura F. 2020. Smooth, striated, or rough: how substrate textures affect the feeding performance of tadpoles with different oral morphologies. *Zoomorphology* 139:97–110. doi:10.1007/s00435-019-00469-x.

Annibale F.S., Wassersug R.J., Rossa-Feres D.d.C., Nomura F., Brasileiro C.A., Sabbag A.F. . . . Phillips J.R. 2023. The case for studying tadpole autecology, with comments on strategies to study other small, fast-moving animals in nature. *Austral Ecology* 48:855–876. doi:10.1111/aec.13367.

Araujo-Vieira K., Lourenço A.C.C., Lacerda J.V.A., Lyra M.L., Blotto B.L., Ron S.R. . . . Faivovich J. 2023. Treefrog diversity in the Neotropics: phylogenetic relationships of Scinaxini (Anura: Hylidae: Hylinae). *South American Journal of Herpetology* 27:1–145. doi:10.2994/sajh-d-22-00038.1.

Araújo R.B., Magalhães R.F., Santos D.f., Dubeux M. J.M., Strüssmann C., Lima A.P. . . . Pezzuti T.L. 2025. Ta-

dpole morphology of *Pithecopus* Cope 1866 and a review of larval characters in Phyllomedusinae Günther 1858 (Anura: Hylidae). *Herpetological Monographs* 39:56–99.

Aztekin C., Hiscock T.W., Marioni J.C., Gurdon J.B., Simons B.D. & Jullien J. 2019. Identification of a regeneration-organizing cell in the *Xenopus* tail. *Science* 364:653–658.

Barej M.F., Pfalzgraff T., Hirschfeld M., Liedtke H.C., Penner J., Gonwouo N.L. . . . Rödel M.-O. 2015. The tadpoles of eight West and Central African *Leptopelis* species (Amphibia: Anura: Arthroleptidae). *Amphibian & Reptile Conservation* 9:56–84.

Barsoumian H.A., Martins A.F., Costa J.L. & Schiesari L. 2022. Effects of environmentally relevant concentrations of sertraline on the antipredator behavior of *Scinax fuscovarius* tadpoles. *Research Square*:1–15. doi:10.21203/rs.3.rs-1623314/v1.

Bitschinski D., Warsneski A., Rutkoski C.F., Goncalves G.H.P., Giasson L.O.M., Hasckel R.P. . . . Almeida E.A.d. 2024. Exposure to pesticides used in rice farming (bentazone, chlorantraniliprole and tebuconazole) affects biochemical biomarkers and hepatic histopathological parameters of hammertoad tadpoles (Boana faber). *Comparative Biochemistry and Physiology, Part C* 283:109960. doi:10.1016/j.cbpc.2024.109960.

Blaustein A.R., Romansic J.M., Scheessele E.A., Han B.A., Pessier A.P. & Longcore J.E. 2005. Interspecific variation in susceptibility of frog tadpoles to the pathogenic fungus *Batrachochytrium dendrobatidis*. *Conservation Biology* 19:1460–1468. doi:1010.1111/j.

Bokermann W.C.A. 1957. Notas sôbre a biologia de *Leptodactylus flavopictus* Lutz, 1926. *Revista Brasileira de Biologia* 17:495–500.

Bokermann W.C.A. 1965a. Notas sôbre as espécies de *Thoropa* Fitzinger (Amphibia, Leptodactylidae). *Anais da Academia Brasileira de Ciências* 37:525–537.

Bokermann W.C.A. 1965b. Três novos batráquios da região central de Mato Grosso, Brasil (Amphibia, Salientia). *Revista Brasileira de Biologia* 25.

Bolek M.G., Snyder S.D. & Janovy J., Jr. 2009. Alternative life cycle strategies and colonization of young anurans by *Gorgoderina attenuata* in Nebraska. *Journal of Parasitology* 95:604–616. doi:10.1645/GE-1813.1.

Both C., Solé M., Santos T.G.d. & Cechin S.Z. 2008. The role of spatial and temporal descriptors for neotropical tadpole communities in southern Brazil. *Hydrobiologia* 624:125–138. doi:10.1007/s10750-008-9685-5.

Boulenger G.A. 1892. 7. A synopsis of the tadpoles of the European batrachians. *Proceedings of the Zoological Society of London* 1892:593–627.

Brooker R.W., Callaway R.M., Cavieres L.A., Kikvidze Z., Lortie C.J., Michalet R. . . . Whitham T.G. 2009. Don't diss integration: a comment on Ricklefs's disintegrating communities. *The American Naturalist* 174:919–927. doi:10.1086/648058.

Buskirk J.v. & Arioli M. 2002. Dosage response of an induced defense: How sensitive are tadpoles to predation risk? *Ecology* 83:1580–1585.

Campiao K.M., Morais D.H., Dias O.T., Aguiar A., Toledo Gde M., Tavares L.E. . . . Da Silva R.J. 2014. Checklist of helminth parasites of amphibians from South America. *Zootaxa* 3843:1–93. doi:10.11646/zootaxa.3843.1.1.

Caramaschi U. & Jim J. 1983. Observações sobre hábitos e desenvolvimento dos girinos de *Phyllomedusa vaillanti* Boulenger, 1882 (Amphibia, Anura, Hylidae). *Revista Brasileira de Biologia* 43:261–268.

Caramaschi U. & Pombal Jr. J.P. 2023. João Joaquim Pizarro (1842–1906), the first Brazilian to publish on anuran amphibians. *Bibliotheca Herpetologica* 17:56–66.

Cardoso A.J. & Sazima I. 1977. Batracofagia na fase adulta e larvária da rã pimenta *Leptodactylus labyrinthicus*

(Spix, 1824)–Anura, Leptodactylidae. *Ciência e Cultura* 29:1130–1132.

Carvalho-e-Silva S.P.d. & Carvalho-e-Silva A.M.P.T. 1994. Descrição das larvas de *Ololygon albicans* e de *Ololygon trapicheiroi* com considerações sobre sua biologia (Amphibia, Anura, Hylidae). *Revista Brasileira de Biologia* 54:55–62.

Carvalho-e-Silva S.P.d. & Carvalho-e-Silva A.M.P.T. 1998. Aspects of the biology and description of the larvae of *Scinax argyreornatus* and *Scinax humilis* (Amphibia: Anura: Hylidae). *Revue Française D'Aquariologie Herpetologie* 25:47–52.

Carvalho W.F., Franco F.C., Godoy F.R., Folador D., Avelar J.B., Nomura F. . . . Silva D.d.M.e. 2018. Evaluation of Genotoxic and Mutagenic Effects of Glyphosate Roundup Original® in *Dendropsophus minutus* Peters, 1872 Tadpoles. *South American Journal of Herpetology* 13:220–229. doi:10.2994/sajh-d-17-00016.1.

Caut S., Angulo E., Díaz-Paniagua C. & Gomez-Mestre I. 2013. Plastic changes in tadpole trophic ecology revealed by stable isotope analysis. *Oecologia* 173:95–105. doi:10.1007/s00442-012-2428-3.

Čermak A.M.M., Pavičić I. & Želježić D. 2018. Redox imbalance caused by pesticides: a review of OPENTOX-related research. *Arhiv za higijenu rada i toksikologiju* 69:126–134. doi:10.2478/aiht-2018-69-3105.

Colaço G., Baêta M., Limp G., Batista M.C.S. & da Silva H.R. 2024. Development of buccopharyngeal features in *Thoropa miliaris* (Spix, 1824) tadpoles (Anura: Cycloramphidae): Implications to character coding in systematics studies. *Zoologischer Anzeiger* 312:69–78. doi:10.1016/j.jcz.2024.07.007.

