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NOTA

Morphofunctional anatomy, swimming behavior and conservation of Corydoradinae species from Northwestern La Plata basin

Anatomía morfofuncional, comportamiento natatorio y conservación de especies de Corydoradinae del Noroeste de la Cuenca del Plata

Felipe Alonso[1,2#], Guillermo Enrique Terán[2,3#], Gastón Aguilera[3*], Wilson Sebastián Serra Alanís[2,4,5], Juan Marcos Mirande[3]

[1] Instituto de Bio y Geociencias del NOA (IBIGEO), National Scientific and Technical Research Council (CONICET). Facultad de Ciencias Naturales, Universidad Nacional de Salta (UNSa), Salta Province, Argentina.
[2] Killifish Foundation, La Plata, Buenos Aires Province, Argentina.
[3] Unidad Ejecutora Lillo (UEL)-CONICET-Fundación Miguel Lillo. San Miguel de Tucumán, Tucumán, Tucumán Province, Argentina.
[4] Sección Ictiología, Dpto. de Zoología, Museo Nacional de Historia Natural, Montevideo, Uruguay.
[5] Centro Universitario Regional del Este (CURE) Sede Rocha, Universidad de la República, Rocha, Uruguay.
* Corresponding author: <gaguilera@lillo.org.ar>
# These authors made an equal contribution to this work and should be considered joint first authors.

Abstract

This study focuses on endemic Corydoradinae species from the northwestern La Plata River basin, specifically *Urkumayu micracanthus, Urkumayu gladysae, Urkumayu petracinii,* and *Hoplisoma osvaldoi*, inhabiting piedmont and high-altitude, fast-flowing Andean rivers. Using direct behavioral observations and morphometric analyses, we characterized their swimming behavior and its relationship to the morphology and their habitat conditions characterized by intense seasonal flooding during the summer. The findings reveal that Corydoradinae from these environments exhibit unique swimming behaviors, such as energy-efficient tripod-like resting postures, driven by negative buoyancy and streamlined body shapes. Morphological traits such as reduced pectoral

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and dorsal-fin spines and lower body depth decrease hydrodynamic resistance. Comparisons with congeners from low-flow environments highlight evolutionary convergence among the species from different lineages. Conservation assessments reveal significant threats to these species, including habitat degradation, pollution, and anthropogenic disturbances, particularly for *U. petracinii* and *U. gladysae*, which are classified as Critically Endangered. This study underscores the critical importance of conserving these ecosystems, providing insights into the interplay between morphology, behavior, and environmental pressures, and advancing our understanding of species diversification in Neotropical freshwater ecosystems.

Keywords: Ichthyology, hydrodynamic adaptations, endemism, mountain rivers, anthropogenic threats, evolutionary diversification.

Resumen

Este estudio se centra en las especies endémicas de Corydoradinae de la cuenca noroeste del Río de la Plata, específicamente *Urkumayu micracanthus, Urkumayu gladysae, Urkumayu petracinii* y *Hoplisoma osvaldoi*, que habitan ríos andinos de piedemonte y de gran altitud y de caudal rápido. Mediante observaciones conductuales directas y análisis morfométricos, caracterizamos su comportamiento natatorio y su relación con la morfología y las condiciones de su hábitat caracterizadas por inundaciones estacionales intensas durante el verano. Los hallazgos revelan que los Corydoradinae de estos ambientes exhiben comportamientos natatorios únicos, como posturas de descanso energéticamente eficientes similares a trípodes, impulsadas por flotabilidad negativa y formas corporales aerodinámicas. Los rasgos morfológicos como espinas reducidas en las aletas pectorales y dorsales y menor profundidad corporal disminuyen la resistencia hidrodinámica. Las comparaciones con congéneres de ambientes de bajo caudal resaltan la convergencia evolutiva entre las especies de diferentes linajes. Las evaluaciones de conservación revelan amenazas significativas para estas especies, incluyendo la degradación del hábitat, la contaminación y las perturbaciones antropogénicas, en particular para *U. petracinii* y *U. gladysae*, que están clasificadas como En Peligro Crítico. Este estudio subraya la importancia crítica de conservar estos ecosistemas, brindando información sobre la interacción entre la morfología, el comportamiento y las presiones ambientales, y avanzando en nuestra comprensión de la diversificación de especies en los ecosistemas de agua dulce neotropicales.

Palabras clave: Ictiología, adaptaciones hidrodinámicas, endemismos, ríos de montaña, amenazas antropogénicas, diversificación evolutiva.

