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ALIEN INVASIVE SPECIES AT THE ROMANIAN BLACK SEA COAST – PRESENT AND PERSPECTIVES

MARIUS SKOLKA, CRISTINA PREDA

Abstract. Using literature data and personal field observations we present an overview of aquatic animal alien invasive species at the Romanian Black Sea coast, including freshwater species encountered in this area. We discuss records, pathways of introduction, origin and impact on native communities for some of these alien invasive species. In perspective, we draw attention on the potential of other alien species to become invasive in the study area.

Résumé. Ce travail présente le résultat d'une synthèse effectuée en utilisant la littérature de spécialité et des observations et études personnelles concernant les espèces invasives dans la région côtière roumaine de la Mer Noire. On présente des aspects concernant les différentes catégories d'espèces invasives – stabilisées, occasionnelles et incertes – des écosystèmes marins et dulcicoles. L'origine géographique, l'impact sur les communautés d'organismes natifs, l'impact économique et les perspectives de ce phénomène sont aussi discutés.

Key words: alien invasive species, Black Sea, Romania.

INTRODUCTION

Invasive species are one of the great problems of the modern times. Globalization, increase of commercial trades and climatic changes make invasive species a general threat for all kinds of terrestrial, freshwater or marine ecosystems (Mooney, 2005; Perrings et al., 2010). Perhaps polar areas or the deep seas are the only ecosystems not affected by this global phenomenon.

Black Sea is a particular marine basin, with special hydrological characteristics, formed 10,000 years BP, when Mediterranean waters flowed to the Black Sea over the Bosporus strait. The low salinity, low species diversity and highly affected coastal ecosystems by eutrophication combined with the high trade rate in the area have encouraged the establishment of alien species with high ecological plasticity (Leppäkoski & Mihnea, 1996). Some of these species had a radical impact on native communities in marine and freshwater ecosystems while others remained almost unnoticed (Zaitsev & Ozturk, 2001; Mee et al., 2005). The aim of the present paper is to present an overview of the alien invasive species' current status at the Romanian Black Sea coast (between Chilia Branch of the Danube to Vama Veche) including some species present in the freshwater coastal waters (paramarine lakes, coastal lagoons or estuaries connected with the sea and the Danube Delta). Aspects concerning records, pathways of introduction, origin and impact on native communities are discussed. New potential alien species for the referenced area are also presented.

MATERIAL AND METHODS

The terminology used for describing alien invasive species is sometimes confusing. Specialists and international organizations failed to adopt a unique terminology. In an attempt to offer an overview of the terms used in English

scientific literature in connection with the ecological problems of the invasive species phenomena, Colautti & MacIsaac (2004) listed no less than 33 terms. The impact of invasive species is considered from many points of view – impact on environment, on economy or human health, short or long-term impact, negative or positive effect etc. – and specialists failed to present a concrete and comprehensive definition. The reason is the lack of a general consensus of the scientists, economists and politicians about the importance of the different criteria used to define an invasive species.

In this paper, we divided alien species in three major categories: alien invasive species, casual species and questionable species (Carlton, 1996; Ruiz & Carlton, 2003; Mooney, 2005; Cox, 2004; Zenetos et al., 2005), as described below:

Alien invasive species are considered those species that established self-sustaining populations in new habitats situated at long distance from their native habitat, capable to spread in new territories independent from human activities. We consider in this category *established* and *naturalized* alien species, namely those species that are able to develop self-maintaining populations independent of any human activity, after their direct or indirect introduction (EU Commission, 2004). *Cryptogenic* species were also included in this category, which are species introduced before 1800 with uncertain origin and unknown way of introduction, or species with no evidence of their native or non-native status (Carlton, 1996; Ruiz & Carlton, 2003; Zenetos et al., 2005).

We also consider that an alien species always has "*per se*" a negative effect on native ecosystems. The presence of such a species changes the structure of native communities, affecting biodiversity. Considering the invasive status of one species or another, we should not take into account the impact on economy or the impact on human health (Mooney, 2005; Cox, 2004), but only the effect on biodiversity. An alien species is always an invasive one.

Casual invasive species category comprises, according to CIESM criteria (http://www.ciesm.org/online/atlas/index.htm), species mentioned once or for few times in a new area, requiring further investigations of their situation.

