Contribution to the taxonomic study of *Theodoxus* Montfort, 1810 (Mollusca, Gastropoda: Neritidae) from the Iberian Peninsula and Balearic Islands

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Abstract

Contribution to the taxonomic study of Theodoxus *Montfort, 1810 (Mollusca, Gastropoda: Neritidae) from the Iberian Peninsula and Balearic Islands.* In this study the taxonomic status of the freshwater mollusc species of *Theodoxus* from the Iberian Peninsula and Balearic Islands is clarified, based on previous molecular studies carried out on more than 60 European samples. The results obtained largely corroborate the data obtained by Bunje & Lindberg (2007), and allow us to know for the moment four species in the study area: *T. fluviatilis*, *T. meridionalis*, *T. mixta* and *T. valentinus*, being these last two species mentioned very similar according to their molecular sequences. So, we maintain them as valid species. *Neritina baetica* and *Neritina hispalensis* must be considered as *nomina dubia*. The rest of the taxa described in the study area are considered junior synonyms of *T. meridionalis*. The use of the operculum to determine the species treated in the study area is questioned. In addition, at the museum level, the type series of various species such as *Neritina baetica*, *N. hidalgoi*, *N. mixta*, *N. valentina*, *N. velascoi* and *Nerita meridionalis* are reviewed, designating some of their type specimens.

Keywords: Neritidae, *Theodoxus*, taxonomy, Iberian Peninsula, Spain, Balearic Islands, Portugal.

Resumen

Contribución al estudio taxonómico de Theodoxus *Montfort, 1810 (Mollusca, Gastropoda: Neritidae) de la península ibérica y Baleares.* En este estudio se clarifica el estatus taxonómico de las especies de moluscos de agua dulce del género *Theodoxus* que viven en la península ibérica y Baleares, basado en los estudios moleculares previos realizados sobre más de 60 muestras europeas. Los resultados obtenidos corroboran en gran medida los datos obtenidos por Bunje & Lindberg (2007), y nos permiten conocer por el momento cuatro especies en el área de estudio: *T. fluviatilis*, *T. meridionalis*, *T. mixta* y *T. valentinus*, siendo estas dos últimas especies muy similares atendiendo a sus secuencias moleculares, por lo que, por el momento, las mantenemos como especies válidas. *Neritina baetica* y *N. hispalensis* deben ser considerados *nomina dubia*. El resto de taxones descritos en el área de estudio se consideran sinónimos posteriores de *T. meridionalis*. Se cuestiona el uso del opérculo para determinar las especies tratadas en el área de estudio. Además, a nivel museistico se revisan las series tipo de varias especies como *Neritina baetica*, *N. hidalgoi*, *N. mixta*, *N. valentina*, *N. velascoi* y *Nerita meridionalis*, designando algunos de sus ejemplares tipo.

Palabras clave: Neritidae, *Theodoxus*, taxonomía, península ibérica, España, islas Baleares, Portugal.
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Introduction

Theodoxus Montfort, 1810, a taxon of freshwater gastropod mollusc, is widely distributed throughout the Iberian Peninsula and Balearic Islands (Vidal–Abarca & Suárez, 1985; Welter–Schultes, 2012; Glöer, 2019, among others), but it is not known from the Macaronesian islands (Falkner *et al*., 2002). Several species of *Theodoxu*s are known from the Iberian Peninsula: *T. fluviatilis* (Linnaeus, 1758), a species with a wide Palaearctic distribution, and *T. baeticus* (Lamarck, 1822), *T. hispalensis* (von Martens, 1879) and *T. mixta* (Westerlund , 1892), all them species described from Andalusia, as well as *T. hidalgoi* (Crosse, 1881), *T. valentinus* (Graells, 1846) and *T. velascoi* (Graells, 1846), described from the Valencian Community, and *T. elongatulus* (Morelet, 1845), *T. violaceus* (Morelet, 1845), *T. inquinatus* (Morelet, 1845) and *T. guadianensis* (Morelet, 1845) from Portugal. Traditionally, according to authors, three or four valid species had been considered as present in Spain (Gasull, 1971; Fechter & Falkner, 1993; Alonso *et al*., 2001; Martínez–Ortí & Robles, 2003, and others): *T. baeticus*, *T. fluviatilis*, *T. valentinus* and/or *T. velascoi*. *Theodoxus fluviatilis* was widely distributed throughout the peninsula, *T. baeticus* extended from Andalusia to the Valencian Community and the Balearic Islands, and *T. valentinus* that has been considered as a valid species and as a junior synonym of *T. velascoi*, both Valencian endemisms (Gasull, 1971; Fechter & Falkner, 1993; Alonso *et al*., 2001; Martínez–Ortí & Robles, 2003; Martínez–Ortí *et al.*, 2006b, 2006c, 2009b, 2009c; Martínez–Ortí, 2007). *Theodoxus velascoi* was listed in the National Catalogue of Threatened Species with the category of "endangered" until August 2015 (BOE, 2015; Martínez–Ortí, 2017), when it was excluded from this list after a report sent in 2014 by one of the authors (Martínez–Ortí) to the Scientific Committee of the "Ministerio Español para la Transición Ecológica y Reto Demográfico". In that report appeared the results of the molecular studies carried out on the genus *Theodoxus* in Spain. Martínez–Ortí & Robles (1996) proposed the selection of a neotype for both species and thus ensure the stability of the nomenclature, in accordance with Article 75 of the I.C.N.Z., given that the identity of *T. velascoi* and *T. valentinus* had not been sufficiently justified. In 1996 Martínez–Ortí discovered a population of *T. valentinus* in the Verd river (Massalavés, Valencia), considered the only known living population of this species (Robles *et al*., 1996; Martínez–Ortí, 1998; Alonso *et al*., 2001; Martínez–Ortí & Robles, 2003; Martínez–Ortí *et al*., 2006b, 2009b). Alonso *et al*. (2001) and Martínez–Ortí & Robles (2003) pointed out that *T. baeticus* constitutes a complex of species that has not been clarified yet, and they also considered *T. velascoi* and *T. valentinus* different species, according to the morphological differences of the shells.

