

The morphological plasticity of *Theodoxus fluviatilis* (Linnaeus, 1758) (Mollusca: Gastropoda: Neritidae)

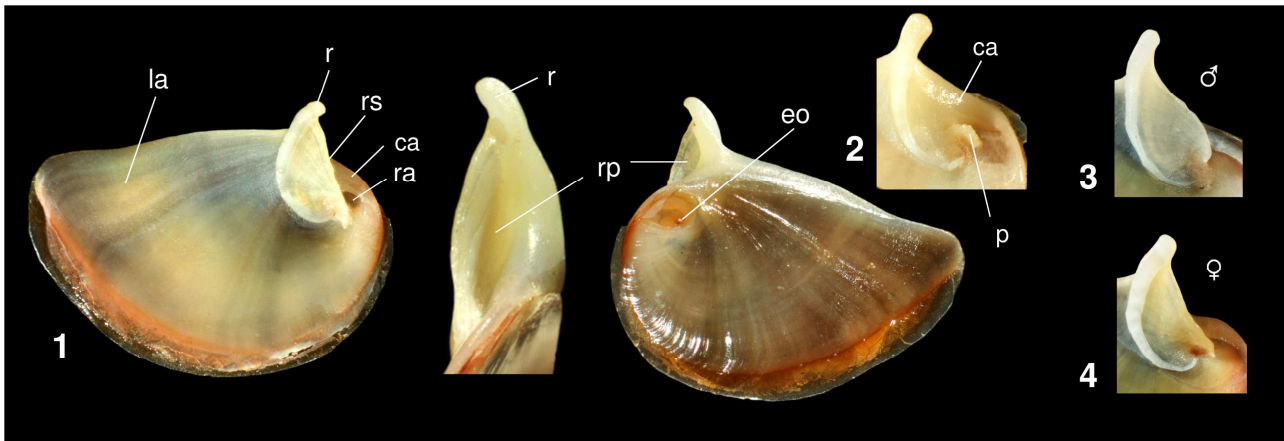
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Theodoxus fluviatilis is a widely distributed species, ranging from the Ireland (Lucey *et al.* 1992) to Iran (Glöer & Pešić 2012). The records from Africa were considered as doubtful (Brown 2002), but recently the senior author found this species in Algeria (Glöer unpublished record). The species prefers the lowlands (in Switzerland up to 275 m a.s.l., Turner *et al.* 1998), and calcium-rich waters, living on hard benthic substrates, typically rocks. On the territory of the Central and Eastern Balkans three species are present (Marković *et al.* 2014): *Theodoxus fluviatilis* (Linnaeus, 1758), *T. danubialis* (C. Pfeiffer, 1828) and *T. transversalis* (C. Pfeiffer, 1828). For Montenegro, Wohlberedt (1909), Karaman & Karaman (2007), Glöer & Pešić (2008), and Pešić & Glöer (2013) listed only *Theodoxus fluviatilis*.

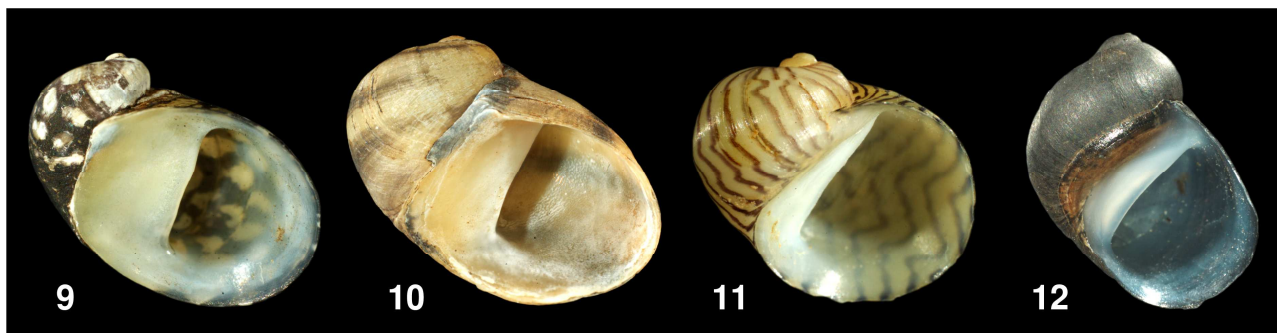


Figures 1-4. The operculum. **1:** *Theodoxus fluviatilis* (Linnaeus, 1758); **2:** *T. danubialis* (C. Pfeiffer, 1828); **3-4:** Rib shield of *T. fluviatilis*. Abbreviations: ca = callus, eo = embryonic operculum, la = left adductor, p = peg, r = rib, ra = right adductor, rp = rib pit, rs = rib shield.

