

Occurrence of non-indigenous invasive bivalve *Arcuatula senhousia* in aggregations of non-indigenous invasive polychaete *Ficopomatus enigmaticus* in Neretva River Delta on the Eastern Adriatic coast

Marija DESPALATOVIĆ¹, Marijana CUKROV², IVAN CVITKOVIĆ^{1*},
Neven CUKROV³ and Ante ŽULJEVIĆ¹

¹*Institute of Oceanography and Fisheries, Šet. I. Meštrovića 63, 21000 Split, Croatia*

²*Croatian Biospeleological Society, Demetrova 1, 10000 Zagreb, Croatia*

³*Rudjer Boskovic Institute, Bijenicka 54, 10000 Zagreb, Croatia*

**Corresponding author, e-mail: cvite@izor.hr*

*Non-indigenous invasive bivalve *Arcuatula senhousia* was recorded in the area of the eastern Adriatic Sea in Neretva River Delta, in 2010, among tubes of well established aggregations of non-indigenous species of sedentary polychaete *Ficopomatus enigmaticus* at depths from 0.5 to 1 m. It was very abundant, with the maximal abundance of 102 N/400 cm², only in very thick fouling aggregations, but any traces of colonization of this species on soft sediments were not observed. Community that inhabits aggregations of invasive polychaete was described in the paper. Occurrence of *Arcuatula senhousia* in wider area of very important port for international maritime transport suggests that the ballast waters could be possible vector of introduction of this species. The analysis of the sediment revealed that the species was introduced recently. In contrary, *Ficopomatus enigmaticus* was introduced in the area earlier.*

Key words: *Arcuatula senhousia*, *Ficopomatus enigmaticus*, invasive species, non-indigenous species, Neretva River Delta

INTRODUCTION

Numerous non-indigenous species were recorded in the area of the Adriatic Sea in last decades (DESPALATOVIĆ *et al.*, 2008; DRAGIČEVIĆ & DULČIĆ, 2010). One of these non-indigenous species in the Adriatic Sea is Asian mussel, *Arcuatula senhousia* (Benson in Cantor, 1842). It is small mytilid, with thin, oval and elongate shell attaining a maximum length of about 32 mm, but the common size is from 10 to 25 mm in length and up to 12 mm in width (CROOKS, 1996; ZENETOS *et al.*, 2003). Asian mussel is suspension-feeder that inhabits both, hard and soft substrata, where it lives, attached with

its bissus, in intertidal and subtidal to 20 m deep (CROOKS, 1996; ZENETOS *et al.*, 2003). It is an opportunist, short-lived species (maximum life span is approximately 2 years), that grows quickly, suffers high mortality, but it could be very abundant within its native range of distribution or in the areas where it has been introduced (MORTON, 1974; CROOKS, 1996).

Its native range of distribution is Asian continent, from Siberian coast to Malay Peninsula, and in the Red Sea, but it was introduced in different parts of the world: western coast of North America, Australia, New Zealand, the Atlantic coast of Europe and the Mediterranean Sea (MACDONALD, 1969; BARASH

& DANIN, 1971, 1973; WILLAN, 1985, 1987; CROOKS, 1996; BACHELET *et al.*, 2009).

In the Mediterranean Sea the species was first recorded in the eastern part, in Israel and Egypt (BARASH & DANIN, 1971, 1973), then in the southern France (HOENSELAAR & HOENSELAAR, 1989), in Italy in the area of Ravenna in the northern Adriatic Sea (LAZZARI & RINALDI, 1994), and Slovenia (DE MIN & VIO, 1997; MAVRIČ *et al.*, 2010). Additionally, in the Adriatic Sea the species was found in the Gulf of Trieste (CROSETTA, 2011), along the northern part of the western coast, in Venezia (MIZZAN, 2002), in the Sacca di Goro lagoon and other areas of the Po River Delta (MISTRI, 2002, 2003; MISTRI *et al.*, 2004), in the brackish-water lakes in Gargano National Park (FLORIO *et al.*, 2008), and in the coastal waters (SOLUSTRI *et al.*, 2003). *Arcuatula senhousia*, was also recorded in the Ionian Sea (Taranto seas) (MASTROTOTARO *et al.*, 2003), in the Tyrrhenian Sea (Gulf of Olbia, Gizzzeria) (SAVARINO & TUROLLA, 2000; MUNARI, 2008; CROSETTA *et al.*, 2010), and Ligurian Sea (port of Livorno) (CAMPANI *et al.*, 2004).