Until Bunje (2004, 2005) and Bunje & Lindberg (2007) the species of the genus *Theodoxus* in the Iberian Peninsula had been identified exclusively based on conchological characters. These authors studied the phylogeny of the genus using Spanish material that Martínez–Ortí previously identified and then sent to P. Bunje in 2002: *T. velascoi*, *T. valentinus* (from Verd river, Valencia), *T. baeticus* and *T. fluviatilis*. For the first time, molecular studies were carried out on numerous *Theodoxus* taxa from various European, North African and Near Eastern countries. The results of the phylogenetic study by Bunje & Lindberg (2007) indicated that there are populations conchiologically determined by A. Martínez–Ortí for the same species which are included in different clades of their phylogenetic tree, such as some populations assigned to *T. baeticus*, which were reassigned to *T. fluviatilis.* In addition, they grouped the Valencian populations identified as *T. baeticus*, with those from Sicily, Tunisia, Greece and Turkey, and reassigned the populations of *T. valentinus* and *T. velascoi* of the Verd river, from

specimens sent by A. Martínez–Ortí, to *T. baeticus*. It was still pending to know the taxonomic status of *T. valentinus* from Sants river ("riu dels Sants") (locus typicus). For thats reason, A. Martínez–Ortí and F. Robles subsequently started a project based on molecular data to clarify that issue. Martínez–Ortí *et al*. (2015), at the Forum of the Spanish Society of Malacology that took place in Málaga, presented the results of that project carried out on specimens from 54 Iberian and Balearic populations of *Theodoxus*. Some of these samples were part of the same ones that were sent to P. Bunje for his molecular study. Welter–Schultes (2012) had indicated the presence of six species in the Iberian Peninsula and the Balearic Islands: *T. baeticus, T. elongatulus, T. fluviatilis, T. hispalensis, T. valentinus* and *T. velascoi*. However, Martínez–Ortí *et al*. (2015), based on the molecular data obtained, concluded that the species that live in Spain and the Balearic Islands are *T. fluviatilis*, *T. meridionalis* (Philippi, 1836) and *T. valentinus*, and also considered *T. baeticus* as junior synonym of *T. fluviatili*s. In addition, they considered *T. valentinus* as extinct, and renamed *T. baeticus* (Lamarck, 1822) as *T. meridionalis*, being the first authors to do it. More recently, Glöer (2018, 2019) disagrees with Martínez–Ortí *et al*. (2015) and indicates the presence in the Peninsula of only three species: *T. fluviatilis, T. valentinus* (from Verd river) and *T. baeticus*, and considers *T. elongatulus* and *T. meridionalis* junior synonyms of *T. baeticus* and *T. velascoi* junior synonym of *T. valentinus*. Glöer (2018, 2019) considers that the operculum is a discriminating character within the genus *Theodoxus*, being the most important structures the apophysis and the pseudo-apophysis. Sands *et al*. (2020) consider that *T. baeticus* lives in the Iberian Peninsula and the Balearic Islands, as already said Bunje & Lindberg (2007) and later Martínez–Ortí *et al*. (2015), named it as *T. meridionalis*, designate the lectotype of *T. baeticus*, deposited at the Museum of Natural History of Geneva (MNHG), and also consider *T. meridionalis* a junior synonym of *T. baeticus*. About *T. valentinus* they refrain until type material is studied genetically, although however Martínez–Ortí *et al*. (2015) and Martínez–Ortí (2017) had already confirmed that. In this work we want to clarify the current taxonomic status of the *Theodoxus* species that live in the Iberian Peninsula and the Balearic Islands through a phylogenetic study, continuing the previous work of Bunje & Lindberg (2007), mainly with respect to *T. valentinus* and *T. meridionalis*. Numerous opercula of specimens from the studied area are shown and compared herein to verify their validity to discriminate species of *Theodoxus*. In addition, we illustrate the type series of several species, deposited at various European and South American museums, such as *T. baeticus*, *T. hidalgoi, T. mixta, T. meridionalis, T. valentinus* and *T. velascoi*, and also designate some of their type specimens to stabilize their taxonomic status.

Material and methods

Since the 1990s, one of the authors (Martínez–Ortí) has analized numerous samples of *Theodoxus* housed at various museums such as "Museo Nacional de Ciencias Naturales" of Madrid (MNCN), "Museu de Ciències Naturals" of Barcelona and "Museu Valencià d'Història Natural" (Alginet, Valencia) (MVHN). In this project, one of the important tasks has been the revision and iconography of the some type series, such as *Neritina valentina* and *N. velascoi*, deposited at the MNCN, *N. baetica* at the MNHG of Geneva, *N. mixta* Westerlund, 1892 at the Swedish Museum of Natural History of Stockholm (SMNH) and at the MNCN, *N. hidalgoi* Crosse, 1881 at the "Muséum National d'Historie Naturelle" of Paris (MNHN) and *Nerita meridionalis* present in the Philippi collection at the "Museo Nacional de Historia Natural" of

Santiago de Chile (MNHNCL), all of them discussed later. Shells and opercula of the treated taxa are illustrated.

Results and discussion

Theodoxus species that we have considered as present in the Iberian Peninsula and Balearic Islands, based in the analysis of our phylogenetic study, are *T. fluviatilis*, *T. meridionalis*, *T. mixta* and *T. valentinus*. In addition, data on other taxons described in the studied area are provided such as "uncertain or junior synonyms".

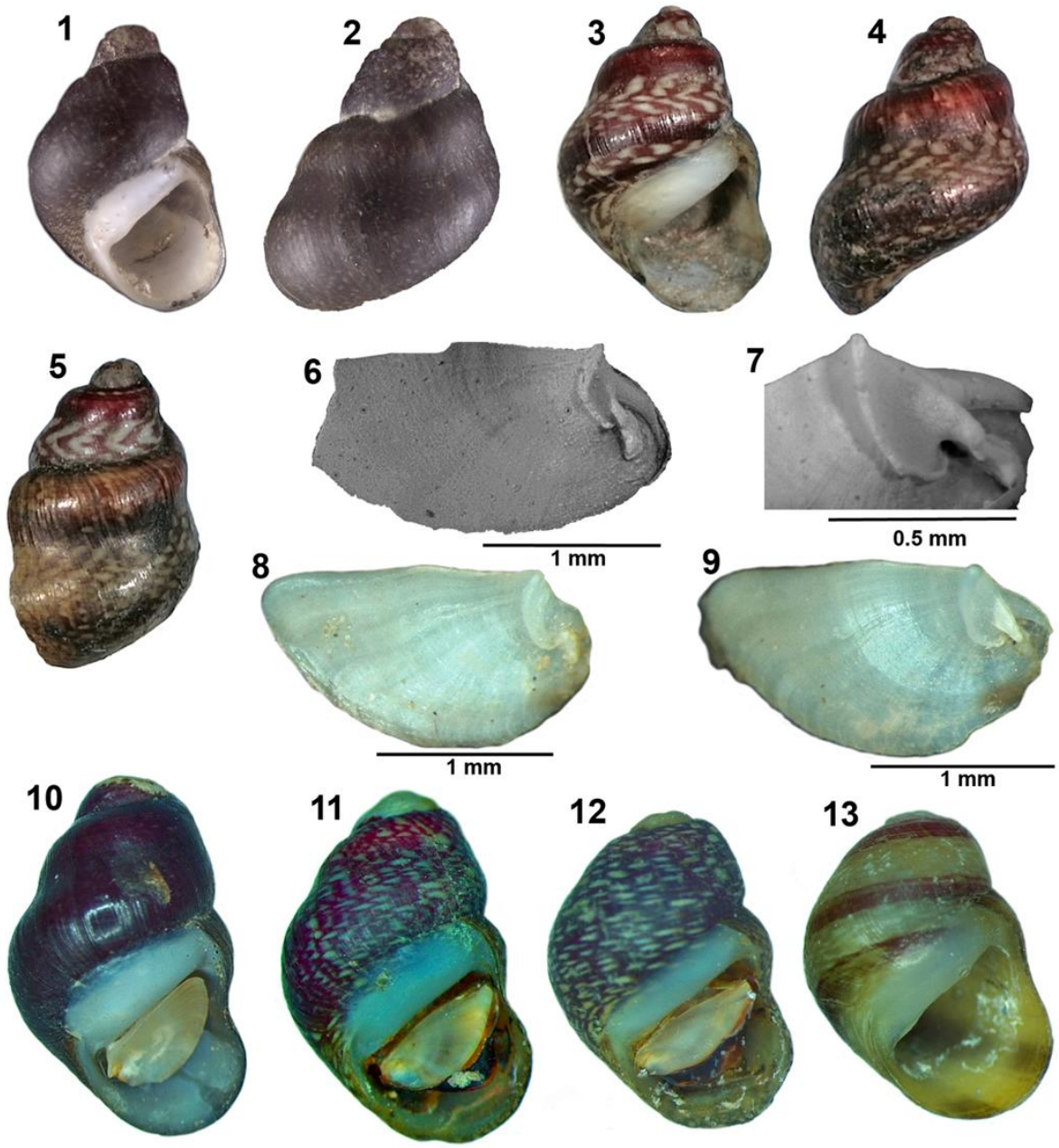
Theodoxus valentinus (Graells, 1846) (Figs 1–13)