A third category – *questionable species* (Zenetos et al., 2005) should be used for species of which there is insufficient information, for alien species not verified by specialists or for species with uncertain taxonomic status.

The list of aquatic alien invasive species mentioned in this paper is based on published data from both national and international scientific papers, and on personal field observations performed during the last fifteen years. The list comprises 49 marine animal species and 20 freshwater species already present at the Romanian Black Sea coast.

RESULTS AND DISCUSSION

In comparison with the total number of marine animal taxa (Metazoa) mentioned for the Romanian littoral, the number of alien invasive species represents about 3.3% (Skolka et al., 2006). In the last decades of the 20th century, about 17.4% of these alien invasive species induced notable changes in native communities, both in marine and freshwater ecosystems. The most affected were the benthic (for example sandy bottoms in Sulina – Cap Midia sector) and pelagic ecosystems.

Invasive species at the Romanian littoral – short history

The first alien invasive species that reached the Black Sea (Tab. 1) were species from fouling associations. Probably the first of these species were the shipworm *Teredo navalis*, and the barnacle *Balanus improvisus*, arrived in the Black Sea area before 1900 (Grossu, 1962; Gomoiu & Skolka, 1996; Zaitsev & Ozturk, 2001). Started in the first decades of the 20th century, the rate of acclimatization of alien species increased, especially in the 1970 – 1990s (Fig. 1), due to the growing commercial changes and to the high human impact resulting from eutrophication, pollution, coastal development, overfishing.

Between 1900 and 1950 marine invasive species mentioned in this period such as *Blackfordia virginica* (Coelenterata: Hydrozoa) and *Perigonimus* (*Bougainvillia*) *megas* (Coelenterata: Hydrozoa) (Mordukhai-Boltovskoy, 1968) have not had major impacts on native communities. In freshwater ecosystems (Tab. 2) only the pumpkinseed fish *Lepomis gibosus* (Bănărescu, 1964) developed self sustaining populations and became widespread. The western mosquitofish *Gambusia affinis*, introduced in 1927 (Bănărescu, 1964), has an uncertain status in Romania and the influence of the kamptozoan *Urnatella gracilis* (Băcescu, 1954) on benthic communities is almost insignificant.

In 1950 – 1980 periods, the number of alien invasive species reports increased both in marine and freshwater ecosystems. Some of the most important marine species recorded in this period are the crab *Rithropanopaeus harrisii* (Băcescu, 1952, 1967), the gastropoda *Rapana venosa* (Grossu, 1986) and the bivalve *Mya arenaria* (Gomoiu, 1981 a, b) as well as the polychaete *Ficopomatus aenigmaticus* reported in mass populations in Constanța harbor (Pitiș & Lăcătușu, 1971). A small paddle-footed annelid of *Polydora* complex (Losovskaya & Nestorova, 1964; Surugiu, 2008) had established self-sustaining populations in marine benthic communities. Some marine species of pelagic copepods are reported also in this period (Porumb, 1980) but the most spectacular event for this period is the intrusion and afterwards the development of mass populations of the ctenophore *Mnemiopsis leidyi*, mentioned in the Black Sea in early 1990s (Malyshev & Arkhipov, 1992). In freshwater ecosystems, several species of East Asian cyprinid fishes were acclimatized for aquaculture at this time (Bănărescu, 1964; Iacob & Petrescu-Mag, 2008) including the Asian clam *Sinanodonta woodiana* (Petro, 1984). From benthic brackish water communities, the gastropod *Potamopyrgus antipodarum* (Grossu, 1986) is reported.

In 1980s and 1990s, the number of pelagic copepods reported at the Romanian littoral increased (Porumb, 1980; Skolka & Gomoiu, 2004). From benthic association the bivalves *Crassostrea virginica* which was introduced for aquaculture in 1970s and *Anadara inaequivalvis* recorded at the Romanian littoral in 1984 (Gomoiu, 1984), and the gastropod *Corambe obscura* observed at the Romanian coast only in 1997 (Gomoiu & Skolka, 1997) are registered.

Between 1990 and 2000, other invasive species were mentioned in the western part of the Black Sea, such as the nude comb-jelly *Beroe ovata* and the American blue crab *Callinectes sapidus* (Skolka, 1998). In freshwater ecosystems, the intrusion of the crab *Eriocheir sinensis* (Skolka & Gomoiu, 2004; Skolka et al., 2006) and the bivalve *Corbicula fluminea* (Bij de Vaate & Hulea, 2000) were reported.

