

Integrative taxonomy reveals a new species of the *Hoplias malabaricus* species complex (Teleostei: Erythrinidae)

Juan J. Rosso^{*,***}, Mariano González-Castro^{*,****}, Sergio Bogan^{**},
Yamila P. Cardoso^{***,****}, Ezequiel Mabragaña^{*,****},
Matías Delpiani^{*,****} and Juan M. Díaz de Astarloa^{*,****}

By means of an integrative taxonomic approach, a new species of the *H. malabaricus* group from the Río de La Plata basin is described. *Hoplias argentinensis*, new species, is characterized by: 17–19 predorsal scales, 42–43 vertebrae, 20 scales around caudal peduncle, no distinctive brown bands in lower jaw, last series of vertical scales on caudal fin nearly straight, 41–44 lateral-line scales and snout width (18.4–24.9 % of SL). *Hoplias argentinensis* is discriminated from all other species of the *H. malabaricus* group by means of traditional characters, landmarks-based morphometrics and genetics. A key to species of the *Hoplias malabaricus* group is provided.

Introduction

With more than 5100 species, Neotropical freshwater fishes represent about one-third of all freshwater fishes worldwide, albeit some estimates regard a final diversity between 8000 and 9000 species (Reis et al., 2016). Wolf fishes of the family Erythrinidae are predator fishes that inhabit a large array of aquatic ecosystems throughout South America and comprise three genera: *Erythrinus*, *Hoplerythrinus* and *Hoplias*

(Oyakawa, 2003). *Hoplias*, the most species-rich genus within Erythrinid fishes, comprises 13 valid species (Eschmeyer et al., 2017). Species of *Hoplias* can be morphologically discriminated into three different groups by means of the arrangement of medial margins and number of latero-sensory pores of dentaries and the presence of tooth plates on basihyal and basibranchial bones (Oyakawa, 1990; Oyakawa & Mattox, 2009; Mattox et al., 2006). One of these groups, the *Hoplias malabaricus* species group, includes *Hoplias malabaricus*, which

* Grupo de Biotaxonomía Morfológica y Molecular de Peces, Instituto de Investigaciones Marinas y Costeras (IIMyC), Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, CONICET, Funes 3350, (7600) Mar del Plata, Argentina. JJR (corresponding author). E-mail: pluroso@yahoo.com.ar

** Fundación de Historia Natural “Félix de Azara”. Departamento de Ciencias Naturales y Antropología. Universidad Maimónides. Hidalgo 775, piso 7. 1405-BDB Buenos Aires, Argentina

*** Laboratorio de Sistemática y Biología Evolutiva (LASBE), Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Paseo del Bosque S/N, B1900FWA, La Plata, Buenos Aires, Argentina

**** Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Godoy Cruz 2290, C1425FQB, Buenos Aires, Argentina

Literature cited

- Aguirre, W. E., V. R. Shervette, R. Navarrete, P. Calle & S. Agorastos. 2013. Morphological and genetic divergence of *Hoplias microlepis* (Characiformes: Erythrinidae) in rivers and artificial impoundments of western Ecuador. *Copeia*, 2013: 312–323.
- Azpelicueta, M. M., M. F. Benítez, D. R. Aichino & C. M. D. Mendez. 2015. A new species of the genus *Hoplias* (Characiformes, Erythrinidae), a tararira from the lower Paraná River, in Misiones, Argentina. *Acta Zoológica Lilloana*, 59: 71–82.
- Balboni, L., D. C. Colautti & C. R. M. Baigún. 2011. Biology of growth of *Hoplias malabaricus* (Bloch, 1794) in a shallow pampean lake (Argentina). *Neotropical Ichthyology*, 9: 437–444.
- Brannan, D. A., M. F. Esplen & J. J. Gray. 1999. *Geometry*. Cambridge University Press, Cambridge, 497 pp.
- Bertollo, L. A. C., O. Moreira-Filho & P. M. Galetti. 1986. Cytogenetics and taxonomy: considerations based on chromosome studies of freshwater fish. *Journal of Fish Biology*, 28: 153–159.
- Bertollo, L. A. C., G. G. Born, J. A. Dergam, A. S. Fenocchio & O. Moreira-Filho. 2000. A biodiversity approach in the Neotropical fish *Hoplias malabaricus*. Karyotypic survey, geographic distribution of cytotypes and cytotoxic considerations. *Chromosome Research*, 8: 603–613.
- Blanco, D. R., R. L. Lui, L. A. C. Bertollo, D. Diniz & O. Moreira-Filho. 2010. Characterization of invasive fish species in a river transposition region: evolutionary chromosome studies in the genus *Hoplias* (Characiformes, Erythrinidae). *Reviews in Fish Biology and Fisheries*, 20: 1–8.
- Bookstein, F. B., R. Chernoff, J. Elder, Jr. Humpries, G. R. Smith & R. E. Strauss. 1985. *Morphometrics in evolutionary biology*. Academy of Natural Sciences of Philadelphia Special Publications, 15: 1–277.
- Cioffi, M. B., C. Martins, L. Centofante, U. Jacobina & L. A. C. Bertollo. 2009. Chromosomal variability among allopatric populations of Erythrinidae fish *Hoplias malabaricus*: mapping of three classes of repetitive DNAs. *Cytogenetic and Genome Research*, 125: 132–141.
- Díaz, J., G. V. Villanova, F. Brancolini, F. Del Pazo, V. M. Posner, A. Grimberg & S. E. Arranz. 2016. First DNA barcode reference library for the identification of South American freshwater fish from the lower Paraná River. *PLoS One*, 11: 1–20.
- Dománico, A. A. 1998. Edad y crecimiento de *Hoplias malabaricus malabaricus* (Bloch, 1794) (Teleostei, Erythrinidae) en la laguna de San Miguel del Monte (Argentina) y comparación con otros ambientes lénticos pampásicos. *Revista del Museo Argentino de Ciencias Naturales*, 7: 31–41.
- Dománico, A. A., R. Delfino & L. Freyre. 1993. Edad y crecimiento de *Hoplias malabaricus malabaricus* (Bloch, 1794) (Teleostei, Erythrinidae) en la laguna de Lobos (Argentina). *Iheringia, Série Zoológica*, 74: 141–149.
- Edgar, R. C. 2004. MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research*, 32: 1792–1797.
- Eschmeyer, W. N., R. Fricke & R. van der Laan. 2017. *Catalog of Fishes: genera, species and references*. Available from: <http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcat-main.asp> (accessed 2 August 2017).
- Fink, W. L. & S. H. Weitzman. 1974. The so-called cheirodontin fishes of Central America with descriptions of two new species (Pisces: Characidae). *Smithsonian Contributions to Zoology*, 172: 1–46.
- García-Vásquez, A. R., G. Vargas, H. Sanchez-Ribeiro, R. A. Ismiño-Orbe, C. Nolorbe-Payahua, C. R. García-Dávila & J. S. Tello-Martín. 2014. Recursos pesqueros y pesca en los ríos Curaray, Arabela y Napo (Amazonía peruana). *Folia Amazónica*, 23: 95–104.
- González-Castro, M., A. L. Ibáñez, S. Heras, M. I. Roldán & M. B. Cousseau. 2012. Assessment of lineal versus landmarks-based morphometry for discriminating species of Mugilidae (Actinopterygii). *Zoological Studies*, 51: 1515–1528.
- González-Castro, M., J. J. Rosso, E. Mabragna & J. M. Díaz de Astarloa. 2016. Surfing among species, populations and morphotypes: inferring boundaries between two species of new world silversides (Atherinopsidae). *Comptes Rendus Biologies*, 399: 10–29.
- González-Castro, M. & J. M. Díaz de Astarloa. 2017. Metodologías morfométricas aplicadas a la taxonomía integrativa de peces. Pp. 163–181 in: V. Abdala et al. (eds.), *Morfología de vertebrados: conceptos, métodos y grupos de investigación en Argentina*. EUDEM, Mar del Plata.
- Goulding, M. 1980. *The fishes and the forest: explorations in Amazonian natural history*. University of California Press, Berkeley, 280 pp.
- Grassi, D. J., A. C. Swarcz, J. A. Dergam, M. C. Pastori & A. S. Fenocchio. 2017. Cytogenetic characterization of *Hoplias malabaricus* (Bloch, 1794) from the Ctlamochita River (Córdoba, Argentina): first evidence for southernmost populations of this species complex and comments on its biogeography. *Comparative Cytogenetics*, 11: 15–28.
- Ivanova, N. V., J. R. Dewaard & P. D. N. Hebert. 2006. An inexpensive, automation friendly protocol for recovering high-quality DNA. *Molecular Ecology Notes*, 6: 998–1002.
- Ivanova, N. V., T. S. Zemlak, R. H. Hanner & P. D. N. Hebert. 2007. Universal primer cocktails for fish DNA barcoding. *Molecular Ecology Notes*, 7: 544–548.
- Iwaszkiv, J. M. & F. Firpo Lacoste. 2011. La pesca artesanal en la Cuenca del Plata (Argentina) y sus implicancias en la conservación de la biodiversidad. *Revista del Museo Argentino de Ciencias Naturales*, 13: 21–25.
- Kimura, M. 1980. A simple method for estimating evolutionary rate of base substitutions through comparative studies of nucleotide sequences. *Journal of Molecular Evolution*, 16: 111–120.