Neritina valentina Graells, 1846

Type locality: Venta del Conde, Alcudia de Crespins (Valencia).

Type material: Martínez–Ortí & Robles (1996) selected a specimen for its designation as neotype (MNCN 15.05/24887) (Figs 3–5) from a sample containing 45 specimens (MNCN 15.05/9736). More recently, Arconada *et al*. (2020) found the type series of *N. valentina*, an original sample from the M. Graells collection that they considered composed by syntypes, although they did not designate the lectotype, an action herein with the code MNCN 15.05/9717L (Figs 1–2). This species lived in the Sants river near "La Venta del Conde" (Alcudia de Crespíns, Valencia) (Martínez–Ortí & Robles, 1996, 2003; Alonso *et al*., 2001; Martínez–Ortí, 2007).

Remarks: Traditionally, *T. valentinus* was considered junior synonym of *T. velascoi* (Gasull, 1971; Robles *et al*., 1996; Glöer, 2019). Gasull (1971) collected living specimens of *T. valentinus* in December 1967 and Robles *et al*. (1996), in various samplings, between June 1979 and March 1982, as well. Samples from the F. Robles collection, having collection dates coincident with two samplings carried out by this specialist, are deposited at the MVHN (MVHN–030719RL04 and MVHN–2061). Starting in 1983, as a consequence of the diversion of the waters of the Sants river (locus typicus) for irrigation, no living specimens had been found again (Martínez–Ortí, 2007). Later, in new detailed samplings carried out between 1993 and 1995 by A. Martínez–Ortí and F. Robles, no living specimens were found either (Robles *et al*., 1996). In 2014, we sampled through the underground waters of Alcudia de Crespins with members of the Valencian Speleology Society, but unsuccessful. However, the finding of mummified soft parts inside some of the specimens preserved in our collections of the MVHN (Figs 10–13), allowed us to present the radula of this species for the first time (Robles *et al*., 1996), which showed differences with respect to that of *T. fluviatilis*. More recently, it allowed successful molecular studies of this species, proving that it is a valid species (Martínez–Ortí *et al*., 2015; Martínez–Ortí, 2017). Unfortunately, this information has also allowed us to consider *T. valentinus*, for the moment, as an extinct species (Martínez–Ortí *et al*., 2015; Martínez–Ortí, 2017). The population discovered in 1996 attributed to *T. valentinus* in the Verd river (Massalavés) corresponds to *T. meridionalis* (Bunje & Lindberg, 2007; Martínez–Ortí *et al*., 2015). Sands *et al.* (2020) indicate that the taxonomic status of *T. valentinus* is dubious given the variation in operculum structure or similarity with other species still require phylogenetic assessment in conjunction with a review of the type material to warrant proper conservation consideration. However, it had already been realized and confirmed by Martínez–Ortí *et al.* (2015) and Martínez–Ortí (2017).



Figures 1–13. *Theodoxus valentinus* Graells, 1846; 1–2. Lectotype (design. nov.) (MNCN 15.05/9717L; height (h)=12.0 mm); 3–5. Specimen selected as neotype by Martínez–Ortí & Robles (1996) (MNCN 1505/24887; h=10.13 mm); 6–7. Opercula (S.E.M. Hitachi S–4100) (MNCN 15.05/9736); 8–9. Opercula of specimens of the sample MVHN–1145; 10. Specimen of the sample MVHN–1145 (h=10.0 mm); 11–12. Specimens with mummified soft parts inside the shells (MVHN–030719RL04) (11: h=9.0 mm; 12: h=8.4 mm); 13. Specimen of the sample MVHN–2061 (h=7.0 mm).

Figuras 1–13. Theodoxus valentinus *Graells, 1846; 1–2. Lectotipo (design. nov.) (MNCN 15.05/9717L; Altura (h)=12,0 mm); 3–5. Ejemplar seleccionado como neotipo por Martínez–Ortí & Robles (1996) (MNCN 1505/24887; h=10,13 mm); 6–7. Opérculos (S.E.M. Hitachi S–4100) (MNCN 15.05/9736); 8–9. Opérculos de ejemplares de la muestra MVHN–1145; 10. Ejemplar de la muestra MVHN–1145 (h=10,0 mm); 11–12. Ejemplares con cuerpo momificado en su interior (MVHN–030719RL04) (11: h=9,0 mm;12: h=8,4 mm); 13. Ejemplar de la muestra MVHN–2061 (h=7,0 mm).*

***Theodoxus meridionalis* (Philippi, 1836) (Figs 14–17, 19–24, 25–46)**

Nerita meridionalis Philippi, 1836

(Junior synonyms: *Neritina elongatula* Morelet, 1845, *Neritina guadianensis* Morelet, 1845, *Neritina hidalgoi*, 1881, *Neritina inquinatus* Morelet, 1845, *Neritina velascoi* Graells, 1846, *Neritina violacea* Morelet, 1845).

Type locality: Siracusa (Sicily, Italy) (locus typicus, restr. nov.). Although Philippi indicates as its habitat in the rivers of Sicily, we restrict the type locality to the freshwaters of Siracusa, based on the label with the locality name that appears handwritten by R. Philippi, found on the sample of his collection (MNHNCL) in Santiago de Chile (Fig. 18).