Combes C., Bartolli P. & Théron A. 2002. Trematode transmission strategies. Pp. 1–12. in: Lewis E.E., J.F. Campbell &M.V.K. Sukhdeo (Eds.), The behavioural ecology of parasites. CABI Publishing, Wallingford, U.K.

Costa C.d.A., Santos A.J.d.S., Silva R.d.A., Sena F.P.d., Uchôa L.R. & Andrade E.B.d. 2024. Description of internal oral anatomy and chondrocranium of Dendropsophus soaresi tadpole (Anura: Hylidae) with comments on its external morphology. *South American Journal of Herpetology* 30:52–63. doi:10.2994/sajh-d-21-00038.1.

Costa R.N. & Nomura F. 2016. Measuring the impacts of Roundup Original® on fluctuating asymmetry and mortality in a Neotropical tadpole. *Hydrobiologia* 765:85–96. doi:10.1007/s10750-015-2404-0.

Cottenie K. 2005. Integrating environmental and spatial processes in ecological community dynamics. *Ecology Letters* 8:1175–1182. doi:10.1111/j.1461-0248.2005.00820.x.

Cruz C.A.G. 1982. Conceituação de grupos de espécies de Phyllomedusinae brasileiras com base em caracteres larvários (Amphibia, Anura, Hylidae). *Arquivos da Universidade Federal Rural do Rio de Janeiro* 5.

Cushman S.A. 2006. Effects of habitat loss and fragmentation on amphibians: A review and prospectus. *Biological Conservation* 128:231–240. doi:10.1016/j.biocon.2005.09.031.

Daam M.A., Ilha P. & Schiesari L.C. 2020. Acute toxicity of inorganic nitrogen (ammonium, nitrate and nitrite) to tadpoles of five tropical amphibian species. *Ecotoxicology* 29:1516–1521. doi:10.1007/s10646-020-02247-8.

de Carvalho A.L. 1949. Notas sôbre os hábitos de "*Dendrophryniscus brevipollicatus*" Espada (Amphibia, Anura). *Revista Brasileira de Biologia* 9:223–227.

de Souza Y.C.M.d., Annibale F.S., Carvalheiro L.G., Vasconcelos T.S. & Rossa-Feres D.d.C. 2022. Differential behavioral responses of benthic and nektonic tadpoles to predation at varying water depths. *Canadian Journal of Zoology* 100:526–538. doi:10.1139/cjz-2021-0236.

Delgado M.L.R., Queiroz M.d.S., Pinto H.A., Pezzuti T.L. & Anjos L.A.d. 2026. First record of natural helminth infection in early larval stages of two Anuran species.

Parasitology Research 125:37. doi:10.1007/s00436-026-08649-7.

Dias P.H.d.S. 2018. The Tadpole of Proceratophrys bigibbosa (Peters, 1872) (Anura: Odontophrynidae), with a description of Its buccopharyngeal morphology and proposal of novel synapomorphies for the *P. bigibbosa* species group. *Copeia* 106:86–93. doi:10.1643/ch-17-630.

Dias P.H.d.S. 2023. First description of buccopharyngeal anatomy in Pelodryadinae larvae: morphological comparison and systematic implications (Anura: Hylidae: Pelodryadinae: *Litoria rubella* and *Ranoidea caerulea*). *Journal of Morphology* 284:e21651. doi:10.1002/jmor.21651.

Dias P.H.d.S. & Anganoy-Criollo M. 2024. Harlequin frog tadpoles-comparative buccopharyngeal morphology in the gastromyzophorous tadpoles of the genus *Atelopus* (Amphibia, Anura, Bufonidae), with discussion on the phylogenetic and evolutionary implication of characters. *Naturwissenschaften* 111:3. doi:10.1007/s00114-024-01889-6.

Dias P.H.d.S., Anganoy-Criollo M., Rada M. & Grant T. 2021a. The tadpoles of the funnel-mouthed dendrobatids (Anura: Dendrobatidae: Colostethinae: *Silverstoneia*): external morphology, musculoskeletal anatomy, buccopharyngeal cavity, and new synapomorphies. *Journal of Zoological Systematics and Evolutionary Research* 59:691–717. doi:10.1111/jzs.12455.

Dias P.H.d.S., Araujo-Vieira K., Carvalho-e-Silva A.M.P.T. & Orrico V.G.D. 2019a. Larval anatomy of *Dendropsophus decipiens* (A. Lutz 1925) (Anura: Hylidae: Dendropsophini) with considerations to larvae of this genus. *PLoS One* 14:e0219716. doi:10.1371/journal.pone.0219716.

Dias P.H.d.S., Araujo-Vieira K., Santos R.F. & Both C. 2019b. Review of the internal larval anatomy of the *Proceratophrys bigibbosa* species group (Anura: Odontophrynidae), with description of the tadpole of *P. brauni* Kwet and Faivovich, 2001. *Copeia* 107:417–429. doi:10.1643/ch-18-138.

Dias P.H.d.S., Delia J., Taboada C., Altig R. & Rada M. 2024a. A hundred-year-old mystery-the reproductive mode and larval morphology of the enigmatic frog genus *Allophryne* (Amphibia; Anura; Allophrynidae). *The Science of Nature* 111:21. doi:10.1007/s00114-024-01910-y.

Dias P.H.d.S., Marcondes B.C., Campos Y.P.P., Weber L.N., Mira-Mendes C.V. & Araujo-Vieira K. 2025. Comparative buccopharyngeal morphology of tadpoles of Sphaenorhynchini (Anura: Hylidae: Hylinae). *The Science of Nature* 112:62. doi:10.1007/s00114-025-02009-8.

Dias P.H.d.S., Marcondes B.C., Pezzuti T.L., Vera Candioti M.F., Araujo-Vieira K., Prodocimo M.M. . . . Haas A. 2022. The missing piece of the puzzle: larval morphology of *Xenohyla truncata* (Anura: Hylidae: Dendropsophini) and its implication to the evolution of Dendropsophini tadpoles. *Zoomorphology* 142:111–126. doi:10.1007/s00435-022-00575-3.

Dias P.H.d.S., Mongin-Aquino M., Vera Candioti M.F., Carvalho-e-Silva A.M.P.T.d. & Baêta D. 2018. Internal larval morphology of two species of shining leaf frogs (Anura: Phyllomedusidae: *Phasmahyla*). *South American Journal of Herpetology* 13:44–53. doi:10.2994/sajh-d-16-00055.1.

Dias P.H.d.S., Phillips J.R., Pereyra M.O., Means D.B., Haas A. & Kok P.J.R. 2024b. The remarkable larval morphology of *Rhaebo nasicus* (Werner, 1903) (Amphibia: Anura: Bufonidae) with the erection of a new bufonid genus and insights into the evolution of suctorial tadpoles. *Zoological Letters* 10:17. doi:10.1186/s40851-024-00241-0.

Dias P.H.d.S., Vera Candioti M.F., Sabbag A.F., Colaço G., Silva H.R., Haddad C.F.B. . . . Grant T. 2021b. Life on the edge: tadpoles of Cycloramphidae (Amphibia; Anura), anatomy, systematics, functional morphology, and comments on the evolution of semiterrestrial tadpoles. *Journal of Zoological Systematics and Evolutionary Research* 59:1297–1321. doi:10.1111/jzs.12483.

