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# First Data on the Alien Mollusc *Fulvia fragilis* (Forsskål in Niebuhr, 1775) (Cardiida: Cardiidae) from the Adriatic Sea

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**Abstract:** The first record of *Fulvia fragilis* (Forsskål in Niebuhr, 1775) from the Adriatic Sea is presented. Two empty shells of *F. fragilis* were found in the area of the Boka Kotorska Bay (South Adriatic Sea), in front of the St. Marko Island. The shipping/maritime transport is the assumed vector of introduction. An overview of the recent findings of this species in the Mediterranean Sea is given.

**Key words:** *Fulvia fragilis*, Lessepsian migrants, Boka Kotorska Bay, Bivalvia

## Introduction

An alien species is an organism occurring outside of its known or consensual range (Occhipinti-Ambrogi & Galil 2004). Such species can negatively affect native species trough different processes, such as predation, competition, introduction of genes – hybridisation, parasite and pathogens diffusion (Strayer et al. 2006). Generally recognised main vectors of introduction of alien species into the Mediterranean waters are: migration through the Suez Canal, also called "Lessepsian migration", transportation on ship hulls (as fouling organisms) and with ballast waters, intentional introduction (mariculture), market discards and other aquaculture-related activities - aquariology (Por 1978, Zibrowius 1992, Katsanevakis et al. 2013, Zenetos et al. 2017). Additionally, the global warming can also be considered as one of the reasons for introduction of species into new areas (Raitsos et al. 2010).

*Fulvia fragilis* (Forsskål in Niebuhr, 1775) is a common species with established populations in Egypt, Israel, Lebanon, Cyprus, Turkey, Greece, Italy, Malta, Albania, Tunisia and Spain (Moazzo 1939, Gofas & Zenetos 2003, Zenetos et al. 2003, 2008, 2009, Passamonti 2006, Goud & Mifsud 2009, Crocetta et al. 2008, 2013, Gerovasileiou et al. 2017). It is recognised as a "Lessepsian migrant" (see Zenetos et al. 2003). *Fulvia fragilis* inhabits littoral to shallow waters 9-37 m deep, with sandy and (or) muddy bottoms as well as sandy bottoms together with *Zostera* spp. Its shell is fragile, equivalve, slightly inequilateral and can reach up to 75 mm in height. Outline of shell is almost circular, with rounded anterior margin; posterior part more or less transversely expanded, possessing c. 41 ribs (34-52). Ribs are generally rounded in the anterior part, flatly rounded to asymmetrically triangular in the median third of the shell; rounded with calcareous spines or tubercles in posterior part. Width of ribs and interstices generally equal, with width of interstices of first anterior ribs sometimes wider. In each valve, anterior and posterior lateral teeth present as well as two cardinal teeth. Internal margin crenulated; with two sub-equal adductor muscle scars. Pallial line broad, without a sinus. Internal surface nearly smooth from umbo to mid-height of valves, and radially ribbed ventralward. External colour of valves whitish-beige to yellow, with purple stain on umbo, while interior is white with purple colour in the posterior third and sometimes in the umbonal cavity (Zenetos et al. 2003, Öztürk & Poutiers 2005).

Native populations of *F. fragilis* are distributed throughout the Indian Ocean, from the Red Sea and the Persian Gulf to Mozambique and Madagascar (Vidal 1994). Since its first record from the Mediterranean Sea, it colonised almost the whole basin until the Otranto Strait (the channel linking the Adriatic and Ionian Seas) (Moazzo 1939, Gofas & Zenetos 2003, Zenetos et al. 2003, 2008, 2009, Passamonti 2006, Goud & Mifsud 2009, Crocetta et al. 2008, Gerovasileiou et al. 2017). Many authors presumed that shipping is the introduction vector for this species, since reports have usually come from harbours (e.g. Zenetos et al. 2003, Galil 2008, Occhipinti-Ambrogi et al. 2010, Gerovasileiou et al. 2017).