The aim of this paper was to present record of *A. senhousia* in the area of the eastern Adriatic coast in the community that inhabits aggregations of the other non-indigenous species, polychaete *Ficopomatus enigmaticus* (Fauvel, 1923). This sedentary suspension-feeding tubeworm, which belongs to family Serpulidae, was recently recorded along the eastern Adriatic coast (CUKROV *et al.*, 2010) and the paper, also, presents data about its community. Additionally, the time of introduction of these invasive species in the area was estimated.

MATERIAL AND METHODS

The samples of the species *Arcuatula senhousia* were collected during the complex investigation of polychaete *Ficopomatus enigmaticus* aggregations in the area of rivulet Crna Rika near town Ploče in Neretva River Delta, in June 2010 (Fig. 1). Neretva River Delta is situated in the central part of the eastern Adriatic coast. It is vast delta whose surface area covers a total of 170 km². Neretva is 218 km long river, with a

source located deeply in the hinterland of Bosnia and Herzegovina. It follows a typical Mediterranean-type hydrological regime, characterised by extensive seasonal and annual fluctuations (GASITH & RESH, 1999).

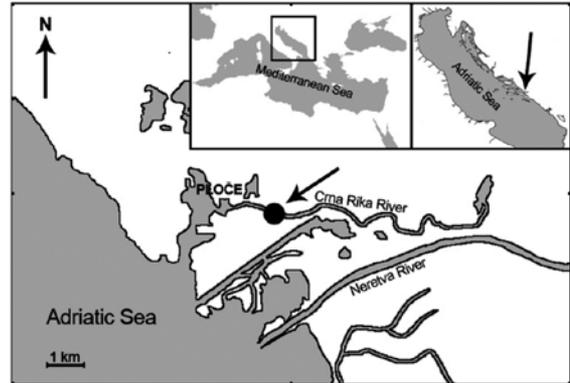


Fig. 1. Sampling station: cement bridge across the rivulet Crna Rika (43°03'05,7" N 17°26'57,6" E) (black circle) near town Ploče in Neretva River Delta on the eastern Adriatic coast

Three squares of 20 x 20 cm of fouling aggregation of *F. enigmaticus* together with associated fauna were sampled by scuba diver from vertical cement bridge construction at depths from 0.5 to 1 m. Samples were preserved in 4% formaldehyd solution for further analysis. All specimens of *A. senhousia* were separated and counted. Other animals collected from polychaete aggregations were also identified and counted.

With the aim to establish the period of appearance of these two non-native species in the area, sediment analysis was carried out. The samples of sediment were collected with the hand driven acrylic corer, 50 cm long and 10 cm in diameter, at three sites (below, and both sides of the bridge) at depths of around 1.5 m. Sediment cores were divided into 5 cm thick layers. The wet samples of sediment were wet sieved with vibratory sieve shaker AS 200 Digit-RETSCH (size 1 mm) and analysed with the magnifying glass (magnification of 20x).

RESULTS

Asian mussel, *Arcuatula senhousia*, was recorded in April, 2010 at investigated station on cement bridge construction across the rivulet Crna Rika (43°03'05,7" N 17°26'57,6" E), in

village Stablina near town Ploče (Fig. 1). It was present among tubes of well established aggregations of non-indigenous species of sedentary polychaete *Ficopomatus enigmaticus* (Fig. 2) at depths from 0.5 to 1 m.

The thickness of *Ficopomatus* aggregations on cement construction was approximately 50 cm, and density of polychaete tubes was from 11 to 25 specimens per sq cm (n=10; average \pm standard deviation: 21 ± 4 N/cm²).

The abundance of *A. senhousia* was 93 ± 11 N/400 cm² of aggregation (average \pm standard deviation; n=3) (Table 1). The maximal recorded length of collected specimens in June 2010 was 26 mm. The other taxa that were very abundant in the aggregations were bivalve *Mytilaster minimus* (Poli, 1795) (1601 ± 161 N/400 cm²), and Amphipoda (*Echinogammarus veneris* (Heller, 1865), *Hyale crassipes* (Heller, 1866)) and Isopoda (*Sphaeroma serratum* (Fabricius, 1787), *Lekanesphaera* sp., *Jaera* sp.) (Table 1). Additionally, in *Ficopomatus* aggregations, very abundant was bryozoan species *Conopeum seurati* (Canu, 1928) covering polychaete tubes and mollusc shells (Fig. 2).