Understanding the evolutionary interplay between morphology of organisms and environmental factors is critical for understanding evolutionary processes (Shulte, Losos and Cruz, 2004). The Corydoradinae armored catfishes (Siluriformes: Callichthyidae) with over 200 species distributed across South America (Fricke, Eschmeyer and van der Laan, 2024), display remarkable diversity in morphology and habitats (Alonso, Terán, Aguilera, Montes, Serra Alanís, et al., 2024), being a good case to study morphofunctional adaptations. Several species are endemic to northwestern La Plata basin, on the Andean slopes at altitudes ranging from ~400 to 2500 m above sea level where these rivers experience significant seasonal floodings, with summer rains reaching over 1500 mm of precipitation (Arias and Bianchi, 1996). This hydrological variability impose strong selective pressures, influencing both the morphology and swimming behavior of the aquatic species. Corydoradinae species endemic to this region, include *Urkumayu micracanthus* (Regan 1912), *Urkumayu gladysae* (Calviño and Alonso 2010), *Urkumayu petracinii* (Calviño and Alonso 2010), and the recently described *Hoplisoma osvaldoi* Alonso et al. (2024). By direct observations in natural habitats, video recordings (GoProHero 3 Black edition) and observations in aquaria, we studied their swimming behavior and its relationship to the body shape of these species, and compared them to other species from the Pampasic region of low flow environments which were also observed in aquarium: *Hoplisoma paleatum* (Jenyns 1842), *Gastrodermus undulatus* (Regan, 1912), and *Osteogaster aenea* (Gill, 1858).

Observations revealed that Corydoradinae species swim near the riverbed, primarily using their tail for propulsion while keeping their dorsal and pectoral fins relatively still. The paired fins, particularly the pectoral fins, function as rudders for maneuvering. These species exhibit negative buoyancy, and their propulsion is driven primarily by movements of the caudal fin. When swimming, Corydoradinae may intermittently pause, adopting a tripod-like posture with the anal and pelvic fins—and occasionally the pectoral spines—as contact points. In contrast, when at rest, they typically lie ventrally on the substrate. During feeding, they sink their snouts into the ground while using the pectoral and pelvic fins as stabilization points (Fig. 1).

In relation to the body and fins morphologies, it is noteworthy that species from the Andean region (*Hoplisoma osvaldoi*, *Urkumayu gladysae*, *U. petracinii*, and *U. micracanthus*), where important increases in water flow occurs during summer, present shorter pectoral and dorsal fins spines than other congeners (see Table 1 from Alonso et al., 2024) This adaptation enhances hydrodynamic efficiency by reducing drag , as does the shallower body depth (<33%SL vs. >35.1%SL) observed in *Urkumayu* species.

Hoplisoma osvaldoi has a distinct morphology, characterized by shorter pectoral and dorsal spines compared to closely related species from other environments. Similar traits are also shared by *Urkumayu* species from this region, which also present a low body depth, showing an evolutionary

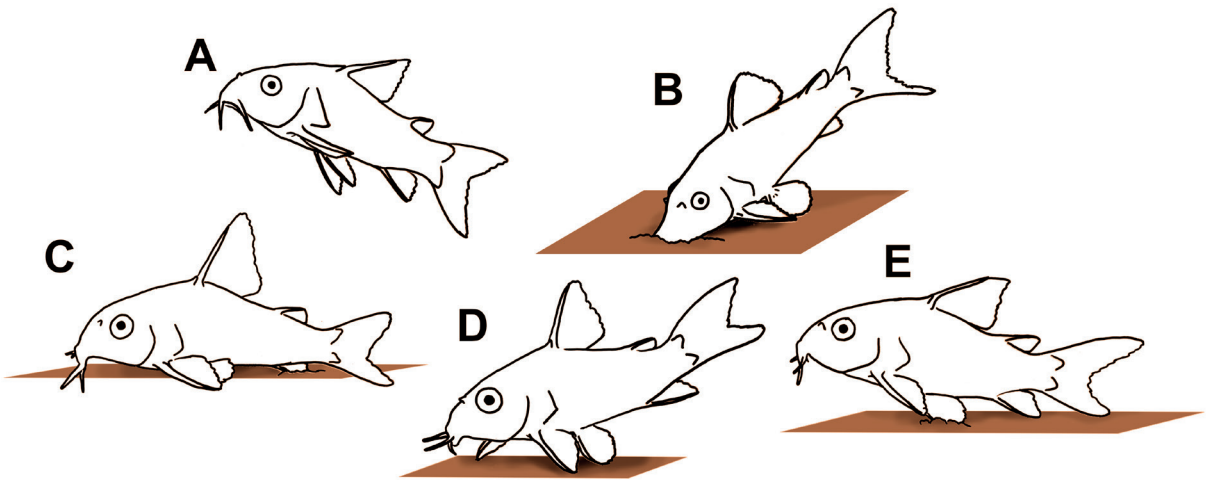

Fig. 1. Swimming behavior of analyzed Corydoradinae species. **(A)** Individuals detach themselves from the bottom and generally fold their pectoral fins when swimming, but they open them to slow down or maneuver. They also fold the dorsal fin when swimming at high speed. **(B)** During feeding from the bottom, individuals lean over the substrate and sink their snouts into it, using their pectoral and pelvic fins as points of support on the bottom. **(C)** When resting on the bottom, they fold their pelvic fins over a concavity of the abdomen, generating a flat surface on the ventral region between the head and the anal fin which stays in contact with the bottom. **(D and E)** Individuals often rest at intervals on the bottom while swimming, typically on the tips of the pectoral, pelvic, or anal fins, using them as a tripod detaching the ventral surface of the body from the bottom.

shift from their sister species *H. flaveolum*. Furthermore, the body shape arrangement presents a dorsally rounded and ventrally flat shape, with pelvic fins inserted in a concavity. This shape likely maximizes substrate contact and hydrodynamic down forces while minimizing drag (Carlson and Lauder 2010). However, the caudal peduncle is separated from the substrate, which may facilitate propulsion. Those features suggest a positive selective pressure towards similar morphologies and a relative convergence towards these morphotypes in *Urkumayu* and *H. osvaldoi* that likely aid in coping with the high-speed flow during summer flooding.

