Biodiversity Journal, 2024,15 (1): 19–26 https://doi.org/10.31396/Biodiv.Jour.2024.15.1.19.26

The non-indigenous freshwater molluscs of Lake Monterosi (Latium, central Italy)

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ABSTRACT In this work, the freshwater molluscs of Lake Monterosi (Latium, central Italy) are examined with the first report of the allochthonous bivalve *Sinanodonta woodiana* (Lea, 1834) from the province of Viterbo (Latium, central Italy). Particular attention is paid to the problem of the introduction of alien organisms due to fish restocking for sporting purposes.

KEY WORDS *Physella acuta*; *Sinanodonta woodiana*; alien freshwater molluscs; Latium.

Received 09.12.2023; accepted 12.01.2024; published online 08.02.2024

INTRODUCTION

Freshwater molluscs are considered key faunal elements of divers aquatic habitats, with many native species prioritized in efforts of aquatic conservation throughout the world (Geist, 2010, 2015; Lopes-Lima et al., 2018; Sousa et al., 2022; Geist et al., 2023). Bivalves regulate energy and nutrient dynamics by filtering, storing, and distributing inorganic and organic matter between the water column and the substrate (Lummer et al., 2016; Vaughn, 2018; Strayer et al., 2019). They also increase benthic oxygenation by active bioturbation of bed substrates, which has distinct effects on microbiological and macroinvertebrate communities (Boeker et al., 2016; Richter et al., 2016). Freshwater molluscs commonly figure among non-indigenous species, being easily transported accidentally or intentionally by humans (Hulme, 2007; Keller et al., 2011; Yanai et al., 2017). In the last several hundred years, many species of snails have proved to be very successful invaders, able even to cross oceans and continents (Kirschner et al., 1997; Pointier et al., 2005; Gittenberger et al., 2006; Gittenberger, 2011; Kappes & Haase, 2012). Due to human activities, a significant increase in the occurrence of alien freshwater molluscs has been recorded in the last decades especially for bivalves (Sousa et al., 2014; Karaouzas et al., 2020). The "100 of the World's Worst Invasive Alien Species" list contains several species of land snails as *Achatina fulica* Bowdich, 1822, *Dreissena polymorpha* (Pallas, 1771), *Pomacea canaliculata* (Lamarck, 1822) and *Potamocorbula amurensis* Schrenk, 1861 (Global Invasive Species Database, 2021).

In Italy, since the second half of the 19th century, there have been reports of the presence of non-indigenous freshwater molluscs, even if the real origin was not known. Most species of molluscs were introduced in Italy more recently, in the second half of the 20th century, as the result of the development of commercial routes and the intensification of intercontinental traffic (Cianfanelli et al., 2007).

MATERIAL AND METHODS

Study area

The volcanic Lake Monterosi (surface area: 0.32

km 2, max. depth: 4.5 m, theoretical renewal time: 3.9 years) is located at 239 m a.s.1. in the "Monti Sabatini" area (north of Rome, Latium, Italy) (Fig. 1). The lake, without inflows, is fed almost exclusively from run-off. Over the years a progressive diminution of maximum depth has been observed (1896: 8 m; 1966: 6 m; 1985: 5 m; 1994: 4.5 m) (Fig. 2), mainly due to increasing of both amount of plant detritus and water utilization for human activities, mainly cultivations (Mastrantuono & Mancinelli, 1999).