Composition of sediments on the bottom of the rivulet Crna Rika was analysed from the surface of sediment down to 37 cm deep at three sites. The shells of Asian mussel, *A. senhousia*, were recorded only in the first surface layer

from 0 to 5 cm. Presence of *F. enigmaticus* was recorded in all sediment layers from 0 to 37 cm deep.

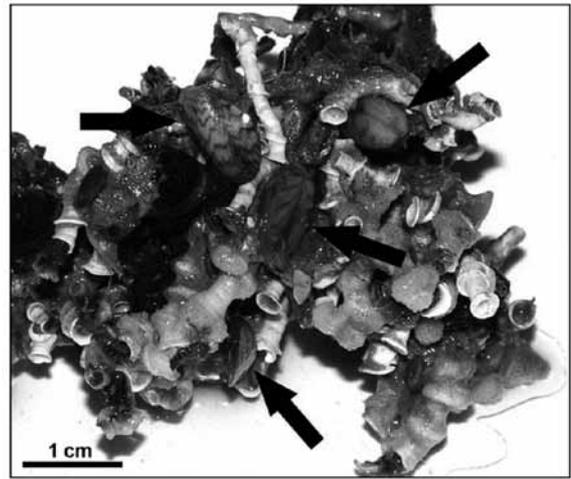


Fig. 2. *Arcuatula senhousia* (Benson in Cantor, 1842) specimens (arrows) inside aggregations of *Ficopomatus enigmaticus* (Fauvel, 1923) tubes covered with bryozoan *Conopeum seurati* (Canu, 1928)

DISCUSSION

In the Adriatic Sea, *Arcuatula senhousia* is present in its northern part and in some areas along the western coast (LAZZARI & RINALDI, 1994; DE MIN & VIO, 1997; MISTRI, 2002, 2003; SOLUSTRI *et al.*, 2003; MISTRI *et al.*, 2004; MAVRIČ *et al.*, 2010; CROCETTA, 2011). Since now, along the

Table 1. Abundance (N/400 cm² of aggregation) of the taxa collected in thick aggregations of *Ficopomatus enigmaticus* (Fauvel, 1923) on cement bridge construction near town Ploče

TAXA	ABUNDANCE (N/400 cm ² of aggregation)				
	N	Min	Max	Mean	\pm SD
<i>Arcuatula senhousia</i>	3	81	102	93	11
<i>Mytilaster minimus</i>	3	1508	1787	1601	161
<i>Parvicardium exiguum</i>	3	16	25	21	5
<i>Tellina</i> sp.	3	1	16	8	8
<i>Theodoxus fluviatilis</i>	3	5	44	29	21
<i>Haminoea</i> sp.	3	1	9	5	4
<i>Gibulla</i> sp.	3	0	7	4	4
<i>Balanus eburneus</i>	3	5	19	13	7
Hydrobiidae	3	48	77	60	15
Amphipoda	3	298	1143	787	438
Isopoda	3	1139	1415	1299	143

N, number of samples; Min, the lowest value; Max, the highest value; SD, standard deviation

eastern coast, the species was not recorded. The area in the northern part where the population was already established is distant from the Neretva River Delta, which disables natural spreading of the species into Delta. In the past, spreading of this species to distant areas was linked to transfer in the ballast waters of ships, as was the case in Australia and New Zealand (WILLAN, 1987); and shellfish farming and trading, as was in the west coast of the North America and in the Mediterranean Sea, including the northern Adriatic Sea (MISTRI *et al.*, 2004). Since there is no fish farm in surrounding area, that vector of introduction in Neretva River Delta is excluded. Nearby town Ploče has a very important port for international maritime transport, and ballast waters could be the possible vector of introduction of the species in the area. The first specimens of *A. senhousia* in the Neretva River Delta were collected in 2010, but it is difficult to establish the time of introduction with certainty.

Analysis of the sediment revealed that the species was introduced recently in the area and its shells were present only in the surface layer of the sediment. In contrary, *Ficopomatus enigmaticus* was introduced in the area earlier. Estimated sedimentation rate in the area of Crna Rika (CUKROV, 2011) suggests that *F. enigmaticus* inhabited the Neretva River Delta at least forty years ago, since parts of its tubes were found in deeper sediment layers.

In the period of the first observation of *A. senhousia*, the species was present in the area for more than one year. The proof for that is maximal recorded length of one individual of 26 mm, suggesting that the investigated population is present in the area for more than a year. This assumption arises if we take into consideration the results of estimation of average growth and life span of the species in populations in a Southern California Bay, that are in accordance with previous studies, showing the growth from 17 to 23 mm in the first year, and that individuals attain maximum length of about 32 mm in less than two years, but most individuals are annual and only small fraction of population lives perhaps up to two years (CROOKS, 1996).