After 2000, the number of invasive species reports decreased (Fig. 1). Only few new species were reported, and none of them became mass-invasive. This is the

Table 1

Marine alien invasive species at the Romanian littoral.

Species	Origin	First mention	Ecologic type	Vector	Pathway	Status and ecologic impact	References
Blackfordia virginica (Mayer, 1910)	North Atlantic	1940	benthos	accidental	fouling	Established. Insignificant impact; changes in benthic and plankton communities	Mordukhai-Boltovskoy, 1968
Perigonimus (Bougainvilia) megas (Kinne, 1956)	North Atlantic	1940	benthos	accidental	fouling	Casual. Insignificant ecologic impact; changes in benthic and plankton communities	Mordukhai-Boltovskoy, 1968
Rathkea octopunctata (Sars, 1835)	Atlanto-Mediterranean	1959	plankton	accidental	ballast water	Casual. Insignificant ecologic impact; changes in benthic and plankton communities	Porumb, 1959 b
Mnemiopsis leidyi (Agassiz, 1865)	North Atlantic	1987	plankton	accidental	ballast water	Established. Species with major ecologic and economic impact on plankton and nekton communities	Harbison & Volovik, 1993 Petran & Moldoveanu, 1994 - 1995
Beroe ovata (Bruguiere, 1789)	North Atlantic	1998	plankton	accidental	ballast water	Established. Predator specialized on *Mnemiopsis.* Major impact	Gomoiu & Skolka, 1998
Polydora cornuta (Bosc, 1802) native communities	Atlantic	1964 (?)	benthos	accidental	fouling	Established. Major ecologic impact on hard bottoms native communities	Surugiu, 2008 (Losovskaya & Nesterova, 1964)
Ficopomatus aenigmaticus (Fauvel, 1923)	North Atlantic	1954	benthos	accidental	fouling	Established. Major ecologic impact on hard bottoms native communities	Pitiş & Lăcătuşu, 1971
Rapana venosa (Valenciennes, 1846)	Indo-Pacific	1963	benthos	accidental	ballast water	Established. Radical changes in benthic native communities	Gomoiu, 1972
Corambe (Doridella) obscura (Verill, 1870)	North Atlantic	1990	benthos	accidental	fouling	Established. Predator; insignificant ecologic impact	Gomoiu & Skolka, 1997

Table 1 (continued)

Species	Origin	First mention	Ecologic type	Vector	Pathway	Status and ecologic impact	References
Anadara (Scapharca) inaequivalvis (Bruguiere, 1789)	Indo-Pacific	1984	benthos	accidental	ballast water	Established. Radical changes in benthic communities Dominant species	Gomoiu, 1984
Musculista senhousia (Conrad, 1837)	Indo-Pacific	2004	benthos	accidental	fouling	Casual. Radical changes in benthic communities	Micu & Micu, 2004
Crassostrea virginica (Gmelin, 1791)	North Atlantic	1974	benthos	deliberate	mariculture	Casual. Unknown	Skolka & Gomoiu, 2004
Crassostrea gigas (Gmelin, 1791)	Indo-Pacific	1980 (?)	benthos	deliberate	mariculture	Casual. Unknown	Skolka & Gomoiu, 2004
Teredo navalis (Linnaeus, 1758)	Atlanto-Mediterranean	?	benthos	accidental	fouling	Established. Minor ecologic impact	Grossu, 1962
Mya arenaria (Linnaeus, 1758)	North Atlantic	1968	benthos	accidental	ballast water	Established. Radical changes in benthic communities Dominant species	Gomoiu & Porumb, 1969
Neocalanus gracilis (Dana, 1849)	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1980
Mesocalanus tenuicornis (Dana, 1849)	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1980
Paracalanus aculeatus (Giesbrecht, 1888)	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1980
Paracalanus nanus Sars, 1907	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Calocalanus pavo (Dana, 1852)	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Calocalanus plunulosus (Claus, 1863)	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Calocalanus arcuicornis (Dana, 1849)	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Ctenocalanus vanus (Giesbrecht, 1888)	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995

Table 1 (continued)