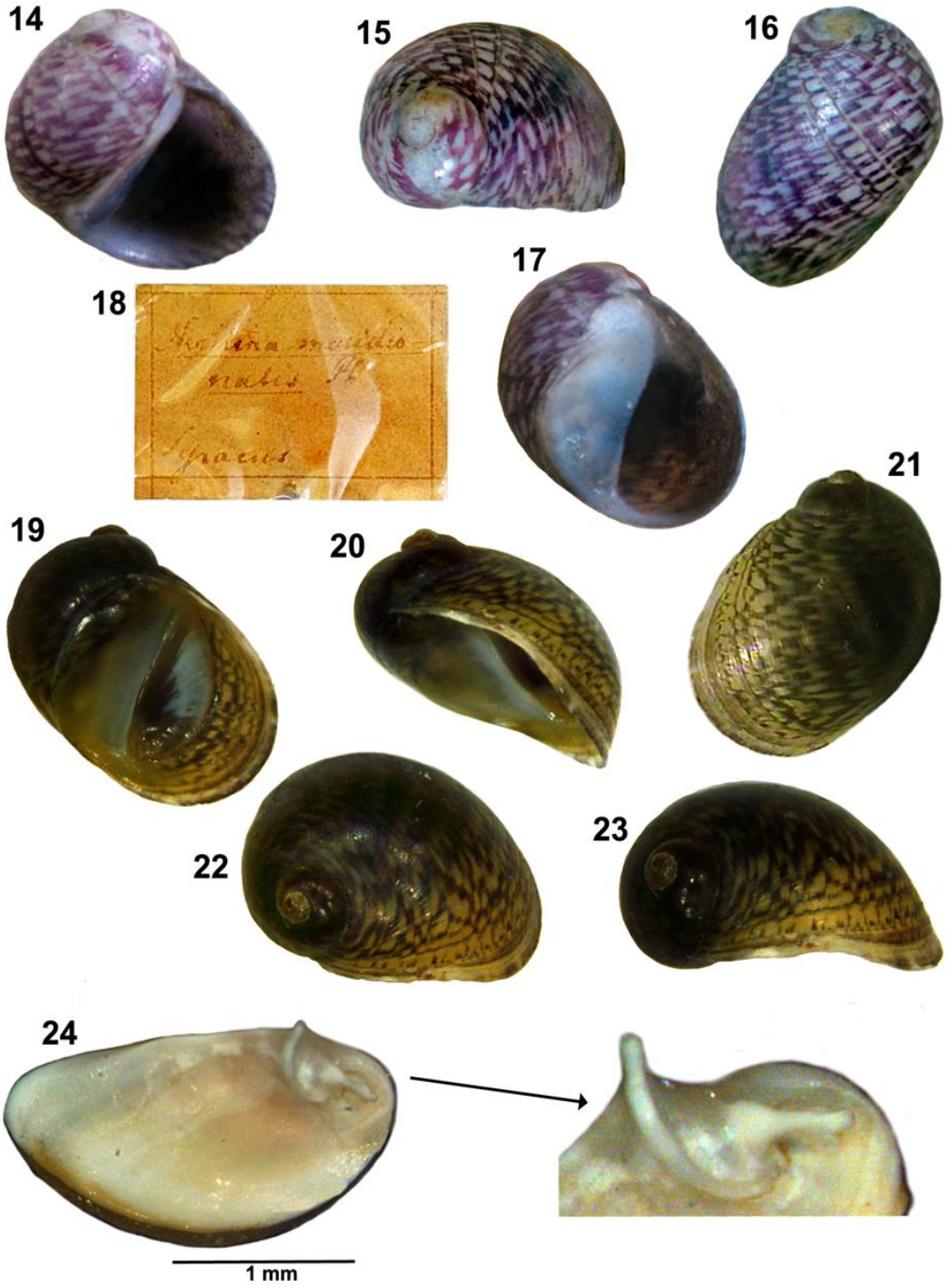
Type material: Part of the type series, 14 syntypes, has been found in the Rodulfo Amando Philippi collection at the National Museum of Natural History in Santiago de Chile (MNHNCL) of which he became the director. From them, the lectotype (design. nov.) is selected and designated, separated with the code MNHNCL–205420 [height (h)=5.3 mm; width (w)=7.2 mm], and the remaining 13 specimens are paralectotypes with the code (MNHNCL–205419). Glöer (2018) and Sands *et al*. (2020) studied forty syntypes of *T. meridionalis* preserved at the Museum für Naturkunde of Berlin, which must now be considered paralectotypes.

Remarks: Bunje & Lindberg (2007) considered *Neritina baetica* and *Nerita meridionalis* the same taxon, and they named it as *Theodoxus baeticus*, by the priority of the date of its description, which is later followed by other authors such as Martínez–Ortí & Robles (2008), Martínez–Ortí *et al*. (2009a), Welter–Schultes (2012), Glöer (2018, 2019) and Sands *et al*. (2020). However, Martínez–Ortí *et al*. (2015) named it as *T. meridionalis*, since they considered *T. baeticus* as a junior synonym of *T. fluviatilis*, because the molecular sequence obtained from the Sevillian sample, assigned to *T. baeticus*, is grouped with that of *T. fluviatilis* of the sample of Uppsala (Sweden). Glöer (2019) considered *T. meridionalis* endemic to Sicily and Zettler & Van Damme (2010) considered that it extends through Sicily and Tunisia, following Bunje & Linberg (2007). Previously, *T. meridionalis* was only known in the Iberian Peninsula from two lists of Spain from the 19th century compiled by Vidal–Abarca & Suárez (1985). In addition, these authors suggested that it does not live in Spain because it was an Italian endemism. Since at present *Neritina baetica* must be considered *nomen dubium* this Andalusian taxon should be named as *T. meridionalis* (see later). This species presents an operculum with a pseudo-apophysis of variable extension towards the edge of the operculum (Figs 24, 28–29, 38, 40–42, 44–46), and in our opinion it lacks sufficient taxonomic value to distinguish that putative species from the other species that live in Andalusia, such as *T. fluviatilis* (Figs 48, 51–52, 54–58, 60–61) or *T. mixta* (Fig. 72), and even *T. valentinus* (Figs 6–9). Welter–Schultes (2012) considered *T. elongatulus* (Morelet, 1845) a valid species restricted to Portugal, but we consider it a junior synonym of *T. meridionalis*.

-*Neritina velascoi* Graells, 1846 (Figs 25–31).