Dias P.H.S., Anganoy-Criollo M., Rada M. & Grant T. 2020. Comparative larval buccopharyngeal morphology of two glass frog species (Anura: Centrolenidae: *Vitreorana*). *Zoologischer Anzeiger* 289:118–122. doi:10.1016/j.jcz.2020.10.007.

Dias P.H.S., Araujo-Vieira K., Carvalho E.S.A. & Orrico V.G.D. 2019c. Larval anatomy of *Dendropsophus decipiens* (A. Lutz 1925) (Anura: Hylidae: Dendropsophini) with considerations to larvae of this genus. *PLoS One* 14:e0219716. doi:10.1371/journal.pone.0219716.

Drummond L.O., Santana D.J., Lima A.P. & Toledo L.F. 2026. List of Amphibians of Brazil. *Herpetologia Brasileira* 15:1–38. doi:10.5281/zenodo.18340087.

Dubeux M.J.M., Nascimento F.A.C.d. & Dias P.H.d.S. 2023. Larval morphology of *Frostius pernambucensis* (Anura): contribution of larval characters for the systematics of the family Bufonidae and evolution of endotrophic tadpoles. *Zoomorphology* 143:159–187. doi:10.1007/s00435-023-00623-6.

Dubeux M.J.M., Nascimento F.A.C.d., Lima L.R., Magalhães F.d.M., Silva I.R.S.d., Gonçalves U. . . . Mott T. 2020. Morphological characterization and taxonomic key of tadpoles (Amphibia: Anura) from the northern region of the Atlantic Forest. *Biota Neotropica* 20:1–24. doi:10.1590/1676-0611-bn-2018-0718.

Eagleson G.W. & Harris W.A. 1990. Mapping of the presumptive brain regions in the neural plate of *Xenopus laevis*. *Journal of Neurobiology* 21:427–440. doi:10.1002/neu.480210305.

Egger D.d.S., Rigotto R.M., Lima F.A.N.d.S.e., Costa A.M. & Aguiar A.C.P. 2021. Ecocide in the *Cerrados* (Brazilian Savanna): agribusiness, water spoliation and pesticide contamination. *Desenvolvimento e Meio Ambiente* 57:16–54. doi:10.5380/dma.v56i0.7621210.5380/dma.v56i0.76212.e-ISSN.

Esch G.W., Barger M.A. & Fellis K.J. 2002. The transmission of digenetic trematodes: Style, elegance, complexity. *Integrative and Comparative Biology* 42:304–312.

Espanha J., Vasconcelos M.F.d. & Eterovick P.C. 2016. The role of tadpole coloration against visually oriented predators. *Behavioral Ecology and Sociobiology* 70:255–267. doi:10.1007/s00265-015-2044-4.

Eterovick P.C., Kloh J.S., Figueredo C.C., Viana P.I.M., Goulart M., Milan D.T. . . . Vences M. 2020. Background choice and immobility as context dependent tadpole responses to perceived predation risk. *Scientific Reports* 10:13577. doi:10.1038/s41598-020-70274-w.

Eterovick P.C., Mendes I.S., Kloh J.S., Pinheiro L.T., Václav A.B.H.P., Santos T. . . . Gontijo A.S.B. 2018. Tadpoles respond to background colour under threat. *Scientific Reports* 8:4085. doi:10.1038/s41598-018-22315-8.

Falaschi M., Manenti R., Thuiller W. & Ficetola G.F. 2019. Continental-scale determinants of population trends in European amphibians and reptiles. *Global Change Biology* 25:3504–3515.

Fanali L.Z., Freitas J.S., Franco-Belussi L., Taboga S.R. & Oliveira C.d. 2021. Liver description in three neotropical anuran species: from anatomy to ultrastructure. *Acta Zoologica* 103:316–325. doi:10.1111/azo.12373.

Fernandes B.M.M. & Kohn A. 2014. South American trematodes parasites of amphibians and reptiles, p. 228. In: Oficina de Livros, Rio de Janeiro.

Ferreira J.L.P., Costa C.A., Uchôa L.R., Sousa B.S. & Andrade E.B. 2023. Chondrocranium and internal oral anatomy of the tadpole of *Pleurodema diplolister* (Peters, 1870) (Anura: Leptodactylidae). *Zoomorphology*. doi:10.1007/s00435-023-00612-9.

Fidalgo G., Paiva K., Mendes G., Barcellos R., Colaco G., Sena G. . . . Barroso R.C. 2020. Synchrotron microtomography applied to the volumetric analysis of internal structures of *Thoropa miliaris* tadpoles. *Scientific Reports* 10:18934. doi:10.1038/s41598-020-75993-8.

Freitas I., Ursenbacher S., Mebert K., Zinenko O., Schweiger S., Wüster W. . . . Martínez-Freiría F. 2020. Evaluating taxonomic inflation: towards evidence-based species delimitation in Eurasian vipers (Serpentes: Viperinae). *Amphibia-Reptilia* 41:285–311. doi:10.1163/15685381-bja10007.

Freitas J.S., Felício A.A., Teresa F.B. & Almeida E.A.d. 2017a. Combined effects of temperature and clomazone (Gamit®) on oxidative stress responses and B-esterase activity of *Physalaemus nattereri* (Leiuperidae) and *Rhinella schneideri* (Bufonidae) tadpoles. *Chemosphere* 185:548–562. doi:10.1016/j.chemosphere.2017.07.061.

Freitas J.S., Girotto L., Goulart B.V., Alho L.O.G., Gebara R.C., Montagner C.C. . . . Espíndola E.L.G. 2019. Effects of 2,4-D-based herbicide (DMA((R)) 806) on sensitivity, respiration rates, energy reserves and behavior of tadpoles. *Ecotoxicology and Environmental Safety* 182:109446. doi:10.1016/j.ecoenv.2019.109446.

Freitas J.S., Kupsco A., Diamante G., Felicio A.A., Almeida E.A. & Schlenk D. 2016. Influence of temperature on the thyroidogenic effects of diuron and its metabolite 3,4-DCA in tadpoles of the American bullfrog (*Lithobates catesbeianus*). *Environmental Science & Technology* 50:13095–13104. doi:10.1021/acs.est.6b04076.

Freitas J.S., Pinto T.J.d.S., Yoshii M.P.C., Silva L.C.M.d., Lopes L.F.d.P., Ogura A.P. . . . Espíndola E.L.G. 2022. Realistic exposure to fipronil, 2,4-D, vinasse and their mixtures impair larval amphibian physiology. *Environmetal Pollution* 299:118894. doi:10.1016/j.envpol.2022.118894.

Freitas J.S., Teresa F.B. & Almeida E.A.d. 2017b. Influence of temperature on the antioxidant responses and lipid peroxidation of two species of tadpoles (*Rhinella schneideri* and *Physalaemus nattereri*) exposed to the herbicide sulfentrazone (Boral 500SC(R)). *Comparative Biochemistry and Physiology, Part C* 197:32–44. doi:10.1016/j.cbpc.2017.04.005.

Gallant A.L., Klaver R.W., Casper G.S. & Lannoo M.J. 2007. Global rates of habitat loss and implications for amphibian conservation. *Copeia* 2007:967–979. doi:10.1643/0045-8511(2007)7[967:Grohla]2.0.Co;2.

Gan L.L., Hertwig S.T., Das I. & Haas A. 2016. The anatomy and structural connectivity of the abdominal sucker in the tadpoles of *Huia cavitympanum*, with comparisons to *Meristogenys jerboa* (Lissamphibia: Anura: Ranidae). *Journal of Zoological Systematics and Evolutionary Research* 54:46–59. doi:10.1111/jzs.12113.

