

Four new species of the genus *Pseudamnicola* Paulucci, 1878 from Morocco (Gastropoda: Hydrobiidae)

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ABSTRACT: New samples of freshwater molluscs collected in the northern part of Morocco revealed four new species of the genus *Pseudamnicola* Paulucci, 1878, i.e., *P. bouhaddiouii* sp.n., *P. berrahoui* sp.n., *P. tafoughaltensis* sp.n., and *P. skourensis* sp.n. Descriptions and photos of the species and the anatomy as well as the type localities are presented.

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KEY WORDS: Geographical barriers, endemism, new species, threatened taxa.

Четыре новых вида *Pseudamnicola* Paulucci, 1878 из Марокко (Gastropoda: Hydrobiidae)

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РЕЗЮМЕ: В новых пробах пресноводных моллюсков из северной части Марокко обнаружены четыре вида рода *Pseudamnicola* Paulucci, 1878: *P. bouhaddiouii* sp.n., *P. berrahoui* sp.n., *P. tafoughaltensis* sp.n. и *P. skourensis* sp.n. Представлены описания и фотографии внешнего вида и анатомии этих видов, а также иллюстрации типовых местонахождений.

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КЛЮЧЕВЫЕ СЛОВА: географические барьеры, эндемизм, новые виды, таксоны, находящиеся под угрозой.

Introduction

The truncatelloid family Hydrobiidae Stimpson, 1865 is supposedly one of the largest gastropod families and it is one of the most diverse gastropod families among freshwater molluscs throughout the Mediterranean region (Cuttelod *et al.*, 2011; Gloër, 2019). They are adapted to live in fresh, brackish water and marine habitats, and they feed on other available surfaces of their habitats (Ponder, 1984).

The family Hydrobiidae has received considerable attention in terms of species discoveries recently in Morocco and it is represented by several genera, among those, the genus *Pseudamnicola* Paulucci, 1878. It was proposed by Paulucci (1878) in order to distinguish it from the North American *Amnicola* Tryon, 1863. Species of the genus *Pseudamnicola* are distributed in the West Mediterranean from south Europe (Spain, France, Italy) to North Africa (Morocco, Algeria, Tunisia), and in the East Mediterranean in Bulgaria, Greece and Turkey, where the highest α -diversity of this genus was registered in the countries with a high investigation rate (Glöer *et al.*, 2010, Glöer *et al.*, 2014).

Previously, the genus *Pseudamnicola* was represented by only five species in Morocco, these are: *Pseudamnicola luteola* (Küster, 1852), *P. leprevieri* Ghamizi, Vala et Bouka, 1997, *P. dupotetiana* (Forbes, 1838), *P. ramosae* Boulaassafer, Ghamizi, Machordom et Delicado, 2020 and *P. ouarzatensis* Boulaassafer, Ghamizi, Machordom et Delicado, 2020. New investigations conducted recently through the Northern part of Morocco revealed four new species of the genus *Pseudamnicola*. The aim of this paper is to describe these new species.

Material and methods

Field surveys were conducted from 2014 (and still ongoing) through the northern part of the country, including in its great natural barriers such as the Moulouya River basin and the Middle Atlas massif. Most of these sampling sites were visited several times. Our goal was to document maximum macroinvertebrate biodi-

versity in the different microhabitats prospected at each sampling site. The samples of benthic fauna were collected by a kick net and clamps. The samples have been fixed in 75% ethanol.

The dissections and measurements of the genital organs and the shells were carried out using a stereo microscope (Leica M205C) with a digital camera (Leica DMC5400). The type material is mostly stored in the Zoological Museum of Hamburg (ZMH).

Results

Phylum Mollusca Cuvier, 1795

Class Gastropoda Cuvier, 1795

Superorder Caenogastropoda Cox, 1960

Superfamily Truncatelloidea Gray, 1840

Family Hydrobiidae Stimpson, 1865

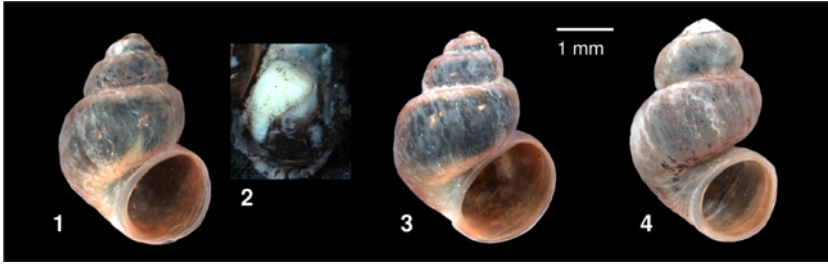
Genus *Pseudamnicola* Paulucci, 1878

TYPE SPECIES. *Bythinia lucensis* Issel, 1866.