In this article, we present the first report of *F. fragilis* from the Adriatic Sea.

## Materials and Methods

The study was performed at the locality of St. Marko (42°41′ N, 18°69′ E), in Tivat Bay (Boka Kotorska Bay, Montenegro, Fig. 1) in the course of the estimation of the distribution and biomass of edible bivalves in the area of the Boka Kotorska Bay during two seasons (May and October, 2016). Sampling was done by SCUBA diving along a 100-m transect. The collected material was identified according to Zenetos et al. (2003), Öztürk & Poutiers (2005) and Huber (2010). Measurements were taken using a calliper (precision of 0.1 mm).

The scientific literature was reviewed in order to show temporal changes in the distribution of *F. fragilis* in the Mediterranean, with numbering corresponding to that in Fig. 3 (1. Moazzo 1939; 2. Barash & Danin 1973; 3. Ghisotti 1974; 4. Barash & Danin 1977; 5. Lindner 1988; 6. Enzenross et al. 1990; 7. Niederhöfer et al. 1991; 8. Fischer 1993; 9. Buzzurro & Greppi 1996; 10. Passamonti 1996; 11. Vardala-Theodorou 1999; 12. Delamotte & Vardala-Theodorou 2001; 13. Enzenros & Enzenros 2001; 14. Ben Souissi et al. 2003; 15. Zenetos et al. 2003; 16. Crocetta 2005; 17. Zenetos et al. 2005; 18. Öztürk & Poutiers 2005; 19. Çinar et al. 2006; 20. Crocetta et al. 2008; 21. Tamayo-Goya 2008; 22. Zenetos et al. 2008; 23. Brancato & Reittano 2009; 24. Crocetta et al. 2009; 25. Goud & Mifsud 2009; 26. López Soriano et al. 2009; 27. Zenetos et al. 2009; 28. Doneddu 2010; 29. Mahmoud et al. 2011; 30. Rifi et al. 2011; 31. Rifi et al. 2012; 32. Angelidis 2013; 33. Crocetta et al. 2013; 34. Marchini et al. 2013; 35. Sperone et al. 2015; 36. Lipej et al. 2017; 37. Gerovasileiou et al. 2017; 38. Crocetta et al. 2017; 39. Present study). The data were divided into five periods: 1939–1960; 1961–1980; 1981–2000; 2001–2010; 2011–present.

## Results

The first record of *F. fragilis* in the Adriatic Sea (Montenegrin coast) represented two empty shells.