In the investigated area of Neretva River Delta *A. senhousia* was observed only among tubes of invasive tubeworm *F. enigmaticus* on hard substratum, and it was very abundant with the maximal abundance of 102 N/400 cm² in very thick fouling aggregation. Any traces of colonization of this species in conspicuous aggregations on soft sediments were not observed during the diving, but the detailed investigation and sampling of soft sediments with the aim to find individual specimens of *A. senhousia* in wider area of the delta was not performed. In the near future, if the conditions would be favourable for spreading of the species on the soft bottoms, we can expect very dense populations, as is the case, for example, in the area of the northern Adriatic lagoon (Sacca di Goro) where the population spread on soft sediments was explosive, and after few years of its first observation, it carpeted thousands of square meters and its densities exceeded 10,000 individuals per square meter (MISTRI *et al.*, 2004). Colonisation and invasion of bottom by this opportunistic invader has potentially positive or negative effect on native fauna and benthic community (CROOKS, 1996, 2001; MISTRI *et al.*, 2004; MUNARI, 2008). It acts as secondary substratum that enhances environmental complexity, and its beds facilitate the presence of other macrofaunal invertebrates (MISTRI, 2002; MUNARI, 2008). Also, its population is a significant additional source of CO₂ to seawater (MISTRI & MUNARI, 2013).

It is obvious that the aggregations of *F. enigmaticus* in Neretva River Delta are favourable substrate for *A. senhousia*, but it is very possible that after initial period of colonisation *A. senhousia* could have negative effect on *F. enigmaticus*, as it was in the area of the northern Adriatic where colonisation of *A. senhousia* inhibited *F. enigmaticus* (MISTRI, 2003). Also, invasive non-indigenous Asian mussel could inhibit other suspension-feeding species, as is native bivalve *Mytilaster minimus* (MISTRI, 2003), that is very abundant in *F. enigmaticus* aggregations in the area of Delta.

The occurrence of Asian mussel on aggregations of non-indigenous species supports the opinion that non-native habitat forming species

may enhance the establishment and population growth of other non-native species and, also, provides living space for native species (HEIMAN *et al.*, 2008).

This first observation and quantification of invasive Asian mussel in the area of Neretva River Delta provides the base to monitor its spreading in surrounding areas, and its impact on native species in the area, since the species

is listed among hundred worst invasive species in the Mediterranean (STREFTARIS & ZENETOS, 2006).

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of Jana BEDEK, Sanja GOTTSTEIN and Maja NOVOSEL in species identification.