In *Pseudamnicola* species, the renal oviduct is pigmented in black and bears a bursa as well as a receptaculum (rs1). The oviduct enters with one to three spiral loops into the kidney, before the pallial oviduct loops to the wall of the stomach.

IDENTIFICATION KEYS FOR *PSEUDAMNICOLA* SPECIES OF MOROCCO

1. Shell ovate-conic, with less than 3 whorls 2
- Shell bearing more than 3 whorls 3
2. Shell height 3.3 mm; penis gradually tapering, unpigmented with folds over the entire surface; penis base large; distal end tapered
..... *P. ouarzatensis*
3. Shell ovate-conic with less than 4 whorls 4
- Shell bearing more than 4 whorls 5
4. Shell height 1.7–2.6 mm; periostracum yellowish; penis slightly black pigmented on its dorsal region, gradually tapering with a rounded tip and folds over the entire inner edge...*P. leprevieri*
- Shell height 2–3.5 mm; penis gradually tapering, black pigmented on distal end, folded along inner edge and base*P. ramosae*
- Shell-height 2.1–2.9 mm; penis slightly black pigmented on the middle section, with folds over the entire inner surface and base
..... *P. dupotetiana*



Figs. 1–4. *Pseudamnicola bouhaddiouii* sp.n. 1 — holotype, 2 — penis *in situ*, 3–4 — paratypes.
Рис. 1–4. *Pseudamnicola bouhaddiouii* sp.n. 1 — голотип, 2 — пенис *in situ*, 3–4 — паратипы.

5. Shell globular-conical 6
 – Shell elongated conical 7
 6. Shell thin, light horn-coloured, glossy, shell height 3.15–3.22. The aperture is ovate, somewhat narrowed at the top. The peristome is slightly thickened at the columella, the umbilicus is slit like *P. tafoughaltensis* sp.n.
 – Shell dark-horn-coloured, shell height 2.58–2.77 mm. The penis is triangular with a broad basis *P. skourensis* sp.n.
 7. The umbilicus is closed 8
 – The umbilicus slit-like to closed. Shell elongated oval, horn-coloured, surface finely striated, glossy, shell height 4.5–5.0 mm. The penis is broad and obtuse at the distal end .. *P. luteola*
 8. Shell conical to elongated conical, dark horn-coloured, surface silky, shell height 3.78–4.28 mm high. The penis has a broad circular basis with a tapered distal part .. *P. berrahoui* sp.n.
 – Shell elongated conical, surface rough with irregular growth lines, shell height 4.01–4.21 mm. The penis is large and triangular *P. bouhaddiouii* sp.n.

Pseudamnicola bouhaddiouii sp.n.

urn:lsid:zoobank.org:act:D098D2DA-FD76-44AF-B557-193DB45550B5

Figs 1–4.

TYPE MATERIAL. Holotype ZMH 140909, Bekrit, Middle Atlas, 16.05.2021, 33° 03'54.9"N 5°13'34.5"W. leg. Y. Mabrouki, A.F. Taybi. 4.01 mm high, 3.0 mm broad. Same locality: 8 paratypes ZMH 140910, 3 paratypes coll. Glöer.

HABITAT. The species was found at a place named Bekrit, Meknes-Tafilalet region, located at an altitude of 1767 m. Located in the Middle Atlas, the region is characterized by various springs and their emissaries (Fig. 18a). The

whole area is disturbed by excessive water pumping and overgrazing. The type locality belongs to the Oum Errabiâ River basin.

DISTRIBUTION. Morocco, Middle Atlas, only known from type locality.

ETYMOLOGY. The new species was named after Dr. Abderrahim Bouhaddiou, who helped finding the new species, and in recognition for his efforts for protection the aquatic ecosystems of the Middle Atlas.

DESCRIPTION. The shell is elongated conical with 4.5–5 convex whorls with a deep suture. The surface is rough with irregular growth lines. The aperture is broad ovate, with a thickened inner lip. The umbilicus is closed. The shell is 4.01–4.21 mm high and 2.8–3.0 mm broad. The mantel as well as head and snout are black, eye spots are visible. The white penis is large and triangular, attached above the head.

DIFFERENTIAL DIAGNOSIS. The new species can be distinguished from the other Moroccan species by its elongated conical shell with more than 4 whorls. It can be confused with *P. luteola*, while the latter has a broad penis, obtuse at the distal end, *P. bouhaddiouii* has a triangular large penis, and in addition, the shell surface is rough with irregular growth lines.