Garey M.V., Gonçalves-Souza T., Nomura F., Souza F.L., Solé M., Menin M. . . . Rossa-Feres D.d.C. 2023. Explaining the anuran beta diversity by pond-living tadpoles: the role of dispersal limitation and environmental gradients through multiple scales. *Diversity and Distributions* 29:1609–1622. doi:10.1111/ddi.13781.

Gehara M., Crawford A.J., Orrico V.G., Rodriguez A., Lotters S., Fouquet A. . . . Kohler J. 2014. High levels of diversity uncovered in a widespread nominal taxon: continental phylogeography of the neotropical tree frog *Dendropsophus minutus*. *PLoS One* 9:e103958. doi:10.1371/journal.pone.0103958.

Girotto L., Espíndola E.L.G., Gebara R.C. & Freitas J.S. 2020. Acute and chronic effects on tadpoles (*Lithobates catesbeianus*) exposed to mining tailings from the dam rupture in Mariana, MG (Brazil). *Water, Air, & Soil Pollution* 231. doi:10.1007/s11270-020-04691-y.

Girotto L., Freitas I.B.F., Yoshii M.P.C., Goulart B.V., Montagner C.C., Schiesari L.C. . . . Freitas J.S. 2023. Using mesocosms to evaluate the impacts of pasture intensification and pasture-sugarcane conversion on tadpoles in Brazil. *Environmental Science and Pollution Research* 30:21010–21024. doi:10.1007/s11356-022-23691-5.

Gonçalves M.W., de Campos C.B.M., Godoy F.R., Gambale P.G., Nunes H.F., Nomura F. . . . de Melo E.S.D. 2019. Assessing genotoxicity and mutagenicity of three common amphibian species inhabiting agroecosystem environment. *Archives of Environmental Contamination and Toxicology* 77:409–420. doi:10.1007/s00244-019-00647-4.

Gonda A., Trokovic N., Herczeg G., Laurila A. & Merilä J. 2010. Predation- and competition-mediated brain plasticity in *Rana temporaria* tadpoles. *Journal of Evolutionary Biology* 23:2300–2308. doi:10.1111/j.1420-9101.2010.02066.x.

Gontijo A.S.B., Espanha J. & Eterovick P.C. 2018. Is tadpole coloration adaptive against bird predation? *acta ethologica* 21:69–79. doi:10.1007/s10211-018-0285-8.

González A., Lópe J.M., Morona R. & Moreno N. 2020. The organization of the central nervous system of Amphibians. Pp. 125–157. in: Haas J.H. (Ed.). Evolutionary Neuroscience. Academic Press, U.K.

Grant T., Rada M., Anganoy-Criollo M., Batista A., Dias P.H., Jeckel A.M. . . . Rueda-Almonacid J.V. 2017. Phylogenetic systematics of dart-poison frogs and their relatives revisited (Anura: Dendrobatoidea). *South American Journal of Herpetology* 12:S1–S90. doi:10.2994/sajh-d-17-00017.1.

Greulich K. & Pflugmacher S. 2003. Differences in susceptibility of various life stages of amphibians to pesticide exposure. *Aquatic Toxicology* 65:329–336. doi:10.1016/s0166-445x(03)00153-x.

Grosjean S., Bordoloi S., Chuaynkern Y., Chakravarty P. & Ohler A. 2015. When young are more conspicuous than adults: a new ranid species (Anura: Ranidae) revealed by its tadpole. *Zootaxa* 4058:471–498. doi:10.11646/zootaxa.4058.4.2.

Grott S.C., Bitschinski D., Israel N.G., Abel G., da Silva S.P., Alves T.C. . . . de Almeida E.A. 2021. Influence of temperature on biomarker responses and histology of the liver of American bullfrog tadpoles (*Lithobates catesbeianus*, Shaw, 1802) exposed to the herbicide Tebuthiuron. *Science of the Total Environment* 771:144971. doi:10.1016/j.scitotenv.2021.144971.

Haas A. 1996. Das larvale Cranium von *Gastrotheca riobambae* und seine Metamorphose (Amphibia, Anura, Hylidae). *Verhandlungen des Naturwissenschaftlichen Vereins in Hamburg* 36:33–162.

Haas A. 2003. Phylogeny of frogs as inferred from primarily larval characters (Amphibia: Anura). *Cladistics* 19:23–89. doi:10.1016/s0748-3007(03)00006-9.

Haas A., Hertwig S. & Das I. 2006. Extreme tadpoles: the morphology of the fossorial megophryid larva, *Leptobrachella mjobergi*. *Zoology* 109:26–42. doi:10.1016/j.zool.2005.09.008.

Hamann M.I. & Gonzalez C.E. 2009. Larval digenetic trematodes in tadpoles of six amphibian species from northeastern Argentina. *Journal of Parasitology* 95:623–628. doi:10.1645/GE-1738.1.

Hamann M.I., González C.E. & Fernández M.V. 2020. Trematode parasites associated with amphibians from a rice field in the northeastern Argentina. *Food Webs* 22:e00139. doi:10.1016/j.fooweb.2019.e00139.

Handrigan G.R. & Wassersug R.J. 2007. The anuran Bauplan: a review of the adaptive, developmental, and genetic underpinnings of frog and tadpole morphology. *Biology Reviews* 82:1–25. doi:10.1111/j.1469-185X.2006.00001.x.

Hayes T.B., Falso P., Gallipeau S. & Stice M. 2010. The cause of global amphibian declines: a developmental endocrinologist's perspective. *The Journal of Experimental Biology* 213:921–933. doi:10.1242/jeb.040865.

Herczeg D., Ujszegi J., Kasler A., Holly D. & Hettyey A. 2021. Host-multiparasite interactions in amphibians: a review. *Parasites & Vectors* 14:296. doi:10.1186/s13071-021-04796-1.

Hernandez-Caballero I., Garcia-Longoria L., Gomez-Mestre I. & Marzal A. 2022. The Adaptive Host Manipulation Hypothesis: Parasites modify the behaviour, morphology, and physiology of Amphibians. *Diversity* 14:739. doi:10.3390/d14090739.

Hero J.-M. 1990. An illustrated key to tadpoles occurring in the Central Amazon rainforest, Manaus, Amazonas, Brasil. *Amazoniana* XI:201–262.

Hoff K.v., Blaustein A.R., McDiarmid R.W. & Altig R. 1999. Behavior: Interactions and Their Consequences. Pp. 215–239. in: McDiarmid R.W. &R. Altig (Eds.), Tadpoles: The biology of anuran larvae. The University of Chicago Press, Chicago and London.

Ishii R., Yoshida M., Suzuki N., Ogino H. & Suzuki M. 2023. X-ray micro-computed tomography of *Xenopus* tadpole reveals changes in brain ventricular morphology during telencephalon regeneration. *Development, Growth & Differentiation* 65:300–310.

Izecksohn E. & Jim J. 1971. Observações sôbre o desenvolvimento e os hábitos de *Myersiella subnigra* (Miranda-Ribeiro) (Amphibia, Anura, Microhylidae). *Arquivos do Museu Nacional* LIV:69–73.

Jorgewich-Cohen G., Dias P.H.d.S. & Targino M. 2019. Relatos sobre a conservação *ex-situ* de anfíbios no Equador: como as experiências do Centro Jambatu e da Balsa de los Sapos podem ser aplicadas no Brasil. *Herpetologia Brasileira* 8:56–75.

Kehr A.I. & Hamann M.I. 2003. Ecological aspects of parasitism in the tadpole of *Pseudis paradoxa* from Argentina. *Herpetological Review* 34:336–341.