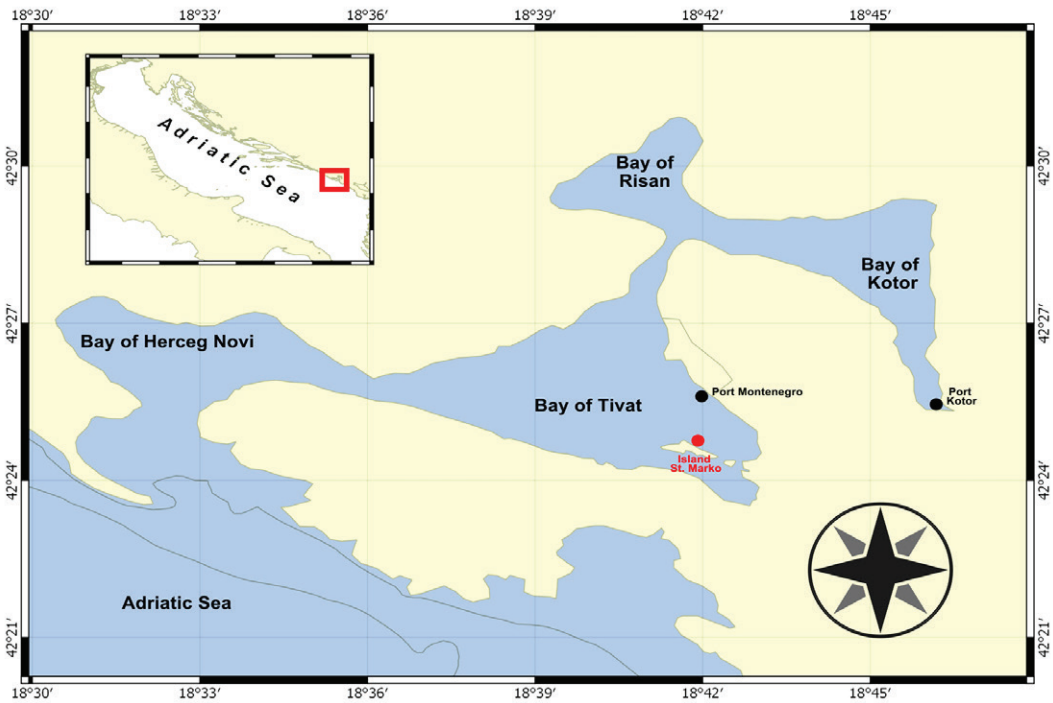


**Fig. 1.** Map showing the locality where *Fulvia fragilis* was found, as well as the position of the marina Porto Montenegro and harbour Port of Kotor.

