



<http://dx.doi.org/10.11646/zootaxa.3835.2.6>

<http://zoobank.org/urn:lsid:zoobank.org:pub:756F0BAC-8D78-48E3-9C07-FFA47FB9E2EA>

A new tardigrade, *Mutaparadoxipus duodigifinis* gen. nov., sp. nov. (Heterotardigrada: Arthrotardigrada), from the Southeastern United States

VLADIMIR GROSS^{1,4}, WILLIAM R. MILLER² & RICK HOCHBERG³

¹*Animal Evolution and Development, Institute of Biology, University of Leipzig, Talstraße 33, D-04103 Leipzig, Germany.
E-mail: Vladimir_Gross@student.uml.edu*

²*Department of Biology, Baker University, Baldwin City, KS 66006, USA. E-mail: William.Miller@bakeru.edu*

³*Department of Biological Sciences, University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854, USA.
E-mail: Rick_Hochberg@uml.edu*

⁴*Corresponding author. E-mail: Vladimir_Gross@student.uml.edu*

Abstract

A new genus and species of Arthrotardigrada is described from Florida, USA based on its unique adhesive pad/claw combinations. *Mutaparadoxipus duodigifinis* gen. nov., sp. nov., is characterized by well-developed, ventral secondary clavae that are adjacent to the mouth, pointed lateral and caudal alae, seminal receptacles with coiled ducts opening lateral to the gonopore, and all legs with digits bearing proximal adhesive pads. Distal claws are present on digits I–III of legs I–III, but are missing from digit IV. On leg IV, distal claws are present only on digits II & III. A single accessory point is present on claws II & III only. This is the fourth species discovered to date with proximal adhesive pads, increasing support for a clade of adhesive-padded arthrotardigrades, and is likely the sister taxon of *Paradoxipus orzeliscoides*. The incomplete set of claws may represent an evolutionary step in a progressive loss of claws hypothesized to have occurred within the Halechiniscidae. The subfamily Orzeliscinae is amended as a result.

Key words: Tardigrada, Capron, Florida, Orzeliscinae, *Orzeliscus*

Introduction

The first marine tardigrade, *Echiniscoides sigismundi* Schultze, 1865 was described almost 150 years ago and today eight families, 43 genera, and more than 160 species of marine heterotardigrades have been described, representing approximately 15% of all currently known tardigrade species (Guidetti & Bertolani 2005; Degma & Guidetti 2007; Degma *et al.* 2014).

In 1928, Thulin erected the family Halechiniscidae within the Arthrotardigrada to include species that lack strongly sclerotized dorsal segmental plates, possess a complete or incomplete set of cephalic appendages, and bear four digits with claws on each adult leg. Currently, Halechiniscidae consists of 8 subfamilies, 28 genera and 89 species, making it the most speciose family of arthrotardigrades (Guidetti & Bertolani 2005; Degma & Guidetti 2007; Degma *et al.* 2014). However, based on molecular evidence, the family Halechiniscidae is considered polyphyletic (Jørgensen *et al.* 2010).

Perhaps reflecting its polyphyletic nature, morphological diversity within the Halechiniscidae is extremely high, evidenced in part by the structure of the digits (toes). Halechiniscids bear four digits on each leg for a total of 32 digits, and because digits may bear morphologically diverse claws and/or adhesive pads, there is the possibility of multiple character states for each digit. Consequently, lower classification within the Halechiniscidae, i.e. genus level, is determined in part by digit morphology, and has been the subject of numerous cases for systematic reclassification. Nowhere is this more evident than in the case of *Orzeliscus*.

Orzeliscus was first described from São Sebastião, Brazil based on the presence of proximal adhesive pads on each of the four digits of the adult legs (du Bois-Reymond Marcus 1952). The genus was subsequently placed in the Onychopodidae based on three shared characters: 1) lateral cirri & primary clava arise from a common base, 2)

