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## The tardigrade fauna of Australian marine caves: With descriptions of nine new species of Arthrotardigrada

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## Abstract

Marine caves are known to support a rich macrofauna; however, few studies have focused on meiofauna. Marine cave meiofaunal tardigrades have been reported from Japan and the Mediterranean Sea and a preliminary list of species including a redescription of *Actinarctus neretinus* Grimaldi de Zio, D'Addabbo Gallo, Morone De Lucia, Vaccarella and Grimaldi, 1982 was reported from Fish Rock Cave and Jim's Cave on the coast of Australia. This study is the fourth in a series describing the unique meiofauna in two Australian submarine caves located off the coast of New South Wales, describing nine new species.

Only 67 tardigrades were collected from the two caves, yet these contained a high diversity of at least 16 different species which are quite different in the two caves. The fauna includes nine arthrotardigrade genera: *Actinarctus*, *Batillipes*, *Dipodarctus*, *Halechiniscus*, *Raiarctus*, *Styraconyx*, *Tanarctus*, *Tholoarctus*, and *Wingstrandarctus*. This fauna is different from that reported for the high energy beaches along the East Coast of Australia.

We describe nine new species comprising a single batillipedid and eight halechiniscids: *Batillipes solitarius* **nov. sp.**, *Dipodarctus australiensis* **nov. sp.**, *Dipodarctus susannae* **nov. sp.**, *Raiarctus jesperii* **nov. sp.**, *Raiarctus katrinae* **nov. sp.**, *Tanarctus hirsutospinosus* **nov. sp.**, *Tholoarctus oleseni* **nov. sp.**, *Wingstrandarctus stinae* **nov. sp.** and *Wingstrandarctus unsculptus* **nov. sp.**

**Key words:** Meiofauna, Tardigrada, *Batillipes*, *Dipodarctus*, *Raiarctus*, *Tanarctus*, *Tholoarctus*, *Wingstrandarctus*

## Introduction

The phylum Tardigrada comprises microscopic animals ca. 100–1200 µm in length with a complex anatomy (Dewel & Dewel 1996, Møbjerg & Dahl 1996, Jørgensen *et al.* 1999, Greven 2007, Halberg *et al.* 2009). Tardigrades are members of the superclade Ecdysozoa, which comprise the molting invertebrates (Aguinaldo *et al.* 1997) and they have become widely known for their ability to survive extreme environmental conditions (Guidetti *et al.* 2011; Møbjerg *et al.* 2011; Welnicz *et al.* 2011). Traditionally tardigrades have been classified in Panarthropoda together with Arthropoda and Onychophora, a classification that has received recent support from mitochondrial genome arrangements (Rota-Stabelli *et al.* 2010) and brain and nerve system anatomy (Persson *et al.* 2012, Mayer *et al.* 2013, Persson *et al.* 2013). This phylogenetic position has, however, been questioned by a phylogenomic study (Dunn *et al.* 2008), who, in some of their analyses, place the tardigrades as the sister-group to Nematoda and Nematomorpha. The phylogenetic relationship between tardigrades and nematodes has been revealed as a possible long branch attraction artefact (Campbell *et al.* 2011). The Tardigrada is currently divided into three classes of Eutardigrada, Heterotardigrada and Mesotardigrada. The monotypic mesotardigrades have not been resampled since their original description from a hot spring in Japan (Rahm 1937). The eutardigrades are predominantly semi-terrestrial and limnic with a few marine species (Kristensen 1982; Møbjerg *et al.* 2007; 2011). Within the heterotardigrades the order Arthrotardigrada is primarily marine whereas the major taxa within the order Echiniscoidea occupy marine (tidal zone), limnic and semi-terrestrial habitats. Recent molecular phylogenies have primarily focused on the eutardigrades (and some echiniscoideans; Sands *et al.* 2008), arthrotardigrades (Jørgensen *et al.* 2010), echiniscoideans (primarily Echiniscidae; Jørgensen *et al.* 2011) and all tardigrades (Guil & Giribet 2011).

The marine arthrotardigrades belong to the meiofauna, the biodiversity of which has only been explored at a few global localities including Italian Mediterranean (de Zio Grimaldi & D'Addabbo Gallo 2001; D'Addabbo *et al.* 2007) and the North Atlantic Faroe Bank (Hansen *et al.* 2001). These investigations have reported several new tardigrade species. The present study investigates the tardigrade fauna in two Australian marine caves. The data obtained from sampling at these caves has previously resulted in *i*) the redescription of *Actinarctus neretinus* previously only known from a marine cave on the coast of Italy; *ii*) the description of a new species of kinorhynch *Echinoderes cavernus* Sørensen, Jørgensen & Boesgaard, 2000; *iii*) the description of a new loriciferan genus and two species *Australoricus oculatus* Heiner, Boesgaard & Kristensen, 2009 and *Pliciloricus cavernicola* Heiner, Boesgaard & Kristensen, 2009 (Sørensen *et al.* 2000; Heiner *et al.* 2009).

Two theories concerning the origin of cave fauna fits with that of the tardigrades. Vicariance proposes that the marine caves have acted as refugia for a relict Mesozoic fauna in coastal waters of the Tethys Sea (see Danielopol 1990). This could explain the distribution pattern of *A. neretinus* in caves of the Mediterranean and Tasman Seas. The deep-sea origin theory proposes that cave and deep-sea species are closely related (Iliffé *et al.* 1984). Support

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