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Rapid Communication

Non-native *Corbicula fluminea* (Müller, 1774) (Bivalvia, Veneroidea) in Central Italy: do the waters pumped by Reclaimed Agencies may have a role in spreading through translocation?

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Abstract

Asian clam, *Corbicula fluminea*, is an invasive mollusk species (Bivalvia, Veneridae) known to cause several negative impacts in freshwater ecosystems where it has been introduced. In the 2022 summer season a total drying up took place in the "Torre Flavia" wetland, a Special Protection Area (Latium, central Italy): it made possible a survey of biological remains deposited in the bottom of the wetland channels (> 2,000 m in total length). During this survey, for the first time, we recorded valves belonging to 68 specimens of Asian clam. We did not record living specimens. This is the first case of occurrence of this mollusk in a wetland basin (the fourth record for Central Italy). The population would not appear to have naturalized locally but, probably, individuals could be accidental arrived by the waters pumped by the Reclaimed Agency. We discussed the implications about the role of these Agencies in favour involuntarily the translocation of both native and non-native species from the dewatering pumps (along the Tiber River) to surrounding land reclaimed wet areas (channels and swamps) and croplands connected to the artificial water system.

Key words: invasive species, indirect impact, Reclamation Agency, awareness, communication, conservation

Introduction

Corbicula fluminea (Müller, 1774), commonly named Asian clam, is a freshwater mollusk (Bivalvia, Veneridae, Corbiculidae), also inhabiting brackish waters and wetlands (Sousa et al. 2008). The species lives both on muddy and sandy substrata, preferring the latter where the density of the individuals is more abundant and can survive for quite a long-life span (3–5 years; Belanger et al. 1985; Fabbri and Landi 1999). Its native distribution range is confined to South-East Asia (Mouthon 1981; Araujo et al. 1993; Crespo et al. 2015). The first reports of species in non-native range correspond to the 1920s on the Pacific coast of the United States, after that the species dispersed worldwide (Counts 1981). *Corbicula fluminea* populations

were also reported in South America in the 1970s (Ituarte 1994) and in Asia, North and South America, Africa and Europe from the '80 onwards (Mouthon 1981). The possible source of introduction is related to Chinese immigration as the species was employed as a food resource (Counts 1981).

In Italy, the first certain report of the species dates to 1998–1999 in the potamal tract of Po River and adjacent inland waters of Emilia-Romagna and Veneto (Northern Italy; Fabbri and Landi 1999; Malavasi et al. 1999). Then, the Asian clam has been reported also in Lake Garda in Veneto (Nardi and Braccia 2004; Ciutti et al. 2007), in Lake Maggiore (Kamburska et al. 2013) and Ticino River (Nicolini and Lodola 2011) in Lumbardy, in Senio River (Pezzi 2008) and in a freshwater channel in Emilia-Romagna (Stagioni 2009). Further South, along the Italian peninsula (central Italy), there were only a report from Tuscany Serchio River (Ercolini and Cenni 2015) and two recently reports of the species for Latium: in Maccarese land reclamation streams (20 km from Rome) and in Lake Albano, all thee located in the Tiber hydrographic basin (Grano and Di Giuseppe 2020). Other taxa of the genus *Corbicula* were recorded in Italy, such as *C. fluminalis*, *C. leana* and *C. largillierti* in Lake Garda (Ciutti and Cappeletti 2009; López-Soriano et al. 2018); the same taxa were also found in Arno and Po Rivers (Bodon et al. 2020).

Asian clam is considered among the 100 worst invasive species in the world (Lowe et al. 2000). Indeed, given the fast growth rate, elevated fecundity, high tolerance to contaminants, production of high amounts of faeces and pseudo-faeces and potential vector of parasites, this specie induces severe ecological (e.g., water deoxygenation, biomagnification process and diseases and fungal dispersion) and economic impacts (e.g., damage to hydraulic works and water derivations; Sousa et al. 2008; Rodolfi et al. 2017; Grano and Di Giuseppe 2020). Moreover, this species often dominates macroinvertebrate communities in aquatic ecosystems affecting the local species and despite management policies, the expansion of Asian clam does not tend to stop (Karaouzas et al. 2020).

Here, we report the presence of the Asian clam for the first time in a small coastal wetland in central Italy. This marks the third instance of its presence at the regional level (Lazio) and the fourth in central Italy. To our knowledge, this is the first record of occurrence in a wetland. Since this ecosystem, (i) is regularly supplied (during periods of water stress), only with water by the local Reclamation Agency that provides through a system of hydraulic pipelines taken from the Tiber River (40 km away, near Rome), and (ii) that many other translocated species (both native and non-native) have been locally recorded, we discussed the implications about the role of these Agencies in favour involuntarily the spreading of species through involuntary translocation.