The shell of adults of *Theodoxus fluviatilis* is 4.5–6.5 mm high and 6–9 mm broad, exceptionally up to 13 mm, and consists of 3–3.5 whorls, including protoconch, with a usually low spire. Due to shell shape the specimens of this species from the Balkan are generally more similar to *T. transversalis* (Figs. 9-10). Two other species occurring in Balkan can be distinguished by the shape of shell which is more spherical (Fig. 11) in *Theodoxus danubialis* and by the shape of the aperture which usually is descending (Fig. 12) in *T. prevostianus*. However all mentioned species display a large morphological plasticity making it difficult to identify the species (Marković *et al.* 2014).



Figures 5-8. The opercula of the species of *Theodoxus*. **5:** *T. fluviatilis* (Linnaeus, 1758), **6:** *T. transversalis* (C.Pfeiffer, 1828), **7:** *T. danubialis* (C. Pfeiffer, 1828), **8:** *T. prevostianus* (C. Pfeiffer, 1828).



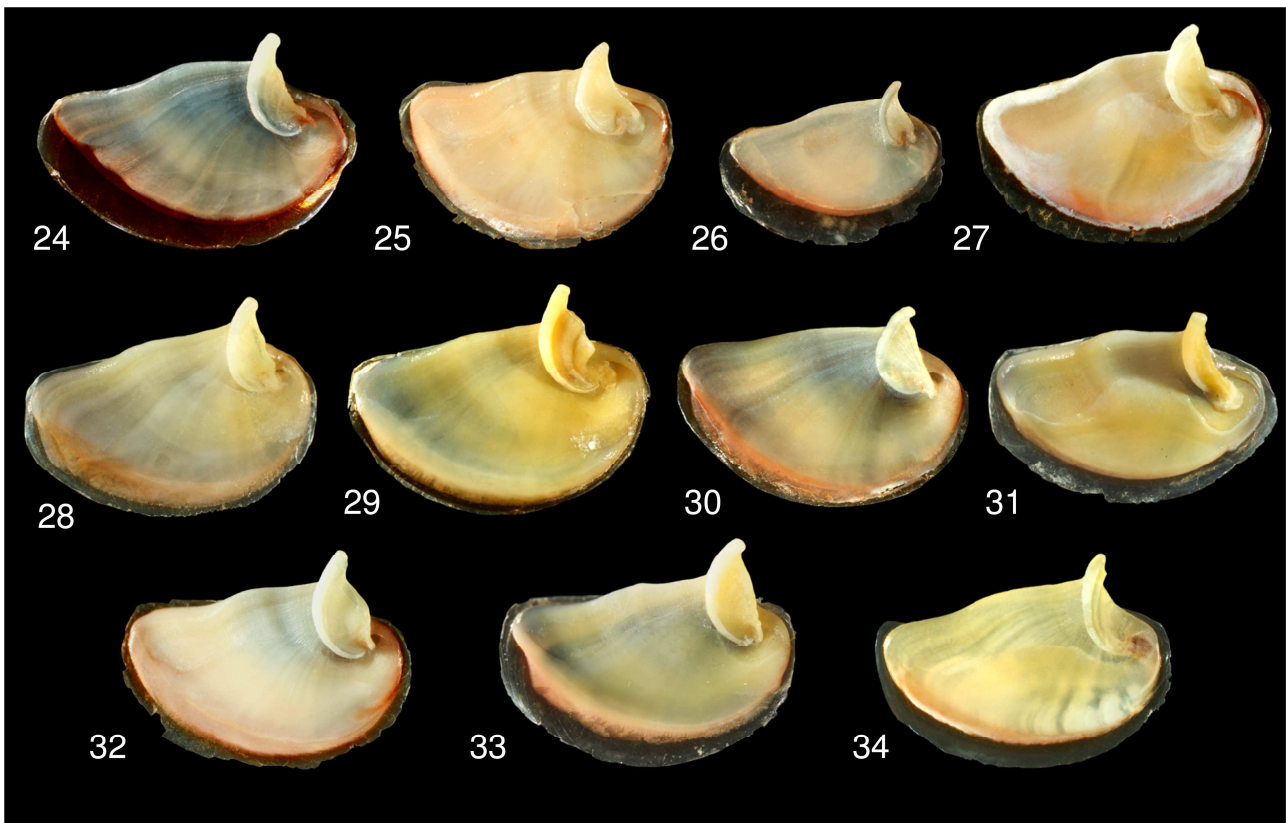
Figures 9-12. The shell of the species of *Theodoxus*. **9:** *T. fluviatilis* (Linnaeus, 1758), **10:** *T. transversalis* (C.Pfeiffer, 1828), **11:** *T. danubialis* (C. Pfeiffer, 1828), **12:** *T. prevostianus* (C. Pfeiffer, 1828).