Species	Origin	First mention	Ecologic type	Vector	Pathway	Status and ecologic impact	References
Microsetella rosea (Dana, 1848)	Cosmopolite	1960 (?)	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Corycaeus furcifer Claus, 1863	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Corycaeus clause F. Dahl, 1894	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Corycaeus (Agetus) typicus Kroyer, 1849	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Corycaeus (Agetus) flaccus Giesbrecht, 1891	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Calocalanus pavoninus Farran, 1936	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Calocalanus tenuis Farran, 1926	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Oncaea mediterranea Claus, 1863	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Oncaea minuta Giesbrecht, 1892	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Oncaea dentipes Giesbrecht, 1891	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Euterpina acutifrons Brian, 1921	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Neocalanus gracilis Dana, 1852	Cosmopolite	?	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Mecynocera clausi Thompson, 1888	Cosmopolite	1979	plankton	accidental	ballast water	Established. Impact unknown.	Porumb, 1994 - 1995
Pontella mediterranea (Claus, 1863)	Atlanto-Mediterranean	?	plankton	accidental	ballast water	Established. Impact unknown.	Skolka & Gomoiu, 2004
Lepas sp.	Atlanto-Mediterranean	?	benthos	accidental	fouling	Casual. Insignificant	Skolka & Gomoiu, 2004
Balanus improvisus (Darwin, 1854)	North Atlantic	1844	benthos	accidental	fouling	Established. Major impact; larval stages represent a valuable food resource	Gomoiu & Skolka, 1996

Table 1 (continued)

Species	Origin	First mention	Ecologic type	Vector	Pathway	Status and ecologic impact	References
Balanus perforatus (Bruguiére, 1789)	North Atlantic	?	benthos	accidental	fouling	Casual. Unknown	Skolka & Gomoiu, 2004
Verruca spengleri (Darwin, 1854)	Atlanto-Mediterranean	1957	benthos	accidental	fouling	Casual. Unknown	Porumb, 1959 a
Sphaeroma walkeri (Stebbing, 1905)	Indo-Pacific	2004	benthos	accidental	fouling	Casual. Minor impact	Skolka & Gomoiu, 2004
Palaemon macrodactylus (Rathbun, 1902)	Indo-Pacific	2009	benthos	accidental	ballast water	Established. Changes in benthic communities	Micu & Niță, 2009
Callinectes sapidus (Rathbun, 1896)	North Atlantic	1980	benthos	accidental	unknown	Casual. Insignificant	Skolka, 1998
Rithropanopaeus harrisii tridentatus (Maitland, 1874)	Indo-Pacific	1950	benthos	accidental	fouling	Established. Major impact in benthic communities	Băcescu, 1967
Hemigrapsus sanguineus (de Haan, 1835)	Indo-Pacific	2010	benthos	accidental	fouling	Casual. Insignificant	Micu et al., 2010
Electra crustulenta (Pallas, 1776)	Atlanto-Mediterranean	?	benthos	accidental	fouling	Casual. Insignificant; changes in structure of benthic communities	Skolka O., 1982
Styela clava (Herdmann, 1881)	American Atlantic waters	2004	benthos	accidental	fouling	Casual. Plankton feeder; changes in benthic communities,	Micu & Micu, 2004
Mugil soiuy (Basilewsky, 1855)	North East Pacific	1972	nekton	deliberate	mariculture	Established. Changes communities in marine fish	Bănărescu, 1964

Table 2

Freshwater alien invasive species in Black Sea Coastal area and Danube Delta.

Species	Origin	First mention	Ecologic type	Vector	Pathway	Status and ecologic impact	References
Urnatella gracilis (Leidy, 1851)	North America	1950	benthos	accidental	fouling	Casual. Insignificant	Băcescu, 1964
Potamopyrgus antipodarum (Gray, 1843)	South Pacific	1952	benthos	accidental	fouling	Established. Insignificant impact. Changes in benthic associations	Grossu, 1986

Table 2 (continued)