Kloh J.S., Figueredo C.C. & Eterovick P.C. 2021. Tadpole dance: the gymnastics of *Ololygon machadoi* larvae to feed on pollen. *Salamandra* 57:89–95.

Kohl K.D. & Yahn J. 2016. Effects of environmental temperature on the gut microbial communities of tadpoles. *Environmental Microbiology* 18:1561–1565. doi:10.1111/1462-2920.13255.

Kopp K. & Eterovick P.C. 2006. Factors influencing spatial and temporal structure of frog assemblages at ponds in southeastern Brazil. *Journal of Natural History* 40:1813–1830. doi:10.1080/00222930601017403.

Kupferberg S.J. 1997. The role of larval diet in anuran metamorphosis. *American Zoologist* 37:149–159.

Lanoo M.J. 1999. Integration nervous and sensory systems. Pp. 149–169. in: McDiarmid R.W. &R. Altig (Eds.), Tadpoles: The biology of anuran larvae. University of Chicago Press, Chicago and London.

Larson P.M. & de Sá R.O. 1998. Chondrocranial morphology of *Leptodactylidae* larvae (Leptodactylidae: Leptodactylinae): Its utility in phylogenetic reconstruction. *Journal of Morphology* 238:287–305.

Lataste M.F. 1879. Étude sur le Discoglosse. *Acta Societé Linnean Bordeaux* 33:275–341.

Ledón-Rettig C.C. & Ragsdale E.J. 2021. Physiological mechanisms and the evolution of plasticity. Pp. 113–137. in: Pfennig D.W. (Ed.). Phenotypic Plasticity & Evolution. CRC Press, Boca Raton.

Levin S.A. 1992. The problem of pattern and scale in ecology: The Robert H. MacArthur Award Lecture. *Ecology* 73:1943–1967. doi:10.2307/1941447.

Liang Z., Abdelshafy A.M., Luo Z., Belwal T., Lin X., Xu Y. . . . Li L. 2022. Occurrence, detection, and dissipation of pesticide residue in plant-derived foodstuff: A state-of-the-art review. *Food Chemistry* 384:132494. doi:10.1016/j.foodchem.2022.132494.

Lima R.C.L., Dias J.E.M., Lima N.G.S., Torres P.F. & Eterovick P.C. 2015. Escape response of tadpoles of two species of *Bokermannohyla* (Anura, Hylidae) to simulated threat. *Journal of Herpetology* 49:176–183. doi:10.1670/12-225.

Lopes A., Benvindo-Souza M., Carvalho W.F., Nunes H.F., de Lima P.N., Costa M.S. . . . Melo e Silva D.d. 2021. Evaluation of the genotoxic, mutagenic, and histopathological hepatic effects of polyoxyethylene amine (POEA) and glyphosate on *Dendropsophus minutus* tadpoles. *Environmental Pollution* 289:117911. doi:10.1016/j.envpol.2021.117911.

Lutz A. 1930. Observações sobre batrachios brasileiros: taxonomia e biologia das Elosiinas. *Memórias do Instituto Oswaldo Cruz* XXIV:195–222.

Lutz B. 1947. Trends towards non-aquatic and direct development in frogs. *Copeia* 1947:242–252.

Maglia A.M., Pugener L.A. & Trueb L. 2001. Comparative development of anurans: using phylogeny to understand ontogeny. *American Zoologist* 41:538–551.

Mamede J.d.L. & Nomura F. 2021. *Dendropsophus minutus* (Hylidae) tadpole evaluation of predation risk by fishing spiders (*Thaumasia* sp.: Pisauridae) is modulated by size and social environment. *Journal of Ethology* 39:217–223. doi:10.1007/s10164-021-00696-0.

Marcondes B.C., Dias P.H.S., Araujo R.B., de Lima G.C.F., Cuervo-Santos C., Oswald C.B. . . . Pezzuti T.L. 2025. Suction feeding in *Dendropsophus cerradensis* tadpoles: new behavioral observations and morphological traits in a member of the *D. microcephalus* group (Anura, Hylidae). *Journal of Morphology* 286:e70050. doi:10.1002/jmor.70050.

Martins Í.M., Vasconcellos A.d.S., Mota T. & Eterovick P.C. 2021. Detectability is in the eye of the beholder—the role of UV reflectance on tadpole detection and predation by a passerine bird. *Behavioral Ecology and Sociobiology* 75:54. doi:10.1007/s00265-021-02983-9.

McClelland S.J. & Woodley S.K. 2022. Developmental exposure to trace concentrations of chlorpyrifos results in nonmonotonic changes in brain shape and behavior in amphibians. *Environmental Science & Technology* 56:9379–9386. doi:10.1021/acs.est.2c01039.

McCoy K.A., Bortnick L.J., Campbell C.M., Hamlin H.J., Guillette L.J. & St. Mary C.M. 2008. Agriculture alters gonadal form and function in the toad *Bufo marinus*. *Environmental Health Perspectives* 116:1526–1532. doi:10.1289/ehp.11536.

McDiarmid R.W. & Altig R. 1999. Tadpoles: the biology of anuran larvae. The University of Chicago Press, Chicago and London.

Mei L.C., Chen H.M., Dong A.Y., Huang G.Y., Liu Y.W., Zhang X. . . . Yang G.F. 2022. Pesticide Informatics Platform (PIP): An International Platform for Pesticide Discovery, Residue, and Risk Evaluation. *Journal of Agricultural and Food Chemistry* 70:6617–6623. doi:10.1021/acs.jafc.2c02141.

Melchior L.G., Rossa-Feres D.C. & Silva F.R.d. 2017. Evaluating multiple spatial scales to understand the distribution of anuran beta diversity in the Brazilian Atlantic Forest. *Ecology and Evolution* 7:2403–2413. doi:10.1002/ece3.2852.

Melo G.R., Solé M. & Eterovick P.C. 2020. Invisible or fearless: tadpole response to predator cues depends on color. *Ethology, Ecology & Evolution* 33:99–107. doi:10.1080/03949370.2020.1830859.

Menezes L.B.C., Severgnini M.R., Pezzuti T.L., Garey M.V. & Provete D.B. 2025. The tadpole of *Chiasmocleis altomontan*a (Anura: Microhylidae). *PeerJ* 13:e19220. doi:10.7717/peerj.19220.

Menge B.A. & Olson A.M. 1990. Role of scale and environmental factors in regulation of community structure. *TREE* 5:52–57.

Miranda-Ribeiro A. 1926. Notas para servirem ao estudo dos Gymnobatrachios (Anura) brasileiros. *Arquivos do Museu Nacional* XXVII:1–227.

Montesinos R., Carvalho A.L.G., da Silva H.R., Anganoy-Criollo M. & Dias P.H.d.S. 2022. The tadpole of *Hylodes perere* Silva & Benmaman 2008 (Anura, Hylodidae). *Zootaxa* 5219:388–396.

Montesinos R., Carvalho A.L.G. & Dias P.H.D.S. 2023. The tadpole of *Hylodes amnicola* Pombal, Feio & Haddad 2002 (Anura: Hylodidae): External morphology and buccopharyngeal anatomy. *Zootaxa* 5380:395–400. doi:10.11646/zootaxa.5380.4.8.

Moran N.A. 1994. Adaptation and constraint in the complex life cycles of animals. *Annual Review of Ecology and Systematics* 25:573–600.

