




# Molecular phylogeny of the snorkel snail *Rhiostoma housei*, a species complex from Thailand with descriptions of three new species

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## ABSTRACT

Snorkel snails (genus *Rhiostoma*) are widely distributed in Indo-China and on the Malay Peninsula. The shell morphology is traditionally used for species identification yet in Thailand, the common snorkel snail, *Rhiostoma housei*, shows considerable variation in shell morphology within and between populations. Therefore species identifications and delimitations are difficult. We used two mitochondrial DNA fragments (*COI* and *16S* rRNA) and morphological characters to delimit species and infer phylogenetic relationships of *Rhiostoma housei* s.l. from eight localities in Thailand, representing potential cryptic species suggested by earlier allozyme and karyological data. Results revealed four distinct clades from different geographic areas in Thailand. Species delimitation analyses confirmed the clades as four separate species and a geometric morphometric analysis demonstrated subtle but consistent conchological differences between the four clades. The high *COI* sequence divergences among the four clades (mean: 14.8%; range: 10.3–16.5%) further supported the species level recognition. As a consequence, three new species are described from Thailand: *R. khoratense*, sp. nov., *R. nakwangense*, sp. nov. and *R. phunangense*, sp. nov.

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## Introduction

Snorkel snails (family Cyclophoridae, genus *Rhiostoma* Benson, 1860) are ground-dwelling terrestrial operculate snails with a peculiar adult shell shape in which the last whorl is often detached from the rest of the shell to some degree. This last whorl is free compared to the weaker physical contact between the last and penultimate whorls due to a circular aperture (Chen *et al.* 2022). Near the end of the last whorl, there is a protruding, backward-bending, tube-like ‘siphon’ or ‘snorkel’ that functions as a breathing device with an incision or tubular shape, allowing gas exchange (Páll-Gergely *et al.* 2016). *Rhiostoma* also has a unique, cup-shaped, multispiral operculum. The snails usually live under leaf litter in limestone areas, feeding on microflora and fungi. Yet some species are also found in non-limestone areas. The genus is endemic to Indo-China and the Malay Peninsula (Benson 1860; Gude 1921). Traditionally the taxonomy of *Rhiostoma* was based solely on shell morphology. However, shell morphology in *Rhiostoma* is highly variable and shows considerable overlap among populations and species, whereas the morphology of the reproductive organs of cyclophorids is uninformative for species discrimination (Nantararat *et al.* 2014a, 2014b, 2019; Tongkerd *et al.* 2023). Therefore morphological species delimitation and identification in *Rhiostoma* remains ambiguous. Recently, however, Tongkerd *et al.* (2023) combined DNA barcode data and morphology to revise the genus and describe twelve new species, hence the