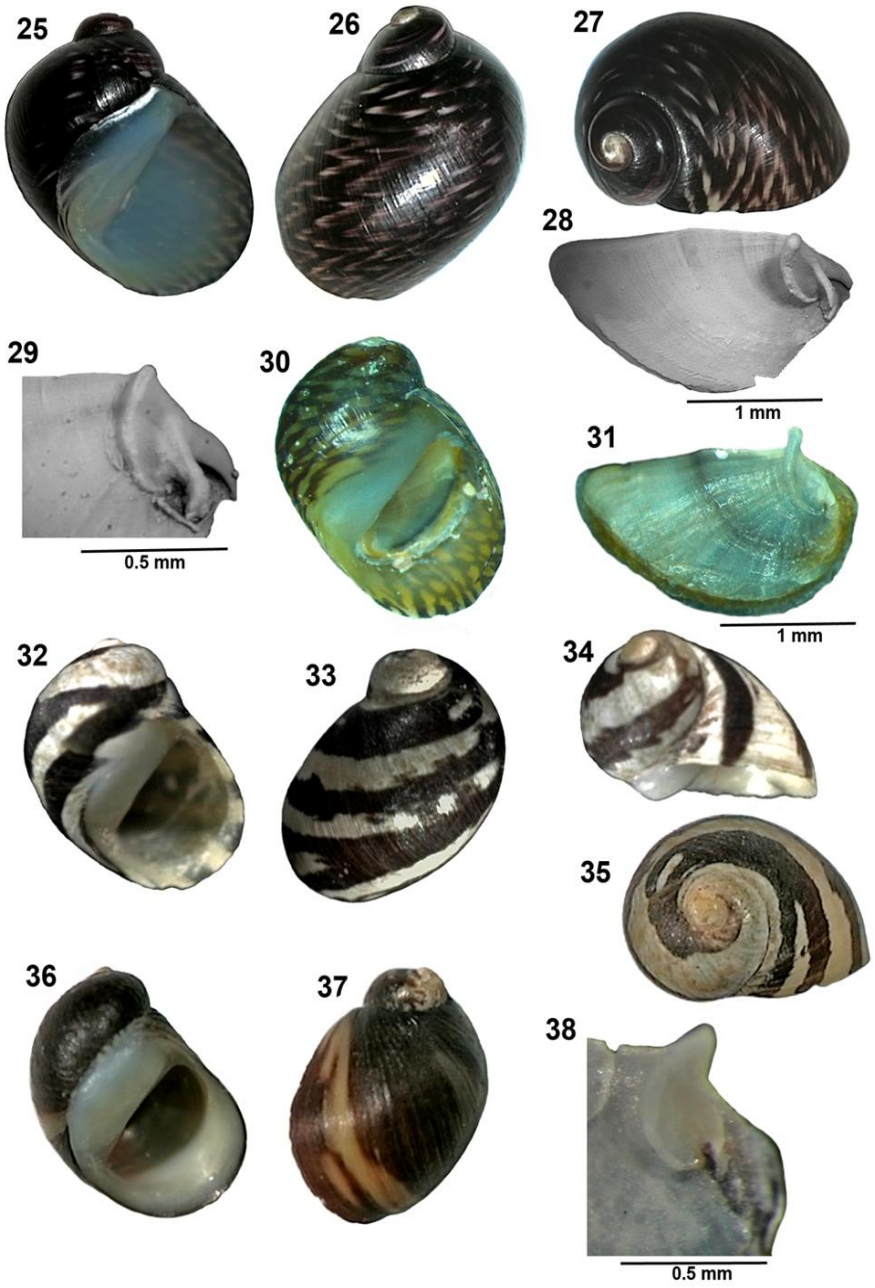
Type locality: Even though Graells (1846) indicated as type locality the surroundings of Albaida and San Felipe of Játiva (=Xàtiva), we restrict the locus typicus to conduction of drinking water to Xátiva (Valencia) (restr. nov.), as already was proposed by Martínez–Ortí & Robles (1996), based on the label present in the sample MNCN 15.05/9708.

Type material: Neotype of *Neritina velascoi* (design. nov.) separate with the code MNCN 15.05/24886 (Figs 25–27). Martínez–Ortí & Robles (1996) already proposed this selected specimen as a neotype that is now confirmed.



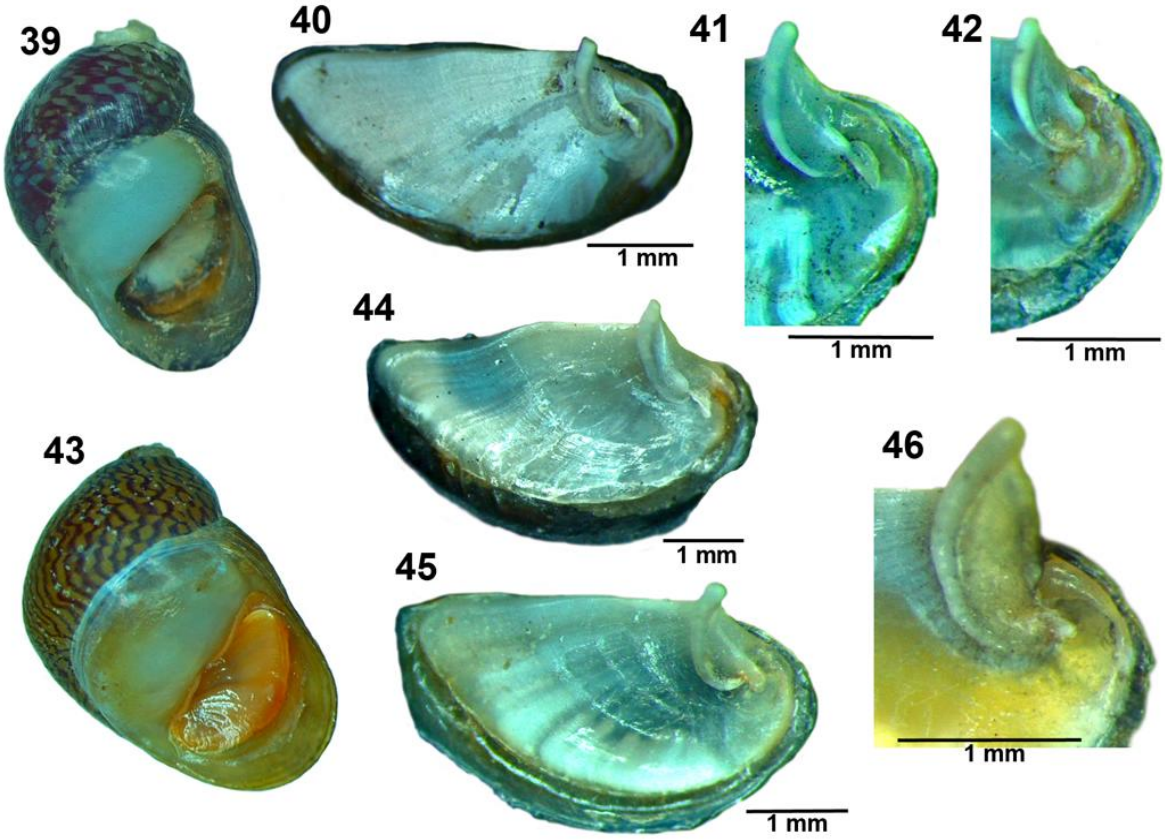
Figures 14–24. *Theodoxus meridionalis* (Philippi, 1836); 14–17. Lectotype (design. nov.) (MNHNCL–205420, Philippi Col., h=5.3 mm), from Siracusa (Sicily, Italy) (locus typicus, restr. nov.); 18. Label of the sample of the type series deposited at the MNHNCL; 19–24. Topotype from the Anapo river, Pantalica, Siracusa, Italy (MVHN–280714SM02) (h=6.9 mm); 24. Operculum of another topotype.