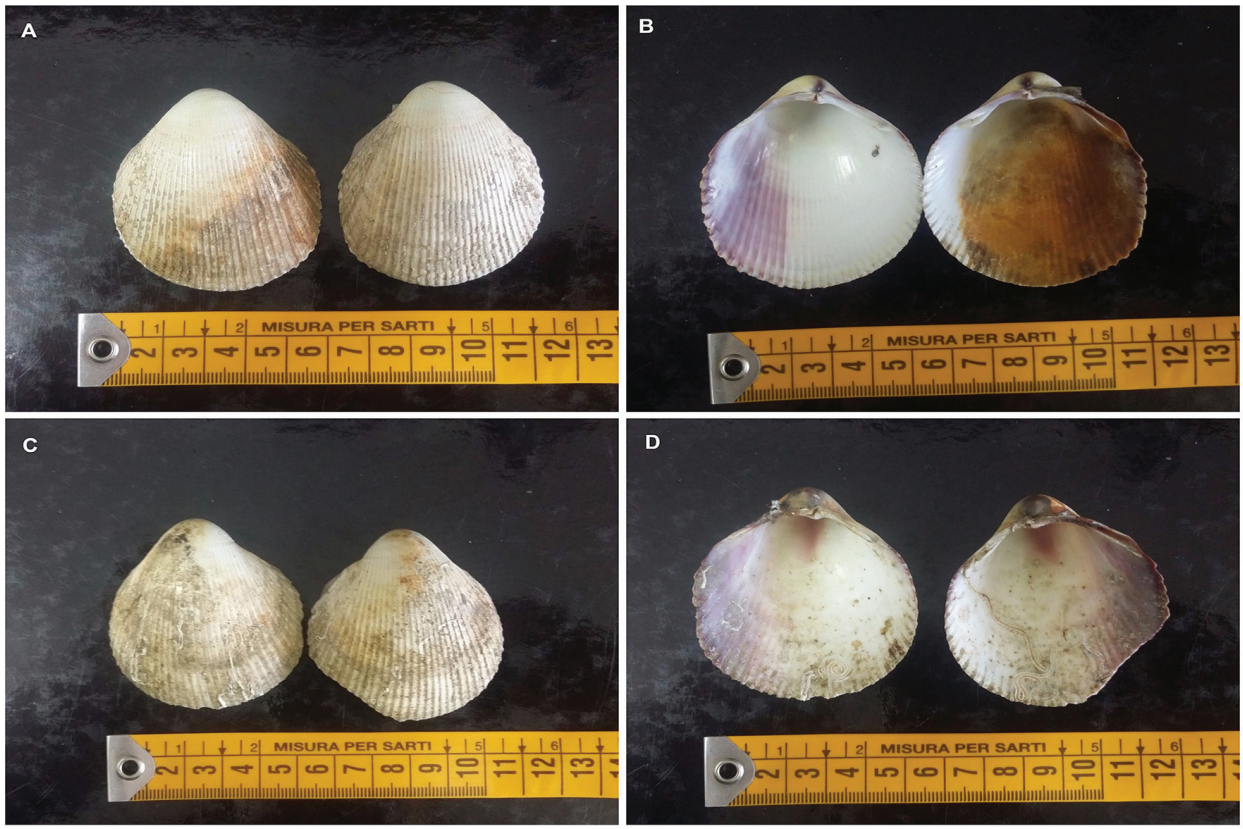


**Fig. 2.** Shells of *Fulvia fragilis*, outside and inside, found in front of the St. Marko Island; A and B shell found on 6th October 2016; C and D shell found on 11th May 2016.

The first shell of *F. fragilis*, found on the 11th May 2016, was 56.5 mm long. The external part of the shell was white-beige with a purple stain on the umbo and had 40 ribs, while the interior was white with purple colour in the posterior third and in the umbonal cavity. The second shell, found on the 6th October 2016, was 56 mm long and had 39 ribs. Its interior was white with purple colour restricted to the posterior third. Both shells were fragile, almost circular with rounded anterior margin, as well as obliquely expanded posterior part. In each valve, anterior and posterior lateral teeth were present, as well as two cardinal teeth. The internal margin was crenulated and two not so evident adductor muscle scars were present internally, as well as a pallial line without a sinus. The internal surface from umbones to mid-height of valves was almost smooth and radially ribbed ventralward (Fig. 2).

The maximum depth of the transect was 12 m and the area surveyed at the depth up to 5 m was characterised by a rocky-gravel bottom and the seaweeds *Cystoseira foeniculacea* (Linnaeus) Greville, 1830 and *Acetabularia acetabulum* (Linnaeus) P.C. Silva, 1952, followed by the seagrasses *Cymodocea nodosa* (*Ucria*) Ascherson, 1870 and *Posidonia oceanica* (Linnaeus) Delile, 1813 meadows, where a large number of the bivalve *Pinna nobilis* (Linnaeus, 1758) was present. This section was followed by a steep abruption of the bottom (4 m deep) and at the depth of 9 m to12 m the bottom was sandy-muddy and muddy.

The species had apparently been present in this area for a certain period of time, since both shells, judging by their length, were adults. No living specimens or shell residues were found in surveys carried along the same transect during 2015 and 2017. Further research is needed to evaluate the establishment status of the species in the area.

## Discussion

The occurrence of *F. fragilis* in the Adriatic Sea has been expected, especially due to the number of findings and its progression throughout the Mediterranean Sea (Fig. 3). The site where it was found, the Island of St. Marko, is located in the vicinity of the "Porto Montenegro" marina, so it is highly probable that this species was introduced by shipping (maritime) transport (Fig. 1). *Fulvia fragilis* is considered as a Lessepsian migrant but its spreading in the Mediterranean Sea seems to be not only through natural dispersal but also via shipping, since it has