Species	Origin	First mention	Ecologic type	Vector	Pathway	Status and ecologic impact	References
Sinanodonta woodiana (Lea, 1834)	East Asia	1962	benthos	deliberate	aquaculture	Established. Significant	Skolka & Gomoiu, 2004; Popa et al., 2007
Dreissena rostriformnis bugensis (Andrusov, 1897)	Ponto-caspic	2005	benthos	accidental	fouling	Casual. Unknown	Micu & Telembici, 2004 Popa & Popa, 2006
Corbicula fluminea (O. F. Müller,1774)	East Asia	1997	benthos	accidental	canal	Established. Major impact; dominant species	Bij de Vatte & Hulea, 2000
Eriocheir sinensis (H. Milne Edwards, 1853)	East Asia	1997	benthos	accidental	unknown	Established. Unclear impact; concurrent species for native crayfish	Skolka, 1998
Gambusia affinis holbrooki (Baird and Girard, 1853)	North America	1925	nekton	deliberate	aquaculture	Questionable. Unclear impact; concurrent for native species. Actual status unclear	Bănărescu, 1964
Aristichthys nobilis (Richardson, 1845)	China	1962	nekton	deliberate	aquaculture	Established. Major impact, radical changes in native fish communities	Source DAISIE
Ctenopharyngodon idella (Valenciennes, 1844)	East Asia	1959	nekton	deliberate	aquaculture	Established. Major impact, radical changes in native fish communities	Source DAISIE
Hypophthalmichthys molytrix (Valenciennes, 1844)	East Asia	1960	nekton	deliberate	aquaculture	Established. Major impact, radical changes in native fish communities	Staraș & Oțel, 1998
Ictalurus melas Rafinesque, 1820	North America	after 1990	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Source DAISIE
Ictalurus nebulosus (Lesueur, 1819)	North America	1910	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Bănărescu, 1964
Ictalurus punctatus (Rafinesque, 1818)	North America	1978	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Source DAISIE

Table 2 (continued)

Species	Origin	First mention	Ecologic type	Vector	Pathway	Status and ecologic impact	References
Ictiobus niger (Rafinesque, 1819)	North America	1978	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Source DAISIE
Carassius gibelio (Bloch, 1782)	East Asia	1912	nekton	deliberate	aquaculture	Established. Major impact, on native fish communities. Dominant species.	Bănărescu, 1964
Lepomis (Eupomatis) gibbosus (Linnaeus, 1758)	North America	1930	nekton	deliberate	aquaculture	Established. Major impact, on native fish communities. Dominant species.	Bănărescu, 1964
Megalobrama terminalis (Richardson, 1846)	East Asia	1965	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Source DAISIE
Mylopharyngodon piceus (Richardson, 1846)	East Asia	1963	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Source DAISIE
Parabramis pekinensis (Basilewsky, 1855)	East Asia	1964	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Source DAISIE
Pseudorasbora parva (Temminck et Schlegel, 1846)	East Asia	1966	nekton	deliberate	aquaculture	Questionable. Impact and changes in native fish communities	Source DAISIE

case of *Musculista senhousia* (Mollusca: Bivalvia), *Styela clava* (Chordata: Ascidiacea) (Micu & Micu, 2004) and the isopod *Sphaeroma walkeri* (Skolka & Gomoiu, 2004) for marine ecosystems and quagga mussel *Dreissena rostriformis bugensis* (Micu & Telembici, 2004) in freshwater ones. Recently, two new invasive species of crustaceans were reported from marine ecosystems: the Asian prawn *Palaemon macrodactylus* which has already established a large population in the northern part of the Romanian Black Sea coast (Micu & Niță, 2009) and the Asian shore crab *Hemigrapsus sanguineus*, a single specimen encountered in Constanța area (Micu et al., 2010).

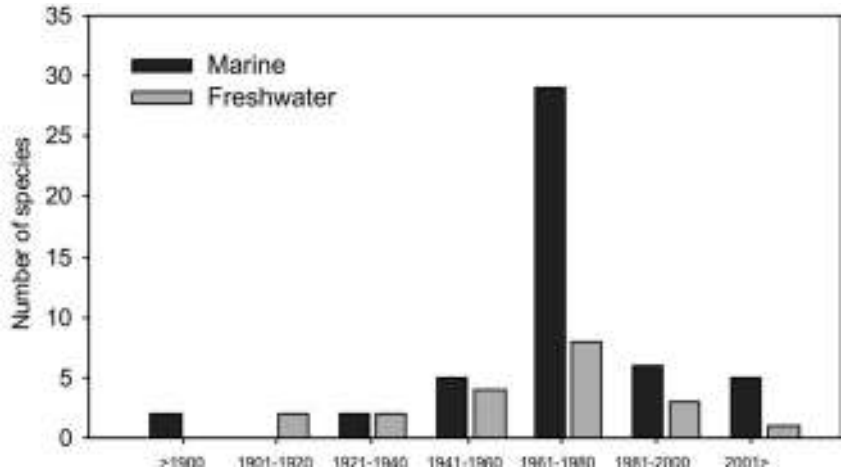

Fig. 1 - Number of marine and freshwater alien invasive species mentioned at the Romanian Black Sea Coast after 1900.