Moreira R.A., Freitas J.S., Pinto T.J.d.S., Schiesari L.C., Daam M.A., Montagner C.C. . . . Espíndola E.L.G. 2019. Mortality, spatial avoidance and swimming behavior of bullfrog tadpoles (*Lithobates catesbeianus*) exposed to the herbicide diuron. *Water, Air, & Soil Pollution* 230:125. doi:10.1007/s11270-019-4168-z.

Moutinho M.F., Almeida E.A.d., Espíndola E.L.G., Daam M.A. & Schiesari L. 2020. Herbicides employed in sugarcane plantations have lethal and sublethal effects to larval *Boana pardalis* (Amphibia, Hylidae). *Ecotoxicology* 29:1043–1051. doi:10.1007/s10646-020-02226-z.

Muñoz R., Edwards-Faret G., Moreno M., Zuñiga N., Cline H. & Larraín J. 2015. Regeneration of *Xenopus laevis* spinal cord requires Sox2/3 expressing cells. *Developmental Biology* 408:229–243. doi:10.1016/j.ydbio.2015.03.009.

Nascimento F.A.C.d., de Sá R.O. & Garcia P.C.d.A. 2021. Tadpole of the Amazonia frog *Edalorhina perezi* (Anura: Leptodactylidae) with description of oral internal and chondrocranial morphology. *Journal of Morphology* 282:115–126. doi:10.1002/jmor.21286.

Nascimento F.A.C.d., de Sá R.O. & Garcia P.C.d.A. 2022. Larval morphology of Amazonia foam-nesting frogs of the genus *Engystomops* (Anura: Leptodactylidae: Leiuperinae). *Journal of Morphology* 283:1299–1317. doi:10.1002/jmor.21503.

Noble G.K. 1926. The importance of larval characters in the classification of South African Salientia. *American Museum Novitates* 237:1–10.

Noble G.K. 1927. The value of life history data in the study of the evolution of the Amphibia. *Annals of the New York Academy of Sciences* 30:31–128.

Nori J., Baldo D., Pereyra M., Grosjean S., Dias P.H.d.S., Müller H. . . . Vera Candioti M.F. 2025. Global key areas for anuran tadpole discovery. *Biological Journal of the Linnean Society* 145:blaf017. doi:10.1093/biolinnean/blaf017.

Orrico V.G.D., Grant T., Faivovich J., Rivera-Correa M., Rada M.A., Lyra M.L. . . . Haddad C.F.B. 2021. The phylogeny of Dendropsophini (Anura: Hylidae: Hylinae). *Cladistics* 37:73–105.

Orton G.L. 1953. The systematics of vertebrate larvae. *Systematic Zoology* 2:63–75.

Peixoto O.L., Caramaschi U. & Freire E.M.X. 2003. Two new species of *Phyllodytes* (Anura: Hylidae) from the state of Alagoas, Northeastern Brazil. *Herpetologica* 59:235–246. doi:10.1655/0018-0831(2003)059[0235:Tnsopa]2.0.Co;2.

Pelinson R.M., Rossa-Feres D.d.C. & Garey M.V. 2022. Disentangling the multiple drivers of tadpole metacommunity structure in different ecoregions and multiple spatial scales. *Hydrobiologia* 849:4185–4202. doi:10.1007/s10750-022-04967-w.

Peluso J., Aronzon C.M., Chehda A.M., Boccioni A.P.C., Peltzer P.M., Gonzalez F. . . . Lajmanovich R.C. 2023. Water and sediment quality of an agro-industrial area through different approaches: Physicochemical parameters and ecotoxicity with amphibians. *Water Environment Research* 95:e10899.

Pérez-Iglesias J.M., Ruiz de Arcaute C., Nikoloff N., Dury L., Soloneski S., Natale G.S. . . . Larramendy M.L. 2014. The genotoxic effects of the imidacloprid-based insecticide formulation Glacoxan Imida on Montevideo tree frog *Hypsiboas pulchellus* tadpoles (Anura, Hylidae). *Ecotoxicology and Environmental Safety* 104:120–126. doi:10.1016/j.ecoenv.2014.03.002.

Petranka J.W. 1989. Chemical interference competition in tadpoles: Does it occur outside laboratory aquaria? *Copeia* 1989:921–930.

Pezzuti T.L., Leite F.S.F., Rossa-Feres D.d.C. & Garcia P.C.A. 2021. The tadpoles of the Iron Quadrangle, Southeastern Brazil: a baseline for larval knowledge and anuran conservation in a diverse and threatened region. *South American Journal of Herpetology* 22:107. doi:10.2994/sajh-d-20-00042.1.

Pezzuti T.L., Santos M.T.T., Martins S.V., Leite F.S.F., Garcia P.C.A. & Faivovich J. 2015. The tadpoles of two species of the *Bokermannohyla circumdata* group (Hylidae, Cophomantini). *Zootaxa* 4048:151–173.

Phillips J.R., Hewes A.E. & Schwenk K. 2020. The mechanics of air breathing in gray tree frog tadpoles, *Hyla versicolor* (Anura: Hylidae). *Journal of Experimental Biology* 223:jeb219311. doi:10.1242/jeb.219311.

Phillips J.R., Hewes A.E., Womack M.C. & Schwenk K. 2022. The mechanics of air breathing in African clawed frog tadpoles, *Xenopus laevis* (Anura: Pipidae). *Journal of Experimental Biology* 225:jeb243102. doi:10.1242/jeb.243102.

Phillips J.R., Nicolau G.K., Ngwenya S.S., Jackson E.A. & Womack M.C. 2024. Habitat and respiratory strategy effects on hypoxia performance in anuran tadpoles. *Integrative and Comparative Biology* 64:336–353. doi:10.1093/icb/icae017.

Pizarro J.J. 1876. Nota descriptiva de um pequeno animal extremamente curioso e denominado *Batrachychthis*. *Arquivos do Museu Nacional* 1:31–35.

Polo-Cavia N., Burraco P. & Gomez-Mestre I. 2016. Low levels of chemical anthropogenic pollution may threaten amphibians by impairing predator recognition. *Aquatic Toxicology* 172:30–35. doi:10.1016/j.aquatox.2015.12.019.

Provete D.B., Franco-Belussi L., De Souza Santos L.R., Zieri R., Moresco R.M., Martins I.A. . . . de Oliveira C. 2012. Phylogenetic signal and variation of visceral pigmentation in eight anuran families. *Zoologica Scripta* 41:547–556. doi:10.1111/j.1463-6409.2012.00559.x.

Provete D.B., Gonçalves-Souza T., Garey M.V., Martins I.A. & Rossa-Feres D.d.C. 2014. Broad-scale spatial patterns of canopy cover and pond morphology affect the structure of a Neotropical amphibian metacommunity. *Hydrobiologia* 734:69–79. doi:10.1007/s10750-014-1870-0.

Pugener L.A., Maglia A.M. & Trueb L. 2003. Revisiting the contribution of larval characters to an analysis of phylogenetic relationships of basal anurans. *Zoological Journal of the Linnean Society* 139:129–155.

Queiroz M.S., Alves P.V., López-Hernández D., Anjos L.A. & Pinto H.A. 2021. Exploring Neotropical anuran parasites: a morphological, life cycle and phylogenetic study of *Catadiscus marinholutzi* (Trematoda: Diplodiscidae). *Parasitology* 148:798–808. doi:10.1017/S0031182021000330.

Queiroz M.S., López-Hernández D., Locke S.A., Pinto H.A. & Anjos L.A. 2019. Metacercariae of *Heterodiplostomum lanceolatum* (Trematoda: Proterodiplostomidae) found in *Leptodactylus podicipinus* (Anura: Leptodactylidae) from Brazil: a morphological, molecular and ecological study. *Journal of Helminthology* 94:e66. doi:10.1017/S0022149X19000646.