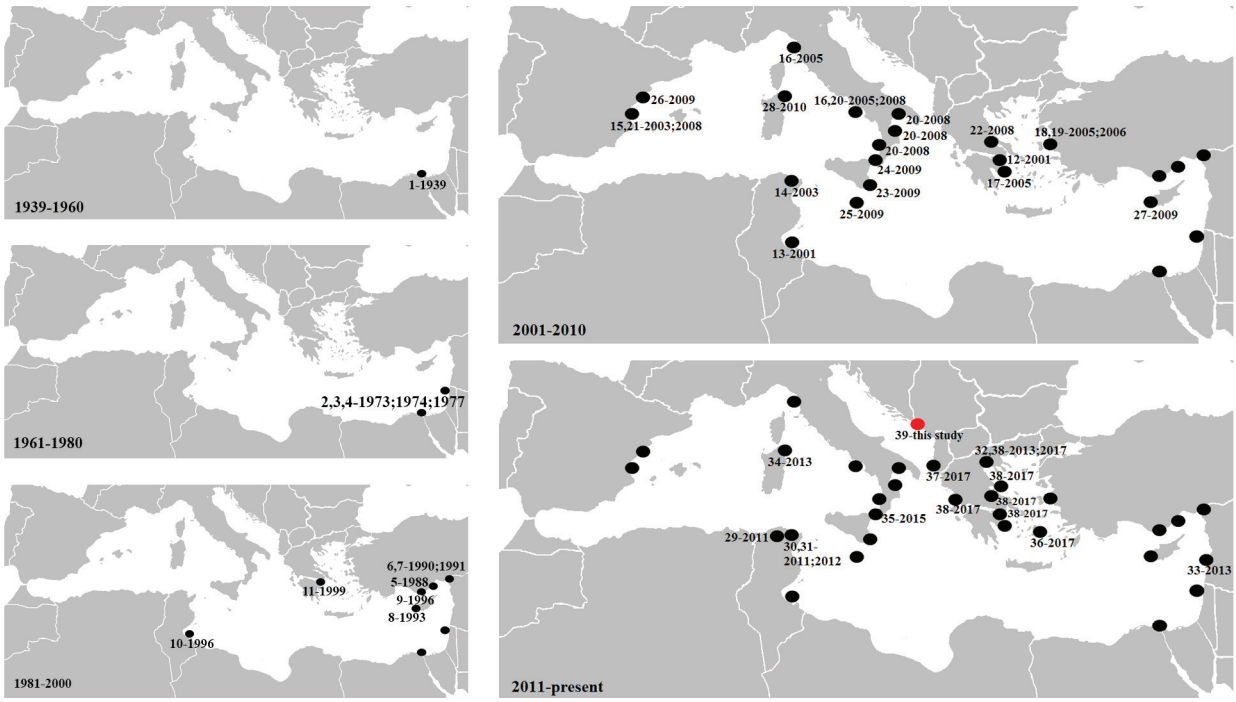


**Fig. 3.** Mediterranean spreading of *Fulvia fragilis* divided into five periods (1939–1960; 1961–1980; 1981–2000; 2001–2010; 2011–present). For numbering of the sites, see Materials and Methods.

been often found near harbours (Gerovasileiou et al. 2017). Zenetos et al. (2004) indicate the typical Lessepsian migrant distribution of *F. fragilis* (recorded in the Suez Canal, then in Israel, Tunisia and S. Turkey) but also suggest transport via shipping based on records in the vicinity of harbours.

Further spreading of *F. fragilis* in the Boka Kotorska Bay can be expected as the bay is home to a number of important harbours such as "The Port of Kotor" (one of the busiest ports in the segment of cruise tourism with more than 350 passenger ships throughout a year). Moreover, further spreading of this species along the Adriatic Sea coast is expected to occur in the years to follow.

The Mediterranean records and temporal changes in distribution of *F. fragilis* from the first record in 1939 up to 2018 are presented in Fig. 3. Spreading has typical east-west character, with early first records in the East and one record in Central Mediterranean up until 2000. During the period 2001–2010, the species has spread in Greece, the Central and West Mediterranean Sea and has been reconfirmed in the Gulf of Tunis, Eleusis Bay and Phapos. Also in this period, the most northern Mediterranean finding was recorded in Livorno (Crocetta 2005). Since 2011 up to present, some new records have been indicated in Greece and the species has been reconfirmed for the Eleusis Bay, Evvoikos Gulf, Tunisia Bay, Olbia and Messina Strait. In the same period, the first record for *F. fragilis* for Albania (Vlore Bay, Strait of Otranto) was published (Gerovasileiou et al. 2017). Our finding in the Boka Kotorska Bay presents its first record for Montenegro, as well as for the Adriatic Sea.

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