Causes of invasion, invasion routes and geographic origin of alien species

The intrusion of alien species in the Romanian Black Sea coastal area has similar causes with those encountered in other regions. Most species were accidentally introduced in fouling communities from ships' hulls and in ballast water while other species were introduced for aquaculture and mariculture (Fig 2). First records of most alien invasive species in the Black Sea basin are mentioned from the north-western and north-eastern part of the basin (Zaitsev & Ozturk, 2001), in the vicinity of Odessa, Sevastopol and Novorossiysk harbors. The development of shipping activities in these areas and the intended species introduction for mariculture between 1970 and 1980 are the main causes of the invasive species phenomenon in the entire Black Sea.

For the marine ecosystems, about 60% of the alien invasive species were accidentally introduced with ballast water and about 33% in fouling associations. Only about 6% were intentionally introduced for economic purposes (Fig. 3). For freshwater ecosystems, the situation is different: the high majority of alien invasive species was introduced for aquaculture (Fig. 3).

Analyzing the geographic origin of marine alien invasive species, most of them (43%) are cosmopolite planktonic species, 12% have Atlantic-Mediterranean origin, 27% are North Atlantic species and 18% are Indo Pacific (Fig. 4).

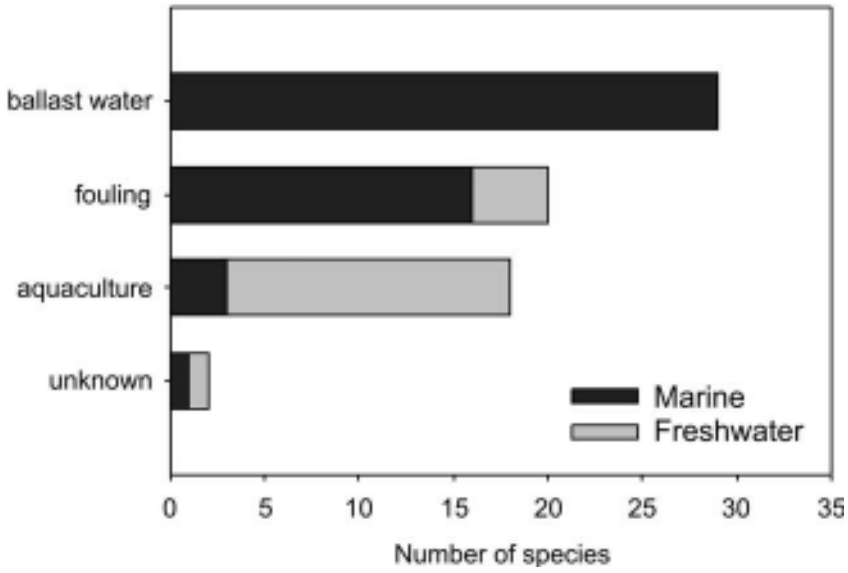

Fig. 2 - Introduction pathways of aquatic invasive species at the Romanian Black Sea Coast.

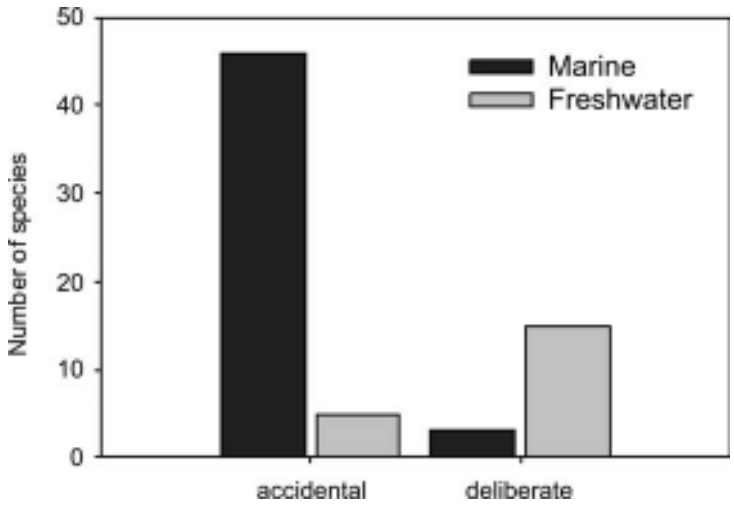

Fig. 3 - Introduction of aquatic invasive species at the Romanian Black Sea Coast.