REFERENCES

- BACHELET, G., H. BLANCHET, M. COTTET, C. DANG, X. DE MONTAUDOUIN, A. DE MOURA QUEIRÓS, B. GOUILLIEUX & N. LAVESQUE. 2009. A round-the-world tour almost completed: first records of the invasive mussel *Musculista senhousia* in the north-east Atlantic (southern Bay of Biscay). *Marine Biodiversity Records*, 2: e119.
- BARASH, A. & Z. DANIN. 1971. Mollusca from the stomach of *Sparus aurata* fished in the lagoon of Bardawil. *Argamon*, 2(3-4): 97-104.
- BARASH, A. & Z. DANIN. 1973. The Indo-Pacific species of Mollusca in the Mediterranean and notes on a collection from the Suez Canal. *Israel J. Zool.*, 21: 301-374.
- CAMPANI, E., M. COPPINI, F. CUNEO & A. MARGELLI. 2004. Bivalvi "alieni" nelle acque del Porto di Livorno: *Theora (Endopleura) lubrica* Gould, 1861 e *Musculista senhousia* (Benson in Cantor, 1842). *Atti. Soc. tosc. Sci. nat., Mem., Serie B*, 111: 1-5.
- CROCETTA, F. 2011. Marine alien Mollusca in the Gulf of Trieste and neighbouring areas: a critical review and state of knowledge (updated in 2011). *Acta Adriat.*, 52(2): 247-260.
- CROCETTA, F., A. VAZZANA & W. RENDA. 2010. The infralittoral mobile bottom molluscs of Gizzeria harbour (Catanzaro, Italy). *Marine Biodiversity Records*, 3: e15.
- CROOKS, J.A. 1996. The Population Ecology of an Exotic Mussel, *Musculista senhousia*, in a Southern California Bay. *Estuaries*, 19(1): 42-50.
- CROOKS, J.A. 2001. Assessing invader roles within changing ecosystems: historical and experimental perspectives on an exotic mussel in an urbanized lagoon. *Biol. Invasions*, 3: 23-36.
- CUKROV, M. 2011. Biology and ecology of the species *Ficopomatus enigmaticus* (Fauvel, 1932) (Annelida, Polychaeta) along the Eastern Adriatic coast. Dissertation, University of Zagreb, 231 pp.
- CUKROV, M., M. DESPALATOVIĆ, A. ŽULJEVIĆ & N. CUKROV. 2010. First record of the introduced fouling tubeworm *Ficopomatus enigmaticus* (Fauvel, 1923) in the eastern Adriatic Sea, Croatia. *Rapp. Comm. int. Mer. Médit.*, 39: p. 483.
- DE MIN, R. & E. VIO. 1997. Molluschi conchiferi del litorale sloveno. *Annals for Istran and Mediterranean Studies, Koper, Annales 11, Ser. hist. nat.*, 4: 241-258.
- DESPALATOVIĆ, M., I. GRUBELIĆ, V. NIKOLIĆ, B. DRAGIČEVIĆ, J. DULČIĆ, A. ŽULJEVIĆ, I. CVITKOVIĆ & B. ANTOLIĆ. 2008. Allochthonous warm water species in the benthic communities in the eastern part of the Adriatic Sea. In: F. Briand (Editor). *Climate warming and related changes in Mediterranean marine biota. CIESM Workshop Monographs*, 35: 51-57.
- DRAGIČEVIĆ, B. & J. DULČIĆ. 2010. Fish Invasions in the Adriatic Sea. In: D. Golani and B. Appelbaum-Golani (Editors). *Fish invasions of the Mediterranean Sea: change and renewal*. Pensoft Publishers, Sofia-Moscow, pp. 255-266.
- FLORIO, M., P. BREBER, T. SCIROCCO, A. SPECCHIULLI, L. CILENTI & L. LUMARE. 2008. Exotic species in Lesina and Varano lakes as new