Discussion

It is not uncommon among halechiniscid taxa that the two internal digits (digits II, III) differ morphologically from the external ones (digits I, IV). However, *Mutaparadoxipus duodigifinis* **gen. nov., sp. nov.** is unique in that digits I and IV differ from each other as well. Although *M. duodigifinis* **gen. nov., sp. nov.** is morphologically very similar to *P. orzeliscoides*, it does not fit the description of the genus *Paradoxipus*, which explicitly states “four similar toes (digits) on each foot. Each toe with proximal suction disc and distal claw” (Kristensen & Higgins 1989). This characterization is clearly violated by *M. duodigifinis* **gen. nov., sp. nov.**, which has at least one clawless toe and as many as three different toe morphologies per foot, including accessory points on digits II & III, which are lacking in *P. orzeliscoides*. Additionally, variation in the digit pattern between legs I–III and leg IV, as occurs in *M. duodigifinis* **gen. nov., sp. nov.**, is a diagnostic feature of at least one other genus in the Halechiniscidae—*Dipodarctus* Pollock, 1995—as well as the non-halechiniscid genera, *Anisonyches* Pollock, 1975, *Carphania* Binda, 1978, and *Megastygarctides* McKirdy *et al.*, 1976.

Paradoxipus orzeliscoides is clearly the sister taxon to *M. duodigifinis* **gen. nov., sp. nov.** but despite the morphologically similar secondary clavae, seminal receptacles, and alae, we believe that the difference in claw arrangement and morphology is too significant and extreme to attribute to intraspecific variation or even to a species-level character, especially considering that at least 30 specimens, both males and females, of the new tardigrade were collected. Consequently, the unique foot construction of this newly discovered tardigrade cannot be accurately represented by any hitherto described genus and so warrants the erection of the new genus, *Mutaparadoxipus* **gen. nov.**

To date, four monospecific genera of Tardigrada have been described possessing elongate adhesive organs on the proximal part of their digits (du Bois-Reymond Marcus 1952, Kristensen & Higgins 1989, Renaud-Mornant 1989, this report), each with different claw structures and arrangements. Renaud-Mornant (1989) suggested that a progressive loss of claws occurred from *Chrysoarctus* to *Opydorscus* and finally to both *Orzeliscus* and *Batillipes*. Although the distal suction discs of *Batillipes* are almost certainly not homologous to the proximal elongate adhesive organs (Pollock 1982), the discovery of *P. orzeliscoides* and now *M. duodigifinis* **gen. nov., sp. nov.** adds support for a clade united by proximal adhesive organs. Additionally, these two species may represent evolutionary events leading to the complete loss of claws in *Orzeliscus*. For this reason, we have placed *P. orzeliscoides* and *M. duodigifinis* **gen. nov., sp. nov.** into the newly amended subfamily, Orzeliscinae. The observation by Jørgensen *et al.* (2010) that *Orzeliscus belopus* is basal within the polyphyletic Halechiniscidae offers further support that this group is likely to be a clade unto itself.

Whatever the case may be, the acquisition of molecular data from *Paradoxipus*, *Opydorscus*, and *Mutaparadoxipus* **gen. nov.**, would go a long way in helping to clarify the relationships within this group of adhesive-padded arthrotardigrades.

Acknowledgements

The authors thank the staff of the Smithsonian Marine Station at Fort Pierce, Florida for their assistance in the collection of specimens. We would also like to thank the anonymous reviewers for their constructive feedback and suggestions for improvements to the manuscript. Funding for this research came from NSF DEB 0918499 to R. Hochberg. This is Smithsonian Marine Station at Fort Pierce, Florida, contribution no. 947.

References

- Binda, M.G. (1978) Ristestemazione di alcuni Tardigradi con l'istituzione di un nuovo genere di Oreellidae e della nuova famiglia Archechiniscidae. *Animalia*, 5, 307–314.
- Degma, P., Bertolani, R. & Guidetti, R. (2014) Actual checklist of Tardigrada species, pp. 41. <http://www.tardigrada.modena.unimo.it/miscellanea/Actual%20checklist%20of%20Tardigrada.pdf> (accessed 10 May 2014)
- Degma, P. & Guidetti, R. (2007) Notes to the current checklist of Tardigrada. *Zootaxa*, 1579, 41–53.
- Doyère, L. (1840) Memoire sur les tardigrades. *Annales des Sciences Naturelles*, 14, 269–361.
- du Bois-Reymond Marcus, E. (1952) On South American Malacopoda. *Boletins da Faculdade de Filosofia, Ciencias e Letras*, 17, 189–209.