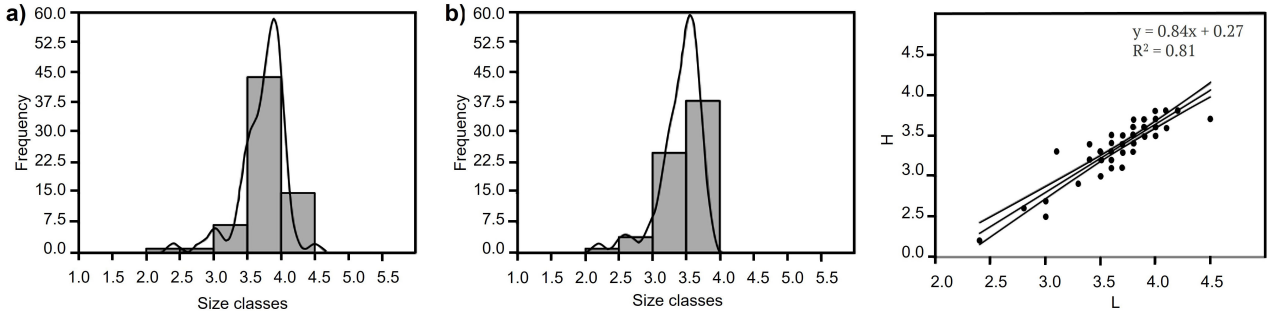

Figure 1. Left: Kernel Density Estimation of *Corbicula fluminea* population considering (a) length of umbo and (b) height of umbo (mm). Right: Correlation between the height of umbo (H) and length of umbo (L) of specimens of *Corbicula fluminea*. Details in Materials and methods.

Materials and methods

"Torre Flavia" wetland is a Special Protection Area (SPA), included in Natura 2000 European network (147/2009 EU European Directive; code IT6030020) and located on the Tyrrhenian coast in Latium region, Central Italy (Municipalities of Ladispoli and Cerveteri; 41°58′N; 12°03′E), belonging to the meso-Mediterranean xeric region.

The wetland area is an important habitat for several animal and plant species, hosting a large number of animal species (mainly migratory birds), also of conservation concern. The protected area is a remnant of a larger wetland, partially drained and currently surrounded by agricultural and urbanized land, as highlighted by land cover maps. Wetland is composed by a system of ponds and channels and is characterized by a vegetation cover with reed-beds and rush-beds, while the section of coastal sandy beach shows a semi-natural patchiness with a seashore area, an intermediate sandy area and an inner dune area characterized by halo-psammophilous plants. Due to proximity to the densely populated urban area, this wetland is subjected to many human-induced threats such as coastal erosion, alien invasive species, trampling, motor vehicle transit, fires, poaching, water/soil pollution and marine litter (Cesarini et al. 2021, 2022; Gallitelli et al. 2021, 2023). During the water stress periods, to prevent the swamp from drying up, the public Agency managing the SPA ("Città metropolitana di Roma Capitale" park Agency), starting from 2001, introduces water supplies (about 100,000 m^3/year) provided by the local land reclamation Agency ("Consorzio di Bonifica Litorale Nord"). The water supplied comes through pipelines from the Tiber River (about 40 km away). There are no streams that enter the wetland, except for runoff water from the surrounding crops after heavy rains: therefore, the only waters arriving in the "Torre Flavia" wetland are those that are artificially introduced by the Reclamation Agency in agreement with the park Agency that manages the Special Protection Area (Figure 1).

In this area, we actively searched for dead specimens (valves) of *Corbicula fluminea* after a waterless period occurred in the Torre Flavia wetland during summer 2022 when all the wetland channels were dried.

All wetland channels (> ~ 2100 m in length) were traversed on foot at a speed of ca. 1.5 km/h in search of animal remains, focusing attention on the Asia clam's specimens whose presence was occasionally noticed during a management activity.

To calculate the mollusk density, we carried out randomly a paired set of 27 1 × 1 m-plots both along the channels and in the ponds immediately surrounding the water pumping. Each mollusk's valve was geo-referenced (GPS Garmin E-trex), collected and placed in a sterile bag and transported to the laboratory (University of Rome Three) where it was identified at the species level. Samples were taxonomically identified using scientific literature (Fabbri and Landi 1999; Bodon et al. 2020; Morhun et al. 2022): peculiar characteristics of the species are slightly raised but swollen umbos and a surface sculpted by concentric, equidistant and moderately raised growth crests (Fabbri and Landi 1999).