Quinzio S.I. & Fabrezi M. 2018. The peripheral nerves of *Lepidobatrachus* tadpoles (Anura, Ceratophryidae). *Journal of Morphology* 280:4–19.

Rada M., Dias P.H.d.S., Perez-Gonzalez J.L., Anganoy-Criollo M., Rueda-Solano L.A., Pinto E.M. . . . Grant T. 2019. The poverty of adult morphology: Bioacoustics, genetics, and internal tadpole morphology reveal a new species of glassfrog (Anura: Centrolenidae: *Ikakogi*) from the Sierra Nevada de Santa Marta, Colombia. *PLoS One* 14:e0215349. doi:10.1371/journal.pone.0215349.

Rapacciuolo G. & Blois J.L. 2019. Understanding ecological change across large spatial, temporal and taxonomic scales: integrating data and methods in light of theory. *Ecography* 42:1247–1351.

Regnet R.A., Lukas P., Rödder D., Wipfler B. & Solé M. 2023. Tadpole morphological characterization of *Ranitomeya variabilis* (Zimmermann & Zimmermann, 1988) (Anura: Dendrobatidae), with skeleton, muscle system and inner organs. *Zoomorphology* 142:477–486. doi:10.1007/s00435-023-00620-9.

Relyea R.A., Schoeppner N.M. & Hoverman J.T. 2005. Pesticides and amphibians: the importane of community context. *Ecological Applications* 15:1125–1134.

Ribeiro J., Colli G.R. & Soares A.M.V.M. 2017. The anurofauna of a vanishing savanna: the case of the Brazilian Cerrado. *Biodiversity and Conservation* 29:1993–2015. doi:10.1007/s10531-017-1468-8.

Rocha M.C.d., Santos M.B.d., Zanella R., Prestes O.D., Gonçalves A.S. & Schuch A.P. 2020. Preserved riparian forest protects endangered forest-specialists amphibian species against the genotoxic impact of sunlight and agrochemicals. *Biological Conservation* 249. doi:10.1016/j.biocon.2020.108746.

Roelants K., Haas A. & Bossuyt F. 2011. Anuran radiations and the evolution of tadpole morphospace. *Proceedings of the National Academy of Sciences* 108:8731–8736. doi:10.1073/pnas.1100633108.

Rosa P.M., Queiroz M.d.S., Pelinson R.M., Anjos L.A. & Rossa-Feres D.d.C. 2024. Parasite-Driven host manipulation: The case of trematodes in Neotropical tadpoles. *International Journal for Parasitology: Parasites and Wildlife* 25:101023. doi:10.1016/j.ijppaw.2024.101023.

Rossa-Feres D.d.C., Venesky M., Nomura F., Eterovick P.C., Vera Candioti M.F., Menin M. . . . Wassersug R. 2015. Taking tadpole biology into the 21st century: a consensus paper from the First Tadpoles International Workshop. *Herpetologia Brasileira* 4:48–59.

Rutkoski C.F., Macagnan N., Folador A., Skovronski V.J., do Amaral A.M.B., Leitemperger J. . . . Hartmann M.T. 2020. Morphological and biochemical traits and mortality in *Physalaemus gracilis* (Anura: Leptodactylidae) tadpoles exposed to the insecticide chlorpyrifos. *Chemosphere* 250:126162. doi:10.1016/j.chemosphere.2020.126162.

Sabbag A.F., Dias P.H.d.S., Brasileiro C.A., Haddad C. F.B. & Wassersug R.J. 2022. Moving forwards, sideways and up in the air: observations on the locomotion of semiterrestrial tadpoles (Cycloramphidae). *Biological Journal of the Linnean Society* 136:92–110.

Samojeden C.G., Pavan F.A., Rutkoski C.F., Folador A., da Fre S.P., Muller C. . . . Hartmann M. 2022. Toxicity and genotoxicity of imidacloprid in the tadpoles of *Leptodactylus luctator* and *Physalaemus cuvieri* (Anura: Leptodactylidae). *Scientific Reports* 12:11926. doi:10.1038/s41598-022-16039-z.

Santos D.L., Feio R.N. & Nomura F. 2023. Morphological characterization and taxonomic key for tadpoles of Brazilian Cerrado. *Biota Neotropica* 23:e20231486. doi:10.1590/1676-0611-bn-2023-1486.

Schiesari L., Grillitsch B. & Grillitsch H. 2007. Biogeographic biases in research and their consequences for linking amphibian declines to pollution. *Conservation Biology* 21:465–471. doi:10.1111/j.1523-1739.2006.00616.x.

Schiesari L., Rossa-Feres D.C., Menin M. & Hodl W. 2022. Tadpoles of Central Amazonia (Amphibia: Anura). *Zootaxa* 5223:1–149. doi:10.11646/zootaxa.5223.1.1.

Schiesari L., Werner E.E. & Kling G.W. 2009. Carnivory and resource-based niche differentiation in anuran larvae: implications for food web and experimental ecology. *Freshwater Biology* 54:572–586. doi:10.1111/j.1365-2427.2008.02134.x.

Schiesari L.C. & Corrêa D.T. 2016. Consequences of agroindustrial sugarcane production to freshwater biodiversity. *GCB Bioenergy* 8:644–657. doi:10.1111/gcbb.12279.

Silva M.B.D., Fraga R.E., Silva F.L., Oliveira L.A.A.D., Queiroz T.S.D., Rocha M.A. . . . Juncá F.A. 2020. Effects of acute exposure of chlorpyrifos on the survival, morphology and swimming ability of *Odontophrynus carvalhoi* tadpoles. *Ecotoxicology and Environmental Contamination* 15:37–42. doi:10.5132/eec.2020.01.05.

Silveira P., Iop S., Santos J.S.d., Lima E.L., Martello F., Ribeiro M.C. . . . Collevatti R.G. 2023. Amount and isolation of aquatic habitat drive anuran diversity in agricultural landscapes in the Brazilian Cerrado. *Landscape Ecology* 38:2261–2275. doi:10.1007/s10980-023-01693-z.

Smith K.G. 2005. Effects of nonindigenous tadpoles on native tadpoles in Florida: evidence of competition. *Biological Conservation* 123:433–441. doi:10.1016/j.biocon.2005.01.005.

Soininen J. 2014. A quantitative analysis of species sorting across organisms and ecosystems. *Ecology* 95:3284–3292.

Soininen J. 2015. Spatial structure in ecological communities–a quantitative analysis. *Oikos* 125:160–166.

Sokol O.M. 1975. The phylogeny of anuran larvae: A new look. *Copeia* 1975:1–23.

Sokol O.M. 1977. A subordinal classification of frogs (Amphibia: Anura). *Journal of Zoology* 182:505–508. doi:10.1111/j.1469-7998.1977.tb04166.x.

Sousa V.T.d., Nomura F., Rossa-Feres D.d.C., Andrade G.V., Pezzuti T.L., Wassersug R.J. . . . Venesky M.D. 2015. Differential effects of temperature on the feeding kinematics of the tadpoles of two sympatric anuran species. *Journal of Experimental Zoology, Part A: Ecological, genetics and physiology* 323:456–465. doi:10.1002/jez.1941.

Sousa V.T.T.d., Teresa F.B. & Rossa-Feres D.d.C. 2011. Predation risk and jumping behavior in *Pseudopaludicola* aff. *falcipes* tadpoles. *Behavioral Ecology* 22:940–946. doi:10.1093/beheco/arr072.