Pseudamnicola berrahoui sp.n.

urn:lsid:zoobank.org:act:6C8847F6-3B8F-4FC7-9027-D1362A4E9128

Figs 5–9.

TYPE MATERIAL. Holotype ZMH 140911, Tamchachet, Middle Atlas, 16.05.2021, 33°04'15.4"N 5°15'37.2"W. leg. Y. Mabrouki,



Figs. 5–9. *Pseudamnicola berrahoui* sp.n. 5 — holotype, 6 — penis *in situ*, 7–9 — paratypes.
Рис. 5–9. *Pseudamnicola berrahoui* sp.n. 5 — голотип, 6 — пенис *in situ*, 7–9 — паратипы.

A.F. Taybi. 3.78 mm high and 3.1 mm broad. Same locality: 8 paratypes ZMH 140912, 4 paratypes coll. Glöer.

HABITAT. The new species was found at an altitude of 1703 m, in a river named Tamchachet (Fig. 5b), fed by numerous springs that rise on the banks. The banks are natural, with sparse herb-lined vegetation on the banks, subjected to strong anthropic pressure by excessive pastoralism. The bottom consists of blocks, stones, pebbles and a lot of plant debris.

DISTRIBUTION. Morocco, Middle Atlas, only known from type locality.

ETYMOLOGY. The species was named after Pr. Berrahou Ali (University Mohamed I of Oujda), in recognition for the many years of teaching generations and for his scientific works carried out on the aquatic ecosystems of Morocco.

DESCRIPTION. The shell is conical to elongated conical, with 4.5–5 slightly convex whorls, separated by a deep suture. The aperture is ovate to circular, the umbilicus is closed. The shell is 2.96–4.28 mm high and 2.32–3.08 mm broad. The mantle as well as head and snout are black, eye spots are visible. The penis is white and has a broad circular basis with a tapered distal part.

DIFFERENTIAL DIAGNOSIS. The new species *Pseudamnicola berrahoui* sp.n. can be distinguished from the other Moroccan species (*P. leprevieri*, *P. dupotetiana*, *P. ramosae* and *P. ouarzazatensis*) by its elongated conical shell with more than 4 whorls. It can be confused with *P. luteola*, while the latter has a broad penis, obtuse at the distal end and larger shells, *Pseudamnicola berrahoui* sp.n. has a broad circular

basis with a tapered distal part and smaller shells. *Pseudamnicola bouhaddioui* sp.n. can be distinguished from *P. berrahoui* sp.n. by shell morphology and the penis. The shell in *P. bouhaddioui* sp.n. has a rough surface with irregular growth lines, and the penis has triangular penis, while *P. berrahoui* sp.n. has smooth surface shells and large penis, broad at the basis and tapered at the distal end. However, further investigations are necessary on the existence of this new species.

Pseudamnicola tafoughaltensis sp.n.

urn:lsid:zoobank.org:act:B2221887-6CEF-4262-AE9B-57165FCAEF8E

Figs. 10–13.

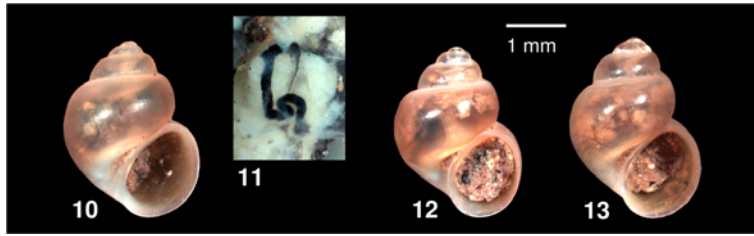
TYPE MATERIAL. Holotype ZMH 140913, Gîte Tagma, Tafoughalt, Bni Snassen, 04.2021, 34°49'26.3"N 2°25'46.1"W. leg. Y. Mabrouki, A.F. Taybi. 3.02 mm high and 3.22 mm broad. Same locality: 4 paratypes ZMH 140914, 2 paratypes in coll. Glöer.

HABITAT. The species was found in a spring partially modified, located in a forest area in the Bni Snassen Mountains at an altitude of 586 m. The vegetation is dense and the area is well shaded (Fig. 18c). The type locality belongs to the Moulouya River basin.

DISTRIBUTION. Morocco, Oriental Region, only known from type locality.

ETYMOLOGY. The species was named after Tafoughalt, the place where it was discovered.