Morphological data of inner surface features were collected from each specimen: maximum length (L), maximum height (H), height of umbo (Hu), height of hinge plate under umbo (Hh), anterior length (between anterior edge and umbo) (La) and posterior length (between posterior edge and umbo) (Lp) (mm) using a digital caliper (approximation: ± 0.01 mm). For the analysis of population dynamics, we refer to Cataldo and Boltovskoy (1999) and Mouthon (2001). We carried out a demographic analysis using the Kernel Density Estimation. After observation of non-parametric data, a Kruskal-Wallis test and Dunn's post hoc test were used to evaluate significant differences between classes on the basis of median value between height and length of umbo (H+L)/2). A Spearman correlation between morphological data were conducted using PAST 4.02 (Hammer et al. 2011). Alpha level was set at 0.05.

Results

Totally, we recorded 68 paired valves belonging to specimens of Asian clam in July 2022 (density: 4.19 ± 3.08/square meter; n = 27 plots), all located surrounding the water intake (where the Reclamation Agency provides water for the wetland), up to a distance of about 50 m away (Supplementary material Figures S1 and S2). No one specimen has been recorded in plots (and along all the transects) randomly located along the channels.

This finding represents the first record for a wetland ecosystem, the third for the Latium region and the fourth for the whole Central Italy.

All morphological parameters measured are presented in Table 1. The morphological data of specimens highlight that the length of the umbo ranged from 24 to 45 mm (mean: 37.25, st. dev. 3.32) and the height of the umbo from 22 to 38 mm (mean: 34.09, st. dev. 3.108).

Table 1. Measured parameters on *Corbicula fluminea* valves (mean and standard deviation). L = maximum length; H = maximum height; Lp = posterior length (between posterior edge and umbo); La = anterior length (between anterior edge and umbo); Hu = height of umbo; Hh = height of hinge plate under umbo.

Parameter	Mean (mm)	St.dev. (±)
L	37.25	3.320
H	34.09	3.108
Lp	21.07	3.010
La	19.15	2.980
Hu	3.37	1.250
Hh	2.45	1.098

Kernel Density Estimation for the population shows a demographic structure with few size class, lacking of juvenile individuals and suggesting a non naturalized population (Figure 1). The average values of the ratios between height and length of umbo, separated in three dimensional classes (≥ 20, ≥ 31, ≥ 41 mm), shown singificant differences ($H = 13.81$; $p < 0.001$). In particular the differences were highlighted between ≥ 20 and ≥ 31 mm classes ($p < 0.001$) and between ≥ 20 and ≥ 41 mm classes ($p < 0.001$).

A significant linear Spearman correlation ($R^2 = 0.81$; $p < 0.0001$) between the length and height of the umbo was found (Figure 1). Given the significant strong correlation parameters, only the height was used to characterize the population demography. Following the classifications available in the literature, specimens > 20 mm of umbo height are individuals of the third year of age (see Ciutti et al. 2007; Cataldo and Boltovskoy 1999; Mouthon 2001).

Discussion

For the first time, we recorded valves of the Asian clam in the Torre Flavia, a Special Protection Area of Central Italy of high conservation concern (Battisti et al. 2008, 2021). The analysis of the population demography suggests that the population has not been naturalized locally: specimens all belong to the few dimensional classes (corresponding to three years of age, as obtained by Kernel Density Estimation). We did not observe juvenile forms. All individuals have been found dead in a small dry pond (about 1 ha in size), on clay soil, surrounded by reed-beds (*Phragmites australis* dominant). Probably all the adult individuals were transported by the Tiber River and introduced into the wetland on only few occasions from the water intake. Another possible explanation it could be that the origin of the population was related to aquarian specimens. However, it must be considered that *Corbicula* populations are usually much denser that what shows up on the dry mud, since they live at some centimetres deep. Therefore, the dead specimens found could be not representative of the actual population. Although this species is tolerant, it does not resist extreme conditions of anoxia (Araujo et al. 1993), a situation that occurred in any Mediterranean wetland in late spring and summer with the drought of the inner ponds. We hypothesize that living specimens would have been

transported by water pipelines managed by the local Reclamation public Agency ("Consorzio di Bonifica "Litorale Nord"). These water pipelines have the function of drilling water in the wetland during the drought periods, drawing water directly from the Tiber River and flow into the Torre Flavia wetland and all the surrounding croplands (the main purpose of the transported water is irrigation for agriculture; secondary, they serve for ecological purposes as in the "Torre Flavia" wetland): therefore, they could be the cause of the presence of *C. fluminea* in the area. Similarly, the connection with the Tiber River has been advanced to be the cause for the finding of the same species in the reclamation channels of Maccarese, near Rome (Central Italy; Grano and Di Giuseppe 2020). In this case, the situation was different as individuals of all sizes were found and the population seems to have naturalised. The presence of Asian clam in Tiber River was recently confirmed (Pieri et al. 2023; *personal observation* in the potamal tract within Rome city). Indeed, Asian clam is usually occurring in muddy or sandy substrata, characteristic of the potamal tract of the Tiber River (Belanger et al. 1985).