- Guidetti, R. & Bertolani, R. (2005) Tardigrade taxonomy: an updated check list of the taxa and a list of characters for their identification. *Zootaxa*, 845, 1–46.
- Jørgensen, A., Faurby, S., Hansen, J.G., Møbjerg, N. & Kristensen, R.M. (2010) Molecular phylogeny of Arthrotardigrada (Tardigrada). *Molecular Phylogenetics and Evolution*, 54, 1006–1015.
<http://dx.doi.org/10.1016/j.ympev.2009.10.006>
- Kristensen, R.M. & Higgins, R.P. (1984) A new family of Arthrotardigrada (Tardigrada: Heterotardigrada) from the Atlantic Coast of Florida, USA. *Transactions of the American Microscopical Society*, 103, 295–311.
<http://dx.doi.org/10.2307/3226191>
- Kristensen, R.M. & Higgins, R.P. (1989) Marine Tardigrada from the Southeastern United States Coastal Waters I. *Paradoxipus orzeliscoides* n. gen., n. sp. (Arthrotardigrada: Halechinisidae). *Transactions of the American Microscopical Society*, 108, 262–282.
<http://dx.doi.org/10.2307/3226344>
- Marcus, E. (1927) Zur anatomie und ökologie mariner Tardigraden. *Zoologische Jahrbücher*, 53, 487–588.
- McKirby, D., Schmidt, P. & McGinty-Bayly, M. (1976) Interstitielle fauna von Galapagos. XVI. Tardigrada. *Mikrofauna des Meeresbodens*, 58, 1–43.
- Pfannkuche, O. & Thiel, H. (1988) Sample Processing. In: Higgins, R.P. & Thiel, H. (Eds.), *Introduction to the Study of Meiofauna*. Smithsonian Institution Press, Washington, D.C., pp. 134–145.
- Pollock, L.W. (1975) Observations on marine Heterotardigrada including a new genus from the western Atlantic Ocean, *Cahiers de Biologie Marine*, 16, 121–132.
- Pollock, L.W. (1982) A closer look at some marine Heterotardigrada. I. The morphology and taxonomy of *Orzeliscus*. In: Nelson, D. (Ed.), *Proceedings of the Third International Symposium on Tardigrada*. East Tennessee State University Press, Johnson City, Tennessee, pp. 193–202.
- Pollock, L.W. (1995) New marine tardigrades from Hawaiian beach sand and phylogeny of the family Halechiniscidae. *Invertebrate Biology*, 114, 220–235.
<http://dx.doi.org/10.2307/3226877>
- Ramazzotti, G. (1962) Il phylum Tardigrada. *Memorie dell' Istituto Italiano di Idrobiologia*, 14, 1–595.
- Rasband, W.S. (1997–2012) ImageJ. U.S. National Institutes of Health, Bethesda, Maryland. Available from: <http://imagej.nih.gov/ij/> (accessed 12 April 2013)
- Renaud-Mornant, J. (1984) Halechiniscidae (Heterotardigrada) de la champagne Benthedi, canal du Mozambique. *Bulletin du Muséum national d'histoire naturelle*, Section A, 6, 67–88.
- Renaud-Mornant, J. (1989) *Opydorscus*, un nouveau genre d'Orzeliscinae et sa signification phylogénique (Tardigrada, Arthrotardigrada). *Bulletin du Muséum national d'histoire naturelle*, 4, 763–771.
- Schultze, M. (1865) *Echiniscus sigismundi*, ein Arctiscoide der Nordsee. *Archiv für mikroskopische Anatomie*, 1, 428–436.
<http://dx.doi.org/10.1007/bf02961427>
- Schulz, E. (1953) *Orzeliscus septentrionalis* nov. spec. ein neuer mariner Tardigrad an der deutschen Nordseeküste. *Kieler Meeresforschung*, 9, 288–292.
- Schulz, E. (1963) Über die Tardigraden. *Zoologischer Anzeiger*, 171, 3–12.
- Thulin, G. (1928) Über die phylogenie und das system der tardigraden. *Hereditas*, 11, 207–266.
<http://dx.doi.org/10.1111/j.1601-5223.1928.tb02488.x>