- guest in Lesina and Varano lakes: Gargano National Park (Italy). *Transit. Waters Bull.*, 2: 69-79.
- GASITH, A. & V.H. RESH. 1999. Streams in Mediterranean climate regions: abiotic influences and biotic responses to predictable seasonal events. *Ann. Rev. Ecol. Syst.*, 30: 51-81.
- HEIMAN, K.W., N. VIDARGAS & F. MICHELI. 2008. Non-native habitat as home for non-native species: comparison of communities associated with invasive tubeworm and native oyster reefs. *Aquat. Biol.*, 2: 47-56.
- HOENSELAAR, H.J. & J. HOENSELAAR. 1989. *Musculista senhousia* (Benson in Cantor, 1842) in the western Mediterranean (Bivalvia, Mytilidae). *Basteria*, 53: 73-76.
- LAZZARI, G. & E. RINALDI. 1994. Alcune considerazioni sulla presenza di specie extra mediterranee nelle lagune salmastre di Ravenna. *Boll. Malacol.*, 30: 195-202.
- MACDONALD, K.B. 1969. Quantitative studies of salt marsh mollusc faunas from the North American Pacific Coast. *Ecol. Monogr.*, 39: 33-59.
- MASTROTOTARO, F., A. MATARRESE & G. D'ONGHIA. 2003. Occurrence of *Musculista senhousia* (Mollusca: Bivalvia) in the Tarento seas (eastern-central Mediterranean Sea). *J. Mar. Biol. Ass. U.K.*, 83: 1279-1280.
- MAVRIČ, B., M. ORLANDO-BONACA, N. BETTOSO & L. LIPEJ. 2010. Soft-bottom macrozoobenthos of the southern part of the Gulf of Trieste: faunistic, biocoenotic and ecological survey. *Acta Adriat.*, 51(2): 203-216.
- MISTRI, M. 2002. Ecological Characteristics of the Invasive Asian Date Mussel, *Musculista senhousia*, in the Sacca di Goro (Adriatic Sea, Italy). *Estuaries*, 25(3): 431-440.
- MISTRI, M. 2003. The non-indigenous mussel *Musculista senhousia* in an Adriatic lagoon: effects on benthic community over a ten year period. *J. Mar. Biol. Ass. U.K.*, 83: 1277-1278.
- MISTRI, M., R. ROSSI & E.A. FANO. 2004. The spread of an alien bivalve (*Musculista senhousia*) in the Sacca di Goro lagoon (Adriatic Sea, Italy). *J. Moll. Stud.*, 70: 257-261.
- MISTRI, M. & C. MUNARI. The invasive bag mussle *Arcuatula senhousia* is a CO₂ generator in near-shore coastal ecosystems. *J. Exp. Mar. Biol. Ecol.*, 440: 164-168.
- MIZZAN, L. 2002. Segnalazioni 19 - *Musculista senhousia*. *Boll. Mus. civ. St. Nat. Venezia*, 53: p. 266.
- MORTON, B. 1974. Some aspects of biology, population dynamics, and functional morphology of *Musculista senhousia* Benson (Bivalvia, Mytilidae). *Pac. Sci.*, 28: 19-33.
- MUNARI, C. 2008. Organism responses to habitat fragmentation in two shallow-water brackish environments: the Goro Lagoon (Adriatic Sea) and the Padrongiano Delta (Tyrrhenian Sea). *J. Mar. Biol. Ass. U.K.*, 88: 1309-1317.
- SAVARINO, R. & E. TUROLLA. 2000. Un ospite indesiderato sbarca ad Olbia. *Informare*, 9: 223-228.
- SOLUSTRI, C., E. MORELLO & C. FROGLIA. 2003. *Musculista senhousia* (Benson in Cantor, 1842) (Bivalvia: Mytilidae) in the coastal waters of the Adriatic Sea (Italy). *Atti. Soc. It. Sci. nat. Museo civ. Stor. Nat. Milano*, 144: 231-240.
- STREFTARIS, N. & A. ZENETOS. 2006. Alien Marine Species in the Mediterranean – the 100 ‘Worst Invasives’ and their Impact. *Medit. Mar. Sci.* 7(1): 87-118.
- WILLAN, R.C. 1985. Successful establishment of the Asian mussel *Musculista senhousia* (Benson in Cantor, 1842) in New Zealand. *Rec. Auckland. Inst. Mus.*, 22: 85-96.
- WILLAN, R.C. 1987. The mussel *Musculista senhousia* in Australasia; another aggressive alien highlights the need for quarantine at ports. *B. Mar. Sci.*, 41(2): 475-489.
- ZENETOS, A., S. GOFAS, G. RUSSO & J. TEMPLADO. 2003. F. BRIAND (Editor). *CIESM Atlas of exotic species in the Mediterranean. Vol. 3. Molluscs.* CIESM Publishers, Monaco, 376 pp.

Received: 28 May 2013

Accepted: 24 September 2013

Pojava stranog invazivnog školjkaša *Arcuatula senhousia* u nakupinama stranog invazivnog mnogočetinaša *Ficopomatus enigmaticus* u delti rijeke Neretve na istočnoj obali Jadranskog mora

Marija DESPALATOVIĆ¹, Marijana CUKROV², Ivan CVITKOVIĆ^{1*},
Neven CUKROV³ i Ante ŽULJEVIĆ¹

¹Institut za oceanografiju i ribarstvo, Šet. I. Meštrovića 63, 21000 Split, Hrvatska

²Hrvatsko biospeleološko društvo, Demetrova 1, 10000 Zagreb, Hrvatska

³ Institut Ruđer Bošković, Bijenička cesta 54, 10000 Zagreb, Hrvatska

*Kontakt adresa, e-mail: cvite@izor.hr

SAŽETAK

Strana invazivna vrsta školjkaša *Arcuatula senhousia* je zabilježena 2010. godine na području istočnog Jadrana u delti rijeke Neretve, između cjevčica dobro razvijenih nakupina strane vrste sedentarnog mnogočetinaša *Ficopomatus enigmaticus* na dubinama od 0,5 do 1 m. Bila je vrlo brojna, s najvećom abundancijom od 102 N/400 cm², samo u vrlo debelim nakupinama u obraštaju. Tragovi kolonizacije ove vrste na sedimentnom dnu nisu opaženi. U radu je opisana i zajednica koja naseljava nakupine ovog invazivnog mnogočetinaša. Pojava vrste *A. senhousia* na širem području vrlo važne luke za međunarodni pomorski promet ukazuje da balastne vode mogu biti vektor unosa ove vrste. Analiza sedimenta je pokazala da je vrsta nedavno unesena. Za razliku od nje, vrsta *F. enigmaticus* je, na ovo područje, unesena ranije.

Ključne riječi: *Arcuatula senhousia*, *Ficopomatus enigmaticus*, invazivne vrste, strane vrste, delta rijeke Neretve