The annual temperature range is 9.3–27.9 °C, typical of these climatic zones, basic pH values (range: 7.4–9.3) and high oxygen contents in all seasons (generally from 7 to 11 ppm). Transparency values were high (range: 3–4.5 m), so the measure of TSIsD (trophic state index, CARLSON 1977) indicates a mesotrophic condition (40.5). The values of phytoplankton primary production are relatively low (46.9–93.7 mg C/m3/h). Percentages of organic matter in the sediment were high (range: 41–46% in the area colonized by *Nelumbo,* range: 24.8–30.5% in the center of the lake). Total phosphorous in the water was high in summer (July 1994:140 pg/1 in surface waters; 240 pg/1 at 3 m) and lower in winter (December 1995:100 pg/1 in surface waters; 10 pg/1 at 3 m). According to EPA (U.S. EPA, 1974) and OECD (1982) classifications of trophic level based on the total P contents in the water, Lake Monterosi can be considered mesoeutrophic (Mastrantuono & Mancinelli, 1999).

The lake has lush coastal vegetation with belts of emerged plants (*Arundo*, *Scirpus*, *Thypha*, *Nymphaea*) and submerged plants (*Ceratophyllum*, *Mynophyllum*, *Nitellopsis*), which completely cover the bottom (Stella & Margaritora, 1965).

The lake of Monterosi falls within the catchment area of the Treia River (Scoppola & Avena, 1987). The SIC IT6010031 "Lago di Monterosi" falls within the ZPS IT6030085 "Comprensorio Bracciano-Martignano" (AA.VV., 2004).

Samples

All the samples object of the present study are stored in the author's private collection (CMMGR, Rome, Italy). The taxonomic-nomenclatural framework of taxa cited in the note relied on Bodon et al. (2021).

Figure 1. Lake Monterosi (Latium, central Italy).

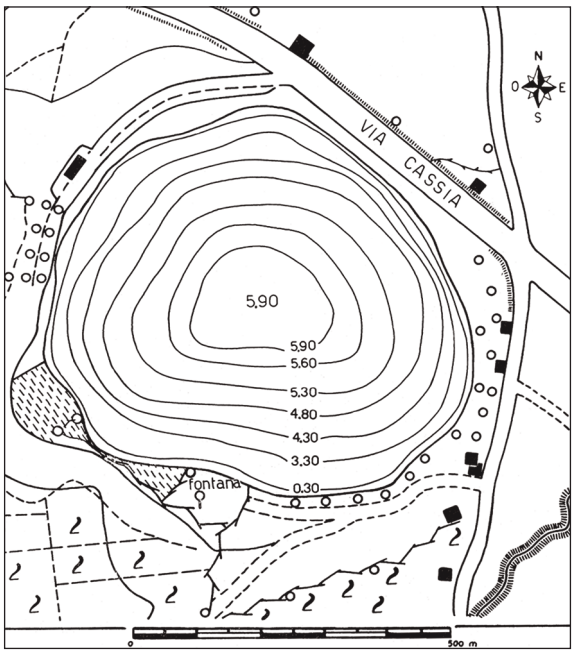

Figure 2. Bathymetric map of Lake Monterosi (from Stella & Margaritora, 1965).

RESULTS AND DISCUSSION

Stella & Margaritora (1965) report in this lake only two gastropod molluscs belonging to the genera *Physa* Draparnaud, 1801 and *Bithynia* Leach, 1818. Subsequently, Mastrantuono & Mancinelli (1999) reported five gastropod molluscs: *Physella acuta* (Draparnaud, 1805) (sub *Physa acuta*), *Hippeutis complanatus* (Linnaeus, 1758), *Acroloxus lacustris* (Linnaeus, 1758), *Viviparus contectus* (Millet, 1813), and *Bithynia tentaculata* (Linnaeus, 1758). Recent research carried out by the author has only led to the discovery of alien species *P. acuta* and *S. woodiana*. *Physella acuta* has been present in this lake at least since the 1960s, while for *S. woodiana* it represents the first report for the province of Viterbo. It is interesting to note that already thirty years ago (1994–1995) the presence of the non-native *P. acuta* was, in percentage terms, much higher than the other native molluscs present in the lake: *P. acuta* (0.2), *H. complanatus* (0.005), *A. lacustris* (0.0006), *V. contectus* (0.01), *B. tentaculata* (0.007) (Mastrantuono & Mancinelli, 1999).