- Leonart, J., J. Salat & G. J. Torres. 2000. Removing allometric effects of body size in morphological analysis. *Journal of Theoretical Biology*, 205: 85–93.
- Lombarte, A. & J. Leonart. 1993. Otolith size changes related with body growth, habitat depth and temperature. *Environmental Biology of Fishes*, 37: 297–306.
- Mac Donagh, E. 1934. Nuevos conceptos sobre distribución geográfica de los peces argentinos basados en expediciones del Museo de La Plata. *Revista del Museo de La Plata*, 34: 21–170.
- Marques, D. F., F. A. Santos, S. S. Silva, I. Sampaio & L. R. R. Rodrigues. 2013. Cytogenetic and DNA barcoding reveals high divergence within the trahira, *Hoplias malabaricus* (Characiformes: Erythrinidae) from the lower Amazon River. *Neotropical Ichthyology*, 11: 459–466.
- Mattox, G. M. T., M. Toledo-Piza & O. T. Oyakawa. 2006. Taxonomic study of *Hoplias aimara* Valenciennes, (1846) and *Hoplias macrophthalmus* (Pellegrin, 1907) (Ostariophysi, Characiformes, Erythrinidae). *Copeia*, 2006: 516–528.
- Mattox, G. M. T., A. G. Bifi & O. T. Oyakawa. 2014. Taxonomic study of *Hoplias microlepis* (Günther, 1864), a trans-Andean species of trahiras (Ostariophysi: Characiformes: Erythrinidae). *Neotropical Ichthyology*, 12: 343–352.
- Oyakawa, O. T. & G. M. T. Mattox. 2009. Revision of the Neotropical trahiras of the *Hoplias lacerdae* species-group (Ostariophysi: Characiformes: Erythrinidae) with descriptions of two new species. *Neotropical Ichthyology*, 7: 117–140.
- Oyakawa, O. T. 1990. Revisão sistemática das espécies do gênero *Hoplias* (grupo *lacerdae*) da Amazônia brasileira e região leste do Brasil (Teleostei: Erythrinidae). M.Sc. Thesis. Universidade de São Paulo, 200 pp.
- Oyakawa, O. T. 2003. Family Erythrinidae. Pp. 238–240 in: R. E. Reis et al. (eds.), Check list of the freshwater fishes of South and Central America. Edipucrs, Porto Alegre.
- Pereira, L. H. G., R. Hanner, F. Foresti & C. Oliveira. 2013. Can DNA barcoding accurately discriminate megadiverse Neotropical freshwater fish fauna? *BMC Genetics*, 14: 1–14.
- Ratnasingham, S. & P. D. N. Hebert. 2007. BOLD: the barcode of life data system (www.barcodinglife.org). *Molecular Ecology Notes*, 7: 355–364.
- Ratnasingham, S. & P. D. N. Hebert. 2013. DNA-based registry for all animal species: the barcode index number (BIN) system. *PLoS ONE*, 8: 8e66213.
- Reis, R. E., J. S. Albert, F. Di Dario, M. M. Mincarone, P. Petry & L. A. Rocha. 2016. Fish biodiversity and conservation in South America. *Journal of Fish Biology*, 89: 12–47.
- Ringuelet, R. A. 1942. Ecología alimenticia del pejerrey (*Odontesthes bonariensis*) con notas limnológicas sobre la laguna Chascomús. *Revista del Museo de La Plata, Nueva Sección, Sección Zoológica*, 2: 427–461.
- Rodrigues Pacheco, M. 2004. Estudo morfológico de duas populações de *Hoplias* grupo *malabaricus* (Characiformes: Erythrinidae) procedentes da bacia do Rio Grande, Estado de São Paulo. M.Sc. Thesis. Universidade Federal de São Carlos, 107 pp.
- Rosso, J. J., E. Mabragaña, M. González-Castro & J. M. Díaz de Astarloa. 2012. DNA barcoding Neotropical fishes: recent advances from the Pampa Plain, Argentina. *Molecular Ecology Resources*, 12: 999–1011.
- Rosso, J. J., E. Mabragaña, M. González-Castro, M. S. Delpiani, E. Avigliano, N. F. Schenone & J. M. Díaz de Astarloa. 2016. A new species of the *Hoplias malabaricus* species complex (Characiformes: Erythrinidae) from the La Plata River basin. *Cybio*, 40: 199–208.
- Scavone, M. D. P. 1994. Sympatric occurrence of two karyotypic forms of *Hoplias malabaricus* (Pisces, Erythrinidae). *Cytobios*, 80: 223–227.
- Tamura, K., D. Peterson, N. Peterson, G. Stecher, M. Nei & S. Kumar. 2011. MEGA5: Molecular Evolutionary Genetics Analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular and Biological Evolution*, 28: 2731–2739.
- Ward, R. D., R. Hanner & P. D. N. Hebert. 2009. The campaign to DNA barcode all fishes, FISH-BOL. *Journal of Fish Biology*, 74: 329–356.