DESCRIPTION. Shell globular-conical, thin, light horn-coloured, has 4.5–5 convex



Figs. 10–13. *Pseudamnicola tafoughaltensis* sp.n. 10 — holotype, 11 — penis *in situ*, 12–13 — paratypes.
Рис. 10–13. *Pseudamnicola tafoughaltensis* sp.n. 10 — голотип, 11 — пенис *in situ*, 12–13 — паратипы.

whorls with a deep suture, with a glossy surface. The aperture is ovate, somewhat narrowed at the top. The peristome is slightly thickened at the columella, the umbilicus is slit like. The shell is 3.15–3.22 mm high and 2.40–2.49 mm broad. The only female specimen had a black coloured oviductual loop, characteristic for *Pseudamnicola* (see also Glöer *et al*, 2010).

DIFFERENTIAL DIAGNOSIS. This new species can be distinguished from the other Moroccan species by its globular-conical shell with more than 4 whorls. *P. tafoughaltensis* sp.n. is readily distinguishable from the other two species described so far, by its globular-conical and light horn-coloured smaller shells.

Pseudamnicola skourensis sp.n.

urn:lsid:zoobank.org:act:145451B1-C3C7-433B-994E-327DB45C3B07

Figs. 14–17.

TYPE MATERIAL. Holotype ZMH 140915, Skoura, M'daz, Middle Atlas, 1.08.2021, 33°30'58.2"N 4°32'17.9"W. leg. Y. Mabrouki, A.F. Taybi. 2.68 mm high and 2.15 mm broad. Same locality: 10 paratypes ZMH

140916, 3 paratypes coll. Glöer.

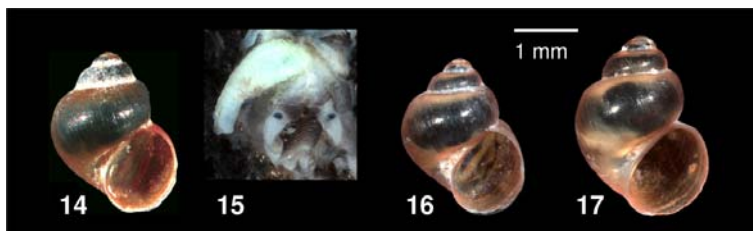
HABITAT. The new species was found in the Skoura waterfall (Fig. 18d) at 1257 m of altitude. Located in the Middle Atlas, Skoura M'daz is a small town and rural commune in Boulemane Province of the Fes-Meknes region of Morocco. The type locality belongs to the Sebou River basin, is in Taddout valley, known for these 3 waterfalls and various springs.

DISTRIBUTION. Morocco, Middle Atlas, only known from type locality.

ETYMOLOGY. The species was named after Skoura M'daz, the place where it was discovered.

DESCRIPTION. The globose-conical shell has 4.5–5 slightly convex whorls with a deep suture, dark horn-coloured. The aperture is ovate, the inner lip is slightly thickened. The umbilicus is slit-like. The shell is 2.58–2.77 mm high and 2.07–2.15 mm broad. The mantle is black with a whitish border, eye spots are visible. The penis is triangular with a broad basis and a tapered distal part.

DIFFERENTIAL DIAGNOSIS. The new species *P. skourensis* sp.n. can be distinguished *P. leprevieri*, *P. dupotetiana*, *P. ramosae* and *P.*



Figs. 14–17. *Pseudamnicola skourensis* sp.n. 14 — holotype, 15 — penis *in situ*, 16–17 — paratypes.
Рис. 14–17. *Pseudamnicola skourensis* sp.n. 14 — голотип, 15 — пенис *in situ*, 16–17 — паратипы.



Fig. 18. Habitats of the new *Pseudamnicola* spp. A — *P. bouhaddioui* sp.n.; B — *P. berrahoui* sp.n.; C — *P. tafoughaltensis* sp.n.; D — *P. skourensis* sp.n.

Рис. 18. Биотопы новых видов *Pseudamnicola* spp. A — *P. bouhaddioui* sp.n.; B — *P. berrahoui* sp.n.; C — *P. tafoughaltensis* sp.n.; D — *P. skourensis* sp.n.