Observations of *Hoplisoma osvaldoi* and other Corydoradinae species in aquariums reveal that they swim close to the bottom, using the tail to propel themselves while keeping the dorsal and pectoral fins relatively still, and utilizing the paired fins, especially the pectoral fins, as a rudder for maneuvering. This swimming style falls under Lindsey's (1978) classification of fish swimming type 1, movements of the caudal fin and/or body. When swimming, we observed that Corydoradinae species exhibit a carangiform style, as observed *in O. aenea* (Mauguit, Olivier, Vandewalle and Vandewalle, 2010), characterized as small magnitude thrust-producing lateral waves passed along the body restricted anteriorly and of high-amplitude caudally. When resting, they tend to have their ventral surface in contact with the bottom. When swimming, they may pause and remain in a standing position before resuming swimming, using a tripod-like use of

the pelvic and anal fins, and sometimes employing the pectoral fins as well avoiding contact of the ventral surface with the bottom. This behavior may help the fish save energy by separating the body from the bottom avoiding a ground soak effect when taking off, like the behavior of tripodfishes of the family Ipnopidae (Davis and Chakrabarty 2011). The relationship between swimming behavior, the anatomy and habitat characteristics are a promising avenue for future research in this group.

Also, we evaluated the conservation status of all Corydoradinae species in this region by employing the IUCN (2012) categories and criteria, identifying the primary threats they confront.

CONSERVATION STATUS

Hoplisoma osvaldoi has been recorded in the Blanco River, and some of its tributaries. The region appears to be relatively well-preserved, and despite this recently described species has not been recorded yet in any formally protected natural areas within this region, it is likely to inhabit these areas. It is important to note that this region falls within the Yungas Biosphere Reserve. Based on the IUCN (2012) categories and criteria, '*Hoplisoma*' *osvaldoi* is classified as Vulnerable under criteria B1ab (iii). It is known to exist at no more than 10 locations (one), the extent of occurrence (EOO) is estimated to be less than 20,000 km^2 (4 km^2), and there is a continuing decline observed and projected in its quality of habitat, due to water extraction, deforestation, and habitat degradation.

Urkumayu micracanthus, is listed as Vulnerable under criteria B1ab (i,ii,iii) (Alonso, 2022a). This species inhabits an area that is subject to agricultural expansion, deforestation, and human population growth, resulting in water use and pollution from towns, industries, and agricultural areas in the region (Alonso, 2018). It is also subject to ornamental collection, which may threaten the species.

Urkumayu petracinii, is assessed as Critically Endangered under criterion B1ab (i,ii,iii)+2ab (i,ii,iii) (Alonso, 2022b). The extent of occurrence (EOO) is estimated to be less than 100 km^2 (4 km^2), the area of occupancy (AOO) is estimated to be less than 10 km^2 (4 km^2), it is known to exist at a single threat-based location, there is continuing decline observed and projected in EOO, AOO and area, extent, and quality of habitat. The habitat of this species was modified by the construction of a highway and a modification of the river course together with river water capture, considerably reducing the area and quality of habitat between different seasons of the year making the conservation of this species with an extremely high risk of extinction in the short term.

Urkumayu gladysae is considered Critically Endangered according to criteria B1ab (i,iii). The extent of occurrence (EOO) is estimated to be less than 100 km^2 (24 km^2) and it is known to exist at only a single location,

with a continuing decline observed in the EOO and quality of habitat. This species inhabits a river that receives sewage from the towns of Payogasta and Cachi, which have a combined population of over 3,000 inhabitants. The riverbanks are also burnt to create pastures for livestock. The presence of *Oncorhynchus mykiss* trout was observed in this area, an invasive exotic species known to predate on small fish. This, together with the influence of different crops in the area with the use of agrochemicals and the extraction of water for irrigation (Alonso 2022c), puts the viability of this species at risk.

Urgent measures must be taken such as to improve water capture and storage and more efficient use, control sewage and industrial discharges, and open dump sites and garbage in the rivers, and the implementation of public education campaigns. The channeling and bulldozing of rivers to prevent flooding in the summer is a terrible and widespread practice in the region, causing severe environmental disturbances and serious ecosystem impacts. The northwest La Plata region is known for its elevated levels of endemism. Our findings highlight the importance of conserving these ecosystems.

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