The freshwater invasive species along the Romanian Black Sea Coast originate in two major areas - North America and East Asia. North-American species represent 55% while 35% of species originate in East Asia**.** Ponto-Caspian and South Pacific species represent only 5% each (Fig. 5).

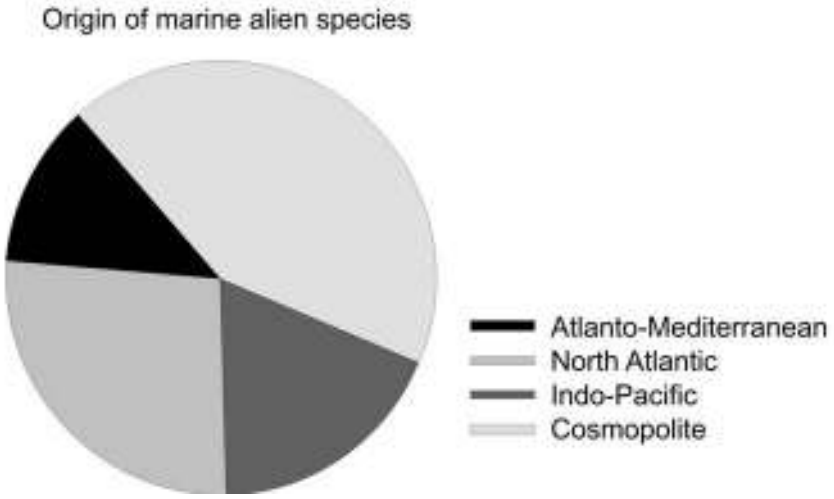

Fig. 4 - Origin of marine alien invasive species at the Romanian Black Sea Coast.

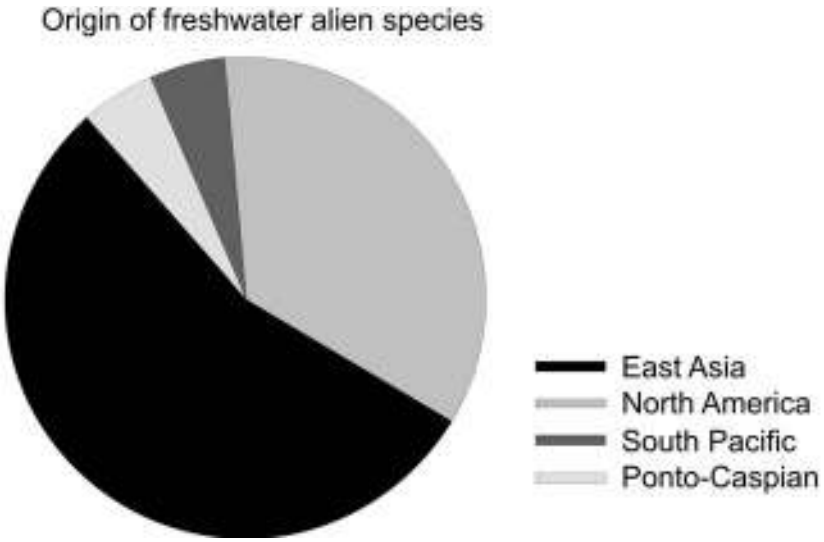

Fig. 5 - Origin of freshwater alien invasive species at the Romanian Black Sea Coast.