Received 29 December 2017
 Revised 19 January 2018
 Accepted 31 May 2018

The whole contribution can be purchased as PDF file.

Availability

Generally all our publications are available as PDF files; full publications as a general rule after the printed version is out of print. If you have questions concerning particular contributions please contact us by e-mail:

pdf@pfeil-verlag.de.

The PDF files are protected by copyright.

The PDF file may be printed for personal use.

The reproduction and dissemination of the content or part of it is permitted.

It is not allowed to transfer the digital personal certificate or the password to other persons.

Prices

Books: Prices are to be found in the catalog.

Articles in journals and single contributions or chapters in books:

10 EURO basic price per order (including the first 10 pages),
and

0.50 EURO per page, beginning with the 11th page.

Page numbers are found in the contents of the publications.

Orders

Use our order form for PDF files or send your order informal per e-mail (pdf@pfeil-verlag.de). The only accepted payment is by credit card. While using the order form for PDF files, your data will be transmitted by secure link (ssl). You also may send the informations informally by e-mail, fax, phone or mail.

Handling

As soon as possible, depending on our business hours and your order, you will receive your PDF file together with the certificate and password by e-mail.

Larger PDF files can be downloaded from our webpage, if necessary.

Your invoice will be sent out by e-mail after we charged your credit card.

To open the encrypted PDF files you have to install your personal certificate after your first order. All PDF files with the same certificate can be opened from that time on.

Dieser Beitrag kann als PDF-Datei erworben werden.

Verfügbarkeit von PDF-Dateien

Prinzipiell sind von allen unseren Publikationen PDF-Dateien erhältlich. Komplette Publikationen in der Regel erst nachdem die gedruckte Version vergriffen ist. Anfragen bezüglich bestimmter Beiträge richten Sie bitte per E-Mail an pdf@pfeil-verlag.de.

Die PDF-Dateien sind urheberrechtlich geschützt.

Ein Ausdruck der PDF-Dateien ist nur für den persönlichen Gebrauch erlaubt.

Die Vervielfältigung von Ausdrucken, erneutes Digitalisieren sowie die Weitergabe von Texten und Abbildungen sind nicht gestattet.

Das persönliche Zertifikat und das Passwort dürfen nicht an Dritte weitergegeben werden.

Preise

Bücher: Die Preise sind dem Katalog zu entnehmen. Zeitschriftenbeiträge und einzelne Kapitel aus Sammelbänden bzw. Büchern:

10 EURO Grundbetrag pro Bestellung (einschließlich der ersten 10 Seiten),
und

0,50 EURO pro Seite ab der 11. Seite.

Den Umfang der Beiträge entnehmen Sie bitte den Inhaltsverzeichnissen.

Bestellungen

Bestellungen sind mit dem PDF-Bestellformular oder formlos per E-Mail (pdf@pfeil-verlag.de) an uns zu richten. Die Bezahlung ist ausschließlich per Kreditkarte möglich. Bei Verwendung unseres Bestellformulars werden die Kreditkartendaten über eine gesicherte Verbindung (ssl) übermittelt. Sie können die Daten aber auch formlos per E-Mail, Fax, Post oder telefonisch übermitteln.

Abwicklung

So bald wie möglich, aber abhängig von unseren Bürozeiten und der gewünschten Bestellung, schicken wir Ihnen die PDF-Datei(en) zusammen mit Ihrem persönlichen Zertifikat und dem zugehörigem Passwort per E-Mail. Größere Dateien bieten wir Ihnen gegebenenfalls zum Herunterladen an.

Der fällige Betrag wird von Ihrer Kreditkarte abgebucht und Sie erhalten die Rechnung ebenfalls per E-Mail.

Um die verschlüsselten PDF-Dateien öffnen zu können, muss bei der ersten Bestellung das passwortgeschützte persönliches Zertifikat installiert werden, welches anschließend auf dem Rechner verbleibt. Alle mit diesem Zertifikat verschlüsselten Dateien können anschließend auf diesem Rechner geöffnet werden.