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New insights into polyphyly of the harpacticoid genus *Delavalia* (Crustacea, Copepoda) through morphological and molecular study of an unprecedented diversity of sympatric species in a small South Korean bay

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Abstract

Polyphyly of the genus *Delavalia* Brady, 1869 has been postulated previously based on intuitive methods, but no phylogenetic study was ever conducted. A chance discovery of seven sympatric species of this genus in the highly industrialized Gwangyang Bay in South Korea, in addition to one species each from the closely related genera *Stenhelia* Boeck, 1865 and *Onychostenhelia* Itô, 1979, prompted a renewed interest in the phylogenetic relationships within the subfamily Stenheliinae Brady, 1880. Additional surveys along the Korean coast failed to produce *Delavalia* species, but comparative material was sourced from Posyet Bay in the Russian Far East. Aims of this study were to reconstruct phylogenetic relationships of the newly collected stenheliins using molecular methods, test the hypothesized polyphyly of *Delavalia,* formally describe any resulting monophyletic units, perform a comparative study of traditional morphological and novel micro-morphological characters, and describe all new *Delavalia* species. A fragment of the mtCOI gene was successfully PCR-amplified from 23 stenheliin specimens and an additional 300 specimens were studied for morphological characters. All phylogenetic analyses supported the presence of at least eight genetically divergent lineages, most with very high bootstrap values, and the polyphyletic nature of *Delavalia* is demonstrated. Three new genera, each supported by molecular data and a number of morphological synapomorphies, were erected to accommodate the newly discovered species and some previously described members of *Delavalia*: *Wellstenhelia* **gen. nov.**, *Itostenhelia* **gen. nov.**, and *Willenstenhelia* **gen. nov.** The Chinese *Wellstenhelia qingdaoensis* (Ma & Li, 2011) **comb. nov.** is recorded for the first time in Korea, and six new species are described from Gwangyang Bay: *Wellstenhelia calliope* **sp. nov.**, *Wellstenhelia clio* **sp. nov.**, *Wellstenhelia erato* **sp. nov.**, *Wellstenhelia euterpe* **sp. nov.**, *Itostenhelia polyhymnia* **sp. nov.**, and *Willenstenhelia thalia* **sp. nov.** Additonally, *Itostenhelia golikovi* (Chisleno, 1978) **comb. nov.** is redescribed from newly collected material from the type locality in Russia and its male described for the first time, while *Wellstenhelia melpomene* **sp. nov.**, *Willenstenhelia urania* **sp. nov.**, and *Willenstenhelia terpsichore* **sp. nov.** are established as new names for previously reported populations of two presumably widely distributed *Delavalia* species.

Key words: Harpacticoida, Miraciidae, marine, systematics, phyogeny, barcoding, new species

are most probably apomorphies accumulated during independent evolution and they include: lack of lateral seta on the second endopodal segment of the first leg, only one seta on the second endopodal segment of the male second leg, completely fused baseonendopod and exopod of the male fifth leg, and lack of armature on the male fifth leg endopodal lobe. Thus, it is quite possible that the peculiar shape of the female fifth leg in these taxa is also a result of convergent evolution. *Delavalia palustris* is the type species of the genus *Delavalia*, but apart from *Delavalia palustris bispinosa* (which could actually be a separate species) has no close relatives among extant species; however, this species is widely distributed, with reported geographic variability (see Lang 1948; Bodin 1970; Apostolov & Marinov 1988; Kornev & Chertoprud 2008), and future detailed study of its morphology and DNA may reveal that we are dealing with a species-complex, as is the case with many supposedly very widely distributed copepods (see Bláha et al. 2010; Karanovic & Krajicek 2012a, b; Hamrova et al. 2012).

Delavalia clavus (Wells & Rao, 1987) and *Delavalia paraclavus* (Wells & Rao, 1987) from the Andaman Islands in the Indian Ocean could also be distantly related to *Willenstenhelia*, as they have a similar armature formula of the swimming legs, and in particular absent seta on the second endopodal segment of the fourth leg. They also have a number of differences, which could be interpreted either as plesiomorphic (female fifth leg endopodal lobe with four setae, and absence of the curved spine on the second exopodal segment of the male fourth leg) or apomorphic features (spiniform process on the fifth leg exopod both in male and female, and only four setae on the second endopodal segment of the male second leg) when compared to the members of *Willenstenhelia*. These two species certainly represent a monophyletic unit among the currently known members of *Delavalia*, and all other species of this genus are even more distantly related to *Willenstenhelia.* The only other *Delavalia* without a seta on the second endopodal segment of the fourth leg is *Delavalia valens* (Wells & Rao, 1987), also from the Andaman Islands (Wells & Rao 1987), but it differs from *Willenstenhelia* in many characters, which probably suggest that the reduction of this seta occurred in stenheliins several times independently.

Two species currently assigned to the genus *Onychostenhelia* Itô, 1979 share with *Willenstenhelia* sexual dimorphism on the fourth leg exopod, but the transformation of this ramus in males of the former involves also a peculiar outgrowth of the proximal part of the third segment, in addition to the curved spine on the second segment (Itô 1979; Huys & Mu 2008). Although this structure may have the same function in both genera, numerous morphological differences between them in the armature and segmentation of the swimming legs, as well as transformations of the fifth leg, suggest that superficial similarities in the male fourth leg exopod could be a product of convergent evolution.

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