However, in the "Torre Flavia" wetland also other species have been recorded, whose presence can be traced back to a translocation due to the accidental transport of water from the Tiber River. In the last years, many live specimens of the Little rudd (*Scardinius erythrophtalmus*), a limnophilic Cyprinid fish, were observed coming out directly from the Reclamation Agency' water intakes (E. De Angelis, C. Galimberti, *pers. obs.*) and, probably, also the presence of another Cyprinid, the Goldfish (*Carassius auratus*), regularly observed into the channels, may be caused by water supply. In the summer 2022 we observed also three dead specimens of Duck mussel (*Anodonta anatina*; Bivalvia Unionidae), an aquatic bivalve mollusk, almost certainly transported by waters coming from Tiber River where this species is present (Grano et al. 2020). Probably, waters can also carry the non-native Mosquitofish (*Gambusia holbrooki*), largely occurring in "Torre Flavia" wetland channels also after the late summer when channels were completely dried up. Some operators working in the Reclamation Agency reported that they also recovered specimens of native Eels (*Anguilla anguilla;* Anguillidae) stranded inside the water pipes (M. Carafa, *pers. comm.*). Finally, the naturalized population of Red swamp crayfish *(Procambarus clarkii*), locally introduced in the wetland by fishermen in 2004 (Chiesa 2006; Scalici et al. 2010), could be enriched by individuals or eggs from the waters of the Reclamation Agency.

The only waters supplied in the "Torre Flavia" wetland are artificially introduced by the Reclamation Agency, aimed to reduce the impact induced by water stress during the late spring-summer; Zacchei et al. 2011; see Study area). Therefore, we hypothesize that many species may be actively and involuntarily translocated by the Tiber River to our study area through the pipelines of the Reclamation Agency. In our case, the "Consorzio

di Bonifica Litorale Nord" develops a territorial water distribution network of 1,100 km (water pipes) with 28,000 hectares of irrigated area (wetlands, channels and croplands) throughout the coastal strip north of Rome (up to over 40 km away; CBLN 2022). In this regard, these Agencies may represent a driving force explaining the anthropogenic spreading of biological species (including non-native taxa) in large landscape areas.

Given the role played by the public Reclamation Agencies in translocating both native and non-native species, changes in the planning of these water resources and greater effort in the controls on their management would be useful. Identified the difficulty of eradicating a non-native species introduced in a new area, the best strategy against biological invasions is prevention and, as in this case, an active communication aimed to increase awareness in operators and managers on the role of water pipelines of Reclamation Agencies to introduce species should be promoted. Even if, at the moment, Asian clam appeared probably not locally naturalized in the "Torre Flavia" wetland, the situation needs to be monitored given the high fecundity and reproductive strategies of the mollusk (e.g., hermaphrodite species; Ciutti et al. 2007; Kraemer and Galloway 1986).

Further research aimed at assessing (i) the presence of Asian clam in the Tiber River (still not confirmed but highly probable; Cesarini et al. 2023) and (ii) the probable continuous translocation and dynamics in the "Torre Flavia" wetland and in the surrounding croplands and channels, correlating it to the ecological traits of this species and local limiting factors (e.g. water temperature, hypoxia; Johnson and McMahon 1998). Moreover, a conservation project (*sensu* IUCN – World Conservation Union: Battisti 2018) focused on (i) monitoring the translocation of large-sized individuals of non-native species through pipes, also adopting specific measures (e.g., selective grids) and (ii) improving the awareness of technicians working in Reclamation Agencies should be carried out. It may include a set of actions aimed to prevent further spreading of native and non-native species from source areas (Tiber River) to surrounding channels, waters, and croplands.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contribution

G.C.: investigation, visualization, writing – original draft, writing – review and editing C.B.: validation, investigation, conceptualization, writing – review and editing. L.G.: investigation, writing – review and editing. M.S.: validation, supervision, conceptualization, writing – review and editing.

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Supplementary material

The following supplementary material is available for this article:

Figure S1. The study area ("Torre Flavia" coastal wetland Special Protection Area; Latium, central Italy) showing ponds, channels surrounded by vegetation (reed-beds with *Phragmites australis* and rush-beds with *Juncus* spp. and *Carex* spp.).

Figure S2. *Corbicula fluminea* specimens found in Torre Flavia wetland.

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