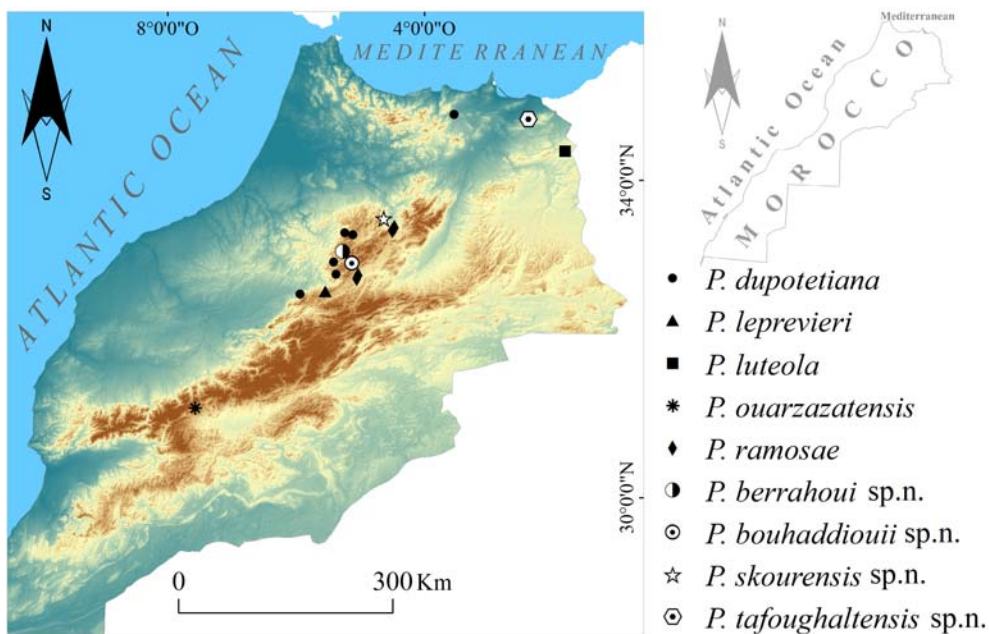


Fig. 19. Distribution of *Pseudamnicola* spp. in Morocco.

Рис. 19. Распространение *Pseudamnicola* spp. в Марокко.

ouarzazatensis by its elongated conical shell with more than 4 whorls, and from its other Moroccan congeners spp. by its smaller shells and its penis triangular with a broad basis and a tapered distal part.

Discussion

Pseudamnicola bouhaddioui sp.n., *P. berahoui* sp.n., *P. tafoughaltensis* sp.n., and *P. skourensis* sp.n. can be distinguished from their Moroccan congeners by anatomy in combination with the shell characters. Species of the genus *Pseudamnicola* seem to be closely related to mountainous areas in Morocco (Fig. 19). *P. ouarzazatensis* seems limited to the High Atlas, *P. tafoughaltensis* sp.n. to the Bni Snassen massif, *P. luteola* to the Horst mountain range. While *P. bouhaddioui* sp.n., *P. berrahoui* sp.n., *P. skourensis* sp.n., *P. ramosae* and *P. dupotetiana* are distributed through the Middle Atlas massif, the latter one can also be found in the oriental Rif at Midar (according to Boulaasafer *et al.*, 2021).

Our findings raise the known biodiversity of *Pseudamnicola* in Morocco to nine species (Mabrouki *et al.*, 2020, Boulaasafer *et al.*, 2021). Considering its various natural barriers and its geographical position, which is a contact area between Africa and Europe receiving influences from both the Atlantic Ocean and the Mediterranean Sea, Morocco possesses a high level of endemism in its freshwater fauna (Mabrouki *et al.*, 2019a, b; Taybi *et al.*, 2020). A rich biodiversity of freshwater snails could be expected, since *Pseudamnicola* is a very rich genus in the western Mediterranean, e.g., 15 species are known from Algeria only (Glöer *et al.*, 2010).

Up to now, 17 genera have been identified belonging to the Hydrobiidae family *sensu stricto* in Morocco (Mabrouki *et al.*, 2021a, 2022). However, despite a growing number of data over the last years, resulting in the discovery of many new taxa (Glöer *et al.*, 2020a, b; Ghamizi, 2021; Mabrouki *et al.*, 2021b; Taybi *et al.*, 2021), our knowledge of freshwater snails of Morocco remains scanty and we could argue

that the picture of hydrobiid species list in North Africa is still incomplete.

Even possessing the most extensive river system in North Africa, Morocco is in the red zone in terms of forecasts in relation to climate change, i.e. at risk of water scarcity with a decrease in precipitation (Sbaa, Vanclooster 2017). In addition, like in most of the North African territory, freshwater ecosystems are considered highly threatened across the country. Therefore, the study and description of new freshwater taxa is an urgent need, before they are gone forever.

Compliance with ethical standards

Conflicts of interest: The authors declare that they have no conflicts of interest.

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