Physella (Acutiana) acuta (Draparnaud, 1805)

Physella (Acutiana) acuta, a species with medium-sized, sinistral, ovate shell (height of up to about 17 mm), is common and abundant in lotic and lentic environments. The systematic and taxonomy of this physid is not well resolved, indeed *Physella acuta* was also called *Haitia acuta* (Draparnaud, 1805) (Taylor, 2003; Roll et al., 2009) and *Phisa acuta* Draparnaud, 1805 (Paraense & Pointer, 2003; Früh et al., 2017; Miyahira et al., 2021). It was introduced to Europe from North America (Taylor, 2003); its first report in Italy dates back to Issel (1866), who described it as *Physa pisana*. Evidence of the early occurrence of *P. acuta* in southern Europe also comes from a shell (or shells) once kept in the private Museum of Niccolò Gualtieri (1688–1744), a pioneer of conchological studies in Italy. His "Index testarum conchyliorum" (Gualtieri, 1742), has been acclaimed as "*a masterpiece of eighteenth-century illustrated malacological literature*" (Manganelli & Benocci, 2011). It includes an illustration of a physid shell (Gualtieri, 1742) that may be identified as *P. acuta* (Vinarski, 2017). Perusal of historical malacological collections demonstrates that its introduction was one of the causes of the gradual rarefaction of the indigenous basommatophora *Physa fontinalis* (Linnaeus, 1758) (Manganelli et al., 2000). For example, the malacological collection of the Museum of Natural History of Florence (Italy) includes many shells of *P. fontinalis* collected since 1857 from areas where the species no longer exists; after 1868, the first shells of *P. acuta* appeared, be coming increasingly numerous and from many parts of Italy (Cianfanelli et al., 2007). *Physella acuta* is currently present in all 20 Italian regions (Bodon et al., 2021; Grano, 2022), including highly polluted water bodies, often forming large populations (Feliksiak, 1939; Saraceni, 1971; Moretti et al., 1979; Melone, 1981). The human-mediated dispersal is the most frequently invoked mechanism explaining its initial arrival and the subsequent rapid widespread in Europe and other continents. However, the real path through which *P. acuta* arrived in Europe is still a matter of debate (Vinarski, 2017).

Sinanodonta woodiana (Lea, 1834)

The large-sized Chinese pond mussel *Sinanodonta woodiana* (Lea, 1834) (Bivalvia: Unionidae) is one of the most invasive aquatic macroinvertebrates worldwide (Colomba et al.,

2013; Tomović et al., 2013; Paganelli et al., 2021) coming from the Amur River and Yangtze rivers (East Asian). The Chinese pond mussel can reach sizes of up to 30 cm and an age of 12–14 years. Yet, they can reproduce in their first year while only 3-4 cm in size. This large freshwater mussel is a habitat generalist with high silt tolerance. It is established worldwide despite having, like all unionid mussels, an obligatory parasitic stage (glochidium), which must encyst on host fish. The species is a broad host generalist, which can complete its development on all fish species tested, both coinvasive and native (Douda et al., 2012). *Sinanodonta woodiana* grows at fast rates and may be able to partition food sources more efficiently than native molluscs (Sárkány-Kiss et al., 2000; Douda & Čadková, 2018). The Chinese pond mussel *S. woodiana* has spread rapidly to central Asia and Europe, mostly due to the transport of farmed cyprinid fish species (Kraszewski, 2007; Bolotov et al., 2016; Konečný et al., 2018). Because of its reproduction success when compared to native mussel species (Huber & Geist, 2019), it spreads rapidly (mainly during the parasitic stage) and can reach high densities in many rivers and standing water bodies (Douda et al., 2012; Benkő-Kiss et al., 2013; Beran, 2020). The first discovery in Europe in 1979 is from fish farms in Romania (Popa et al., 2007).