Figuras 14–24. Theodoxus meridionalis *(Philippi, 1836); 14–17. Lectotipo (design. nov.) (MNHNCL–205420, Col. Philippi, h=5,3 mm), Siracusa (Sicilia, Italia) (locus typicus, restr. nov.); 18. Etiqueta de la muestra de la serie tipo depositada en el MNHNCL; 19–24. Topotipo procedente del Río Anapo, Pantalica, Siracusa, Italia (MVHN–280714SM02) (h=6,9 mm); 24. Opérculo de otro topotipo.*



Figures 25–38. Shells and opercula of *Neritina velascoi* Graells, 1846 and *Neritina hidalgoi* Crosse, 1881; 25–27. Neotype of *N. velascoi* (design. nov.). Conduction of drinking water to Xàtiva (Valencia) (locus typicus, restr. nov.) (MNCN 15.05/24886) (h=9.15 mm); 28–29. Specimen from the same locality as the neotype (MNCN 15.05/9708); 30–31. *N. velascoi*, spring next to the drinking water pipe to Xàtiva, Bellús (Valencia) (topotype) (h=7.8 m); 32–35. Lectotype of *N. hidalgoi* (h=4.8 mm); 36–37. Paralectotypes of *N. hidalgoi* (h=5.62 mm); 38. Operculum of a paralectotype of *N. hidalgoi*.

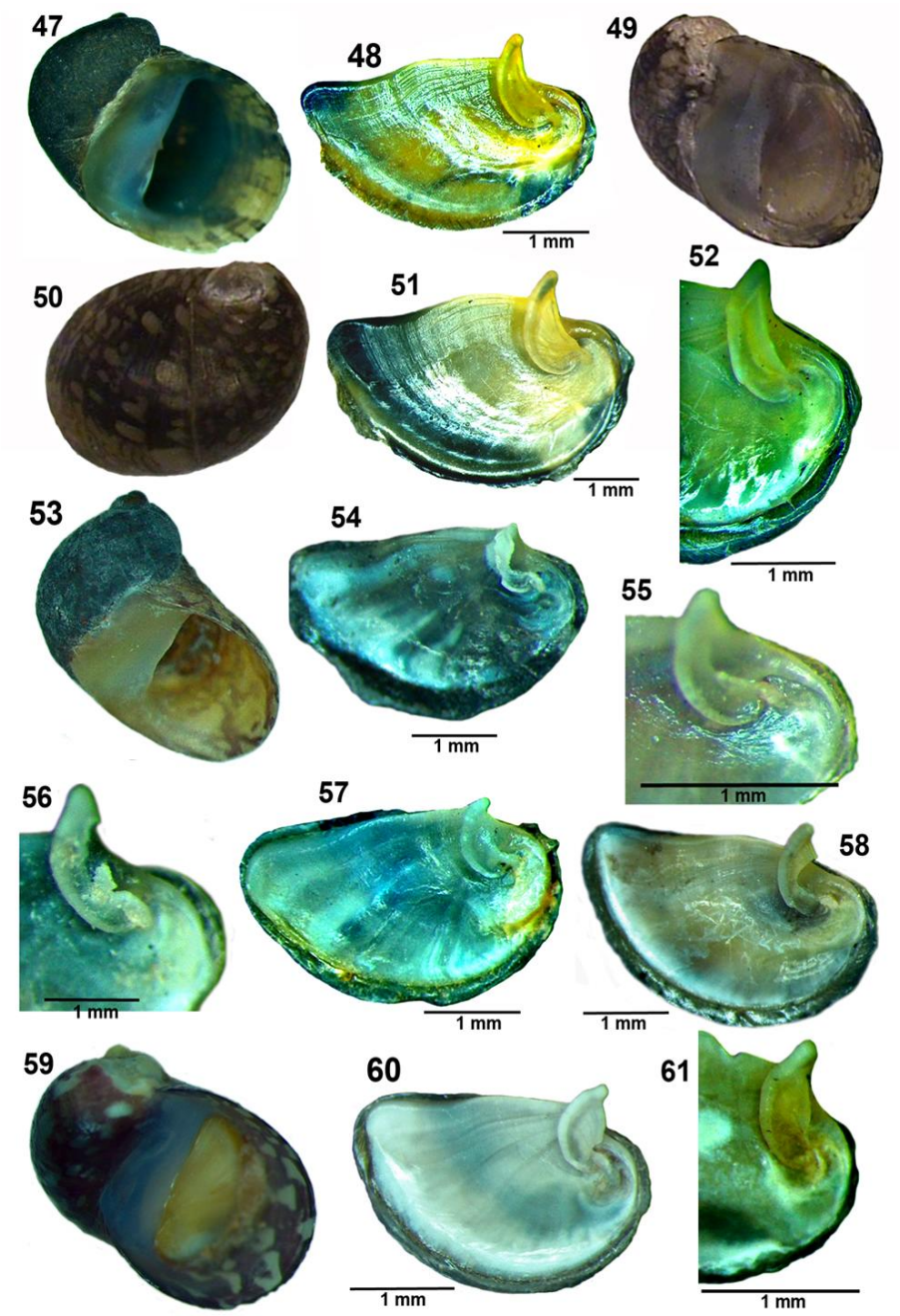
Figuras 25–38. Conchas y opérculos de Neritina velascoi *Graells, 1846 y* Neritina hidalgoi *Crosse, 1881; 25–27. Neotipo de* N. velascoi *(design. nov.). Conducción de agua potable a Xàtiva (Valencia) (locus typicus, restr. nov.) (MNCN 15.05/24886) (h=9,15 mm); 28–29. Ejemplar de la misma localidad que el neotipo (MNCN 15.05/9708); 30–31.* N. velascoi, *fuente junto a la conducción de agua potable a Xàtiva, Bellús (Valencia) (topotipo) (h=7,8 m); 32–35. Lectotipo de* N. hidalgoi *(h=4,8 mm); 36–37. Paralectotipo de* N. hidalgoi *(h=5,62 mm); 38. Opérculo de un paralectotipo de* N. hidalgoi.



Figures 39–45. Shells and opercula of various studied populations of *Theodoxus meridionalis*; 39–40. Verd river (Massalavés, Valencia) (h=8.5 mm) (MVHN–2062); 41. Albufereta, Anna (Valencia) (MVHN–0731); 42. Molí de la Font, Castellón (MVHN–2086); 43–44. Alcoutim, right bank of the river Guadiana (Algarve, Portugal), frente a Sanlúcar de Guadiana (España) (h=10,4 mm) (MVHN–2025); 45. Sóller, Spring (Mallorca) (MVHN–051222HB03); 46. Windmill of San Francisco, Alcalá de Guadaira (Sevilla) (MVHN–140312IY01).
Figuras 39–45. Conchas y opérculos de diversas poblaciones estudiadas de Theodoxus meridionalis*; 39–40. Río Verde (Valencia) (h=8,5 mm) (MVHN–2062); 41 Anna, albufereta (Valencia) (MVHN–0731); 42. Molí de la Font, Castellón (MVHN–2086); 43–44. Alcoutim, margen derecha del río Guadiana (Algarve, Portugal), frente a Sanlúcar de Guadiana (España) (h=10,4 mm) (MVHN–2025); 45. Sóller, Fuente (Mallorca) (MVHN–051222HB03); 46. Molino de San Francisco, Alcalá de Guadaira (Sevilla) (MVHN–140312IY01).*

Remarks: *T. velascoi* is a Valencian endemism also described by Graells in 1846, from the river beds around Albaida and Xàtiva, in the province of Valencia. Gasull (1971) considered *T. valentinus* junior synonym of *T. velascoi*, and collected specimens of this species at four Valencian localities in December 1967: "Acequia de la Vila (Xàtiva)", "Balneario de Bellús" and "Acequia de Ranes" (Cerdà), besides the Sants river for *T. valentinus*.