Figures 13-23. Shells of *Theodoxus fluviatilis* from different sampling sites. **13:** Alster (Hamburg, Germany), **14:** Westensee (Schleswig-Holstein, Germany), **15:** Boiensdorfer Werder (Baltic Sea, Germany), **16:** Nebel, Güstrow (Mecklenburg-Vorpommern, Germany), **17:** Sauvent (France), **18:** Vouvant (France), **19:** Rio Narcea (Spain), **20:** Ohrid Lake (Macedonia), **21:** Zeta River (Montenegro), **22:** Neretva River (Bosnia and Herzegovina), **23:** Bar Spring (Montenegro).

The morphological plasticity of *Theodoxus danubialis* and *T. prevostianus* has been studied by Fehér *et al.* (2009). The latter authors (Fehér *et al.* 2012) studied also variability of *T. transversalis*. In this regard, misidentifications may occur, as in the case of *T. prevostianus* (C. Pfeiffer, 1828) in Romania (Sîrbu & Benedek 2005) or *T. danubialis* (C. Pfeiffer, 1828) (Bunje 2007). In Montenegro, *Theodoxus fluviatilis* has been confused with *T. danubialis* by Jaeckel *et al.* (1958), but also recently by Reischütz *et al.* (2012). It is worth to mention that in recent malacological literature, the shape of shell is still used for species identification (e.g. Welter-Schultes 2012). The aim of this paper is to describe the morphological plasticity of *T. fluviatilis*. Which characteristic features could be used for a proper identification of *Theodoxus* species?

As shown by several studies (Neumann 1960, Heller 1979, Dillon 2000, Zettler *et al.* 2004) the shell coloration and its patterns are very plastic in all species of the genus *Theodoxus* and could be influenced by factors like ionic composition of water, type of substratum and nutrition of individuals of this species in various habitats. Zettler *et al.* (2004) showed that in the outer coastal water of Baltic Sea, the nearly black and often corroded form of shells of *Theodoxus fluviatilis* is predominant, whereas in the inner (sheltered) parts of coastal waters mainly the yellowish-green forms prevail. In our study we observed that specimens from a darker stony substrata are black or dark brown. Concerning the patterns of periostracum *Theodoxus fluviatilis* is also a variable species (Zettler *et al.* 2004). The shells of the specimens of *Theodoxus fluviatilis* from Northern Europe is ornamented with a pattern of white drop-like spots on a dark or red background (Figs 13, 14). In the specimens from South France (Figs. 17-18) and Spain (Fig. 19) is ornamented with a pattern of zigzag stripes, while in the specimens from Balkan all combinations of white drop-like spots and zigzag stripes were observed (Figs. 21-23). The animals from lacustrine habitats show dark or light bands on the shell (Fig. 20).



Figures 24-34. Opercula of *Theodoxus fluviatilis* from different sampling sites (refer to figs 13-23). **24:** Alster (Hamburg, Germany), **25:** Westensee (Schleswig-Holstein, Germany), **26:** Boiensdorfer Werder (Baltic Sea, Germany), **27:** Nebel, Güstrow (Mecklenburg-Vorpommern, Germany), **28:** Sauvent (France), **29:** Vouvant (France), **30:** Rio Narcea (Spain), **31:** Ohrid Lake (Macedonia), **32:** Zeta River (Montenegro), **33:** Neretva River (Bosnia and Herzegovina), **34:** Bar Spring (Montenegro).

Regarding the morphology of the operculum we did not find significant variability. The operculum in *Theodoxus fluviatilis* is reddish with a blood-red border (Fig. 5). The rib is long and thin, attenuated at the basis (Fig. 1), while the callus is thin and a peg is lacking (Fig. 1). In our material examined from several

European sampling sites we found a sexual dimorphism on the border of the rib shield of the operculum, which is straight in females, but curved in males (Figs. 3-4). *Theodoxus fluviatilis* can be distinguished from other three mentioned species by having a rib pit, formed by the rib and the rib shield (Fig. 1). The rib shield, and consequently a rib pit are lacking in *Theodoxus transversalis*, *T. danubialis* and *T. prevostianus*. These three species differs in having in addition to a rib, a peg which is absent in *T. fluviatilis*. The characteristic features of the operculum are already visible in the juveniles. We observed aberration in the shape of operculum: in a specimen from Vouvant (France, Fig. 29) and from a spring near Bar in Montenegro (Fig. 34), respectively, a double rib is present but the rib shield was reduced; in the specimen from Ohrid Lake only the rib shield was reduced.

In summary we can conclude that in the case that coloration and patterns of the shells cannot prove certain identification, the opercular characters can be used for a proper discrimination of *Theodoxus fluviatilis*.

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