Figure 3. Unionidae molluscs sold in a pet store of Longarone (Belluno, Italy).

The species is also sold in garden centers as biofiltration for artificial ponds (Fig. 3). In Italy it was reported for the first time in Emilia-Romagna by Fabbri & Landi (1999); other findings then occurred in Lazio (Manganelli et al., 1998), in Veneto and Tuscany (Niero, 2003), Marche, Piedmont, Umbria and Lombardy (Solustri & Nardi, 2006) and Campania (De Vico et al., 2007) with an overall diffusion highlighted by Cianfanelli et al. (2007). Subsequently, *S. woodiana* was also reported in Sicily (Colomba et al., 2013), Basilicata and Calabria (Renda & Niero, 2014). The process of its introduction into new aquatic habitats usually occurs accidentally through the release of host fish encysted with the mussel glochidia (obligatory parasitic larval stage) during fish stocking (Douda et al., 2012; Spyra et al., 2016). On the other hand, the Chinese pond mussel was also intentionally introduced in some countries, such as Italy, as a pearl producing mollusc (Cianfanelli et al., 2007). Among the hosts of *S. woodiana*, Watters (1997) indicates the black amur *Mylopharyngodon piceus* (Richardson, 1846), grass carp *Ctenopharyngodon idella* (Valenciennes, 1844), silver carp *Hypophtalmichthys molitrix* Linnaeus, 1758, macrocephalic carp *Aristichtys nobilis* (Richardson, 1845), common carp *Cyprinus carpio* Linnaeus, 1758, mosquitofish *Gambusia affinis* Baird & Girard, 1853 and Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758).

CONCLUSIONS

Biological invasions must be routinely tracked (Pergl et al., 2020) to better understand their impacts on native species, their habitats, and ecosystem functions (Geist, 2011). The field investigations conducted as part of the drafting of the SIC Management Plan IT6010031 “Lake Monterosi” indicate a profound alteration of the habitat (AA.VV., 2004) and the critical factors identified already twenty years ago in this lake are mainly represented by the presence of alien species, both vegetal, such as the lotus flower *Nelumbo nucifera*, and animals, such as the little beaver *Myocastor coypus* Molina, 1782 (AA.VV., 2004). The management of this lake entrusted to a sport fishing association has led to the continuous introduction of alien fish to the national territory, and currently the fish population is essentially made up of alien fish such as: grass carp *Ctenopharyngodon*

idella, common carp *Cyprinus carpio*, silver carp *Hypophtalmichthys molitrix*, black bass *Micropterus salmoides*, pumpkinseed *Lepomis gibbosus*, and mosquitofish *Gambusia affinis*. In Italy, the introduction of alien species is considered one of the main causes of threat to indigenous fish fauna; the percentage of alien species compared to indigenous is in fact the highest in Europe (Copp et al., 2005; Sarrocco et al., 2012). In Latium, alien and transfaunal fish species constitute approximately 47% of the total of the species, representing a significant threat to both fish and fish fauna for entire biocenoses, and most introductions are intentional and sport fishing is by far the most important cause of introductions (Sarrocco et al., 2012).

The presence of *S. woodiana* can seriously influence indigenous mollusc populations and frequently ends up dominating its ecological niche and, thus, modifying and altering the diversity and structure of native fauna as well as the functioning of invaded ecosystems (Corsi et al., 2007; Bódis et al., 2014; Sousa et al., 2014; Bensaad-Bendjedid et al., 2023); the presence of this large mollusc, arrived through the introduction of alien fish, in a small lake like that of Monterosi constitutes a great danger for its entire, already highly compromised, delicate ecosystem.

ACKNOWLEDGEMENTS

The author wishes to thank for the information received Stefania Grano (Nepi), Roberto Nistri (Rome) and Riccardo Novaga (Latina). Special thanks go to Cristina Cattaneo (Rome) for her precious presence in my research and in my life.

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