Samples from the Verd river (Massalavés) assigned to *T. velascoi* through the shell were sent in 2002 for molecular study to P. Bunje and the results were later published by Bunje & Lindberg (2007), naming it as *T. baeticus*, and considering *T. velascoi* junior synonym of *T. baeticus*. Later, Martínez–Ortí *et al*. (2015) studied genetically *T. velascoi* from the same Iberian samples that were used by Bunje & Lindberg (2007), obtaining similar results, but they named it as *T. meridionalis*. Glöer (2019) considered *T. velascoi* junior synonym of *T. valentinus*, while Sands *et al*. (2020) considered *T. velascoi* junior synonym of *T. baeticus*. Finally, in our opinion, *Neritina velascoi* must be considered a junior synonym of *Theodoxus meridionalis*.



Figures 47–61. Shells and opercula of *Theodoxus fluviatilis*; 47–48. Uppsala, chanel (Sweden) (topotype) (h=5.7 mm) (MVHN–1440); 49–51. Freskaty, Stockholm (Sweden) (h=7.2 mm) (MVHN–160919TF02); 52. Solsidan, Svärdsö nature reserve (Sweden) (MVHN–051222HB01); 53–56. Corbones river, next to the Guadalquivir, near Sevilla (h=6.1 mm) (MVHN–1428); 57. Spring of Mal Nombre, Padul (Granada) (MVHN–2049); 58. Guadiaro river, Guacín, reservoir El Colmenar (MVHN–2007); 59–60. Valle de Abdalajis, spring (Cádiz) (h=4.6 mm) (MVHN–051222HB04); 61. Sierra de Cádiz (MVHN–2039).

Figuras 47–61. Conchas y opérculos de Theodoxus fluviatilis*; 47–48. Uppsala, canal (Suecia)*) (topotype) *(h=5,7 mm) (MVHN–1440); 49–51. Freskaty, Estocolmo (Suecia) (h=7,2 mm) (MVHN–160919TF02); 52. Solsidan, reserva natural de Svärdsö (Suecia) (MVHN–051222HB01); 53–56. Río Corbones, junto al Guadalquivir, cerca de Sevilla (h=6,1 mm) (MVHN–1428); 57. Fuente del Mal Nombre, Padul (Granada) (MVHN–2049); 58. Río Guadiaro, Guacín, embalse El Colmenar (MVHN–2007); 59–60. Valle de Abdalajis, fuente (Cádiz) (h=4,6 mm) (MVHN–051222HB04); 61. Sierra de Cádiz (MVHN–2039).*

-*Neritina hidalgoi* Crosse, 1881 (Figs 32–38).
Type locality: San Julián river (=Albaida river), Valencia, Spain.
Type material: Two samples having syntypes are deposited at the MNHN of Paris. Fischer–Piette (1950) illustrated, and erroneously designated, the holotype, which actually corresponds to the lectotype (Figs 32–35), as well as three paratypes, which must correspond to paralectotypes. In addition, we herein present and illustrate another sample containing two additional paralectotypes (Figs 36–38). The correct year of publication of the species description actually corresponds to 1881 (*pers. comm*. S. Gofas, 1996). The operculum is similar to those of the rest of the species present in the Iberian Peninsula (Fig. 38). Finally, *Neritina hidalgoi* must be considered a junior synonym of *T. meridionalis.*

-*Neritina baetica* Lamarck, 1822 (Nomen dubium, design. nov.) (Figs 62–63).
Type locality: Freshwaters of Andalusia.
Type material: The two syntypes deposited at the MNHG of Geneve (MHNG 1094/22) (Figs 62–63) sent to us by Dr. Finet in 2003, although the photographs of the operculum, despite having requested them on several occasions, were not sent and therefore Martínez–Ortí *et al.* (2015) were only based on the figure shown by Mermod (1953: fig. 169). Later, the opercula of the two specimens were figured by Glöer (2018, 2019). Sands *et al.* (2020) selected the lectotype (MHNG MOLL–51319) (Fig. 62).

Remarks: Given the presence verified by Martínez–Ortí *et al*. (2015), through molecular studies, of three species of *Theodoxus* in Andalusia [*T. fluviatilis*, *T. mixta* (before as *T. valentinus*) and *T. meridionalis*], and the difficulty for the respective identifications through the shell and/or operculum, we consider that *Neritina baetica* has an incertain taxonomic status as *nomen dubium*, as its taxonomic validity cannot currently be determined. It would be necessary to know the molecular sequence of one syntype, something that we currently believe is very unlikely. According to Glöer (2018), soft parts of the other syntype (lectotype according to Sands *et al*., 2020), was processed in a solution of KOH to remove the operculum, preventing the only possibility of knowing its molecular sequence.Kobelt (in Gasull, 1971) is the first author to cite this species in the Valencian Community, while Gasull (1971) provided a list of localities where this species lives in the provinces of Alicante and Valencia, as well as some for the Region of Murcia, and for Mallorca, where it was cited for the first time by Jaeckel (1954). Martínez–Ortí & Robles (2003) pointed out that under the name *T. baeticus* there is a complex of species yet to be discriminated. Martínez–Ortí & Robles (2008) and Martínez–Ortí *et al*. (2009a) found a population of *Theodoxus* in the neighborhood of Sevilla, which they initially assigned to *T. baeticus*, following the results of Bunje & Lindberg (2007), but whose type locality corresponds to the freshwaters of Andalusia, and they consider that it was most likely collected in the neighborhood of Sevilla, like other species of freshwater molluscs that have been described from that city and its surroundings, such as *T. hispalensis*, *T. mixta*, *Melanopsis cariosa* (Linnaeus, 1767) or *M. harpa* (Westerlund, 1892). However, later, Martínez–Ortí *et al*. (2015) indicated that the Sevillian population initially assigned to *T. baeticus* corresponded genetically to *T. fluviatilis*, and for this reason they were inclined to consider *T. baeticus* as junior synonym of *T. fluviatilis*. In addition, they considered that the morphology of the operculum was not discriminating within this genus due to the variability of the size of the pseudo-apophysis (Figs 53–57, 59–60), that can cause confusion, despite the fact that other authors such as Glöer & Pesic (2015) and Glöer (2018) considered it discriminatory. They are suggested to be more conserved intraspecifically yet more variable interspecifically for *Theodoxus.*

Figures 62–74. Type series of *Neritina baetica* Lamarck, 1822 and *Neritina mixta* Westerlund, 1892; 62–63. Syntypes of *N. baetica* Lamarck, 1822 (MHNG–1094/22); 62. Lectotype (h=4.4 mm); 63. Paralectotype (h=4.2 mm); 64–73. Type series of *T. mixta* (SWNH–6359); 64–67. Lectotype (design. nov.) (SWNH Type–6741) (h=4.5 mm); 68. Paralectotype SWNH–6359 (h=5.2 mm); 69. Otro Paralectotype (SWNH–6359) (5.4 mm); 70–71. Paralectotypes deposited at the MNCN of Madrid (70: MNCN 15.05/9705; h=5.1 mm) (71: MNCN 15.05/9434; h=4.0 mm); 72. Operculum of the lectotype; 73. Operculum of a paralectotype (S.E.M., Hitachi S–4100); 74. Label of the sample MNCN 15.05/9705, containing paralectotypes.

Figuras 62–74. Serie tipo de Neritina baetica *Lamarck, 1822 y de* Neritina mixta *Westerlund, 1892; 62–63. Sintipos de* N. baetica Lamarck, *1822 (MHNG–1094/22); 62. Lectotipo (h=4,4 mm); 63. Paralectotipo (h=4,2 mm); 64–73. Serie tipo de de* T. mixta *(SWNH–6359); 64–67. Lectotipo (design. nov.)* (SWNH Type–6741) *(h=4,5 mm); 68. Paralectotipo SWNH–6359 (h=5,2 mm); 69. Otro Paralectotipo SWNH–6359 (5,4 mm); 70–71. Paralectotipos depositados en el MNCN de Madrid (70: MNCN 15.05/9705; h=5,1 mm) (71: MNCN 15.05/9434; h=4,0 mm); 72. Opérculo del lectotipo; 73. Opérculo de un paralectotipo (M.E.B.,* Hitachi S–4100*); 74. Etiqueta de la muestra MNCN 15.05/9705, que contiene paralectotipos*.

Glöer (2018, 2019) pointed out that the figure of the operculum showing Mermod (1953), where the pseudo-apophysis of the operculum was not visible, was the possible cause of the synonymization to *T. fluviatilis*. Thus, Glöer (2018, 2019) showed the opercula of the syntypes deposited at the MNHG of Geneva to demonstrate the presence and dimensions of the pseudo-apophysis of *N. baetica* and its difference with that of *T. fluviatilis*. According to the data obtained from the study of various opercula, we herein demonstrate that it is not discriminatory between species of *Theodoxus* in the study area, since the morphology of the operculum, and its various anchoring structures, may vary mainly depending on environmental conditions, and on the physical-chemical characteristics of the water, as well as the size, shape and coloration of the shells as they already were indicated by Zettler *et al*. (2004).

Theodoxus mixta **(Westerlund, 1892) (Figs 64–73)**

Neritina mixta Westerlund, 1892

Type locality: Sevilla (Spain). On the label of the sample deposited at the MNCN appears handwritten by S. Calderón, "Sevilla, conductos de agua" (Sevilla, water pipelines) (Fig. 74).
Type material: The type series are deposited at the SMNH of Stockholm (SWNH–6359) and the MNCN of Madrid. In the Westerlung collection of the SMNH there are 14 syntypes, among which the lectotype is designated and listed (SWNH Type–6741) (Stöhr, 2022) and its operculum (Figs 63–66, 71), as well as two paralectotypes (Figs 67–68) (Figs 71–72). The samples containing paralectotypes are kept at the MNCN in Madrid: MNCN 9705 (179 spms) and MNCN 9434 (13 spms). All the material was collected by S. Calderón and partly sent to C.A. Westerlund who described the taxon later (Fig. 74).

Remarks: The molecular study of the soft parts of a paralectotype of the sample 15.05/9705, has allowed us to know that it is a different species, not *T. meridionalis* nor *T. fluviatilis*, but very similar to *T. valentinus*. The low support value of the branch in the phylogenetic trees indicates that it is necessary to carry out a somewhat deeper study to confirm that it is a different species of *T. valentinus*, although here we propose it as a valid species. *T. mixta* is only known for the moment from the type locality of Sevilla (Spain).

Theodoxus fluviatilis **(Linnaeus, 1758) (Figs 46–60)**

Neritina fluviatilis Linnaeus, 1758

Type locality: Near Uppsala (Sweden).
Type material: Anistratenko *et al.* (1999, in Russian) designate the lectotype and later by Anistratenko (2005, in English), without showing the operculum. This material is deposited at The Linnean Society of London (LSL 566) (Sands *et al*., 2020). Gloër (2019) and Sands (2020) point out as type locality "near Uppsala, Sweden".

Remarks: Bunje (2005) confirmed the presence of *T. fluviatlis* in Valencian freshwaters after the samples sent by Martínez–Ortí in 2002. Martínez–Ortí *et al.* (2015) also confirmed the presence of *T. fluviatilis* in Andalusia by molecular techniques. Glöer (2018, 2019) pointed out that the operculum of *T. fluviatilis* presents a reduced or non-existent pseudo-apophysis. However, we found opercula from Swedish and Spanish specimens of *T. fluviatilis*, which allows us to verify that the variability in length towards the edge of the operculum of the pseudo-apophysis (Figs 48, 51–52, 54–58, 60–61), and that can be confused with those of *T. meridionalis* (Figs 24, 28–29, 38, 40–42, 44–46) and *T. mixta* (Fig. 72). Therefore, we consider that the operculum is neither determinant nor sufficient to identify *T. fluviatilis*.

Conclusions

The results obtained largely corroborate the data obtained by Bunje & Lindberg (2007) and allow us to identify for the moment only four species of *Theodoxus* in the Iberian Peninsula and the Balearic Islands: *T. fluviatilis*, *T. meridionalis*, *T. mixta* and *T. valentinus*, being *T. meridionalis* and *T. fluviatilis* widely distributed. In Andalusia there are three species: *T. fluviatilis*, *T. meridionalis* and *T. mixta*, the latter being pending future molecular studies to support its taxonomic status. In the Valencian Community there are *T. fluviatilis*, *T. meridionalis* and *T. valentinus*. *Theodoxus valentinus* should be considered extinct. In Portugal and the Balearic Islands only lives *T. meridionalis*. *Neritina baetica* Lamarck, 1822 must be considered a *nomen dubium*, therefore, this taxon, which lives in the freshwaters of Andalusia, must be named as *Theodoxus meridionalis* (Philippi, 1836), against the general trend since Bunje & Lindberg (2007). In the case of *Neritina hispalensis* some authors consider it as a valid species (Welter–Schultes, 2012), but without justification. Sands *et al.* (2020) indicated that the taxonomic status of *N. hispalensis* must be considered dubious, and we are inclined to consider it a *nomen dubium*, until detailed taxonomic studies could justify a change of status. The rest of the taxa described in the Iberian Peninsula as *N. elongatula* Morelet, 1845, *N. hidalgoi* Crosse, 1881, *N. inquinata* Morelet, 1845, *N. velascoi* Graells, 1846, *N. violacea* Morelet, 1845 and *N. guadianensis* Morelet, 1845, correspond to junior synonyms of *T. meridionalis*. Finally, the use of the operculum morphology to determine the species treated in the study area is questioned.

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