Alien invasive species

Considering the Black Sea ecosystems affected by invasive species, we can notice that the most affected are the pelagic and benthic associations from 0 to 50 m depth, both on rocky and sandy bottoms. The benthic communities below this depth do not seem affected by invasive species (Safriel & Ritte, 1983). Although some alien species proved not only the capacity to adapt to the particular conditions of the Black Sea, but became dominant in native pelagic or benthic associations, other established species had a low impact on native communities. At the Romanian Black Sea Coast, species like *Balanus improvisus, Rapana venosa, Mya arenaria,*

Anadara inaequivalvis, Mnemiopsis leidyi, Beroe ovata, Polydora cornuta etc. can be included in the alien invasive species category. In the category of established species with no visible impact on marine ecosystems are *Blackfordia virginica, Corambe obscura, Teredo navalis* and some pelagic copepods (Tab. 1).

Mnemiopsis leidyi. This ctenophore, the rainbow comb jelly is the invasive species with the highest impact on the associations of zooplanktonic and neritic species in the Black Sea (Malyshev & Arkhipov 1992; Harbison & Volovik, 1993). The feeding habits, ecology and the lack of predators combined with the particular conditions of the Black Sea have transformed it quickly into dominant species and its mass development has affected the whole pelagic zone. Among the effects of its penetration and acclimatization in the Black Sea can be mentioned the drastic reduction of pelagic fish populations (Zaitsev, 1992; Niermann et al., 1993, 1994; Zaitsev & Mamaev, 1997; Shiganova & Bulgakova, 2000) – also affected by overfishing, as well as the modification of the structure of the native gelatinous zooplankton (Shushkina et al., 1990; Petran & Moldoveanu, 1994 – 1995; Shiganova et al., 2000, 2001, 2004).

Beroe ovata. The success of *Mnemiopsis leidyi* is directly connected to the success of the nude ctenophores of genus *Beroe*, which appeared in zooplankton few years after the acclimatization of the first species (Finenko et al., 2000; Lebedeva & Shushkina, 1994; Gomoiu & Skolka, 1998; Skolka, 1998; Shushkina et al., 2000). As a result of the penetration of the second species of ctenophore, the populations of *M. leidyi* decreased after 2000 (Kideys, 2002).

Ficopomatus aenigmaticus (Annelida: Polychaeta) has proved a particular success in populating the habitats in harbor areas. Resistant in a marine environment affected by a high human impact, *Ficopomatus aenigmaticus* developed large populations at the Romanian littoral (Pitiş & Lăcătuşu, 1971). The mass populations of this species induce changes in benthic communities, offering at the same time ecological niches and substrata for various species including other fouling species (Micu & Micu, 2004).

Rapana venosa. The veined rapa whelk, the largest species of predatory gastropod in the Black Sea, has also large populations along the entire length of the Romanian littoral (Gomoiu, 1972). The impact on native bivalve communities was important since *R. venosa* contributed at the disappearance of oyster banks from the eastern part of the Black Sea (Chukhchin, 1984).

Mya arenaria and *Anadara (Scapharca) inaequivalvis*. Both *Mya arenaria* (Beshevly & Kolyagyn, 1967; Gomoiu & Porumb, 1969; Gomoiu & Petran, 1973; Gomoiu, 1981 a, b) and the Asian bivalve *Anadara inaequivalvis* (Gomoiu, 1984) represent two other cases of invasive species with particular success in the invaded areas. Both species succeeded shortly after acclimatization to become dominant species on the shallow sandy bottoms characterized by waters with low salinity.

Pelagic copepods. From the plankton communities of the Black Sea Romanian coastal waters about 20 species of copepods of *Neocalanus, Mesocalanus, Calocalanus, Ctenocalanus, Corycaeus, Euterpina, Oncaea, Microsetella* etc. genera were mentioned (Porumb, 1994 – 1995). All of them are cosmopolite species, reported for the first time in the northern part of the Black Sea in 1960 – 1970 and accidentally introduced with ballast water.

Balanus improvisus is the invasive species with the highest ecological success among the crustaceans. Arrived in the Black Sea in the second half of the 19th century (Gomoiu & Skolka, 1996; Skolka & Gomoiu, 2004) it developed large

populations on all types of hard substrate. A possible collateral effect of its successful establishment could be the inability of other species of barnacles to install on the rocky littoral of the Black Sea. Species like *Balanus eburneus* (Gould, 1841) or *Balanus amphitrite* (Darwin, 1854), frequent in the European marine basins and also resistant to anthropic impact, did not succeed in establishing populations in the Black Sea.

Rhithropanopeus harrisii proved to be the crab with the greatest impact (Băcescu, 1952). Having a large ecological plasticity, it