Souza Y.C.M.d., Annibale F.S., Nomura F. & Rossa-Feres D.C. 2025a. Investigating the behavioral responses of nektonic and benthic tadpoles elicited by the presence of a predatory nektonic fish. *Journal of Zoology* 326:268–276. doi:10.1111/jzo.70020.

Souza Y.C.M.d., Annibale F.S., Pelinson R.M. & Rossa-Feres D.d.C. 2024. Behavioral responses of benthic and nektonic tadpoles to the presence of a benthic predator. *Hydrobiologia* 851:4955–4964. doi:10.1007/s10750-024-05652-w.

Souza Y.C.M.d., Nomura F., Becker C.G., Freitas J.S., Eterovick P.C., Costa R.N. . . . Rossa-Feres D.C. 2025b. Diretrizes para estudos experimentais com girinos. *Herpetologia Brasileira* 14:5–18. doi:10.5281/zenodo.17367039.

Sparling D.W., Fellers G.M. & McConnell L.L. 2001. Pesticides and amphibian population declines in California, USA. *Environmental Toxicology and Chemistry* 20:1591–1595.

Sparling D.W., Linder G., Bishop C.A. & Krest S. 2010. Ecotoxicology of Amphibians and Reptiles. CRC Press, Boca Raton.

Spirhanzlova P., Couderq S., Le Mével S., Leemans M., Krief S., Mughal B.B. . . . Fini J.-B. 2023. Short- and long-term effects of chlorpyrifos on thyroid hormone axis and brain development in *Xenopus laevis*. *Neuroendocrinology* 113:1298–1311.

Tilman D., Isbell F. & Cowles J.M. 2014. Biodiversity and ecosystem functioning. *Annual Review of Ecology, Evolution, and Systematics* 45:471–493. doi:10.1146/annurev-ecolsys-120213-091917.

Travassos L. 1920. Contribuições para o conhecimento da fauna helmintolojica dos batrachios do Brasil. *Memórias do Instituto Oswaldo Cruz* 12:673–687.

Trokovic N., Gonda A., Herczeg G., Laurila A. & Merilä J. 2011. Brain plasticity over the metamorphic boundary: carry-over effect of larval environment on froglet brain development. *Journal of Evolutionary Biology* 24:1380–1385. doi:10.1111/j.1420-9101.2011.02275.x.

Uray N.J., Gona A.G. & Hauser K.F. 1987. Autoradiographic studies of cerebellar histogenesis in the premetamorphic bullfrog tadpole: I. Generation of the external granular layer. *The Journal of Comparative Neurology* 266:234–246. doi:10.1002/cne.902660209.

Van Bambeke C. 1863. Recherches sur la structure de la bouche chez les têtards de batraciens anoures. *Bulletins de l'Académie Royale de Belgique* 16:339–354.

van der Plas F. 2019. Biodiversity and ecosystem functioning in naturally assembled communities. *Biological Reviews* 94:1220–1245. doi:10.1111/brv.12499.

Vasconcelos T.d.S., dos Santos T.G., Rossa-Feres D.d.C. & Haddad C.F.B. 2011. Spatial and temporal distribution of tadpole assemblages (Amphibia, Anura) in a seasonal dry tropical forest of southeastern Brazil. *Hydrobiologia* 673:93–104. doi:10.1007/s10750-011-0762-9.

Vera Candioti M.F. 2007. Anatomy of anuran tadpoles from lentic water bodies: systematic relevance and correlation with feeding habits. *Zootaxa* 1600:1–175.

Vera Candioti M.F., Baldo D., Grosjean S., Pereyra M.O. & Nori J. 2023. Global shortfalls of knowledge on anuran tadpoles. *NPJ Biodiversity* 22:1–12. doi:10.1038/s44185-023-00027-1.

Vera Candioti M.F., Dias P.H.d.S. & Haas A. 2024. Muscoskeletal system. in: Viertel B. (Ed.). Anuran Larvae: Morphology, Anatomy, Development, Funcion, Ecology, Evolution. Edition Chimaira, Frankfurt and Main.

Vera Candioti M.F., Dias P.H.d.S., Rowley J.J.L., Hertwig S., Haas A. & Altig R. 2021. Anatomical features of the phytotelma dwelling, egg-eating, fanged tadpoles of *Rhacophorus vampyrus* (Anura: Rhacophoridae). *Journal of Morphology* 282:769–778. doi:10.1002/jmor.21348.

Viana D.S. & Chase J.M. 2018. Spatial scale modulates the inference of metacommunity assembly processes. *Ecology* 100:e02576.

Virote A., Sotero D.F., Freitas R.M.P., Lopes P.C., Tavares G.R.G., Simoes K. . . . Melo e Silva D.d. 2025. How do insecticides affect non-target animals? The oxidative, genotoxic and histopathological effects of carbofuran in *Dendropsophus minutus* tadpoles. *Environmental Science and Pollution Research* 32:23667–23681. doi:10.1007/s11356-025-37001-2.

Virote A.J.P.P. 2025. Avaliação ecotoxicológica em anfíbios anuros: a aplicação de múltiplos biomarcadores na análise dos efeitos de agrotóxicos. Master's, Universidade Federal de Goiás, Goiânia.

Vizotto L.D. 1973. Aspectos ontogenéticos dos anuros. *Caldasia* 11:113–128.

Wassersug R.J. 1975. The adaptive significance of the tadpole stage with comments on the maintenance of complex life cycles in anurans. *American Zoologist* 15:405–417.

Wassersug R.J. 1980. Internal oral features of larvae from eight anuran families: functional, systematic, evolutionary and ecological considerations. *Miscellaneous Publications*:1–146.

Wibur H.M. 1987. Regulation of structure in complex systems: Experimental temporary pond communities. *Ecology* 68:1437–1452.

Wiens J.A. 1989. Spatial scaling in ecology. *Functional Ecology* 3:385–397.

Wilbur H.M. 1997. Experimental ecology of food webs: complex systems in temporary ponds. *Ecology* 78:2279–2302.

Wilczynski W. 1992. The nervous system. Pp. 9–39. in: Feder M.E. &W.W. Burggren (Eds.), Environmental physiology of the amphibians. The University of Chicago Press, Chicago.

Wrubleswski J., Reichert F.W., Jr., Galon L., Hartmann P.A. & Hartmann M.T. 2018. Acute and chronic toxicity of pesticides on tadpoles of *Physalaemus cuvieri* (Anura, Leptodactylidae). *Ecotoxicology* 27:360–368. doi:10.1007/s10646-018-1900-1.

Yan D., Jiang X., Xu S., Wang L., Bian Y. & Yu G. 2008. Quantitative structure-toxicity relationship study of lethal concentration to tadpole (*Bufo vulgaris formosus*) for organophosphorous pesticides. *Chemosphere* 71:1809–1815. doi:10.1016/j.chemosphere.2008.02.033.

Yost E.E., Stanek J., DeWoskin R.S. & Burgoon L.D. 2016. Estimating the potential toxicity of chemicals associated with hydraulic fracturing operations using quantitative structure-activity relationship modeling. *Environmental Science & Technology* 50:7732–7742. doi:10.1021/acs.est.5b05327.

Zachariah A., Abraham R.K., Das S., Jayan K.C. & Altig R. 2012. A detailed account of the reproductive strategy and developmental stages of *Nasikabatrachus sahyadrensis* (Anura: Nasikabatrachidae), the only extant member of an archaic frog lineage. *Zootaxa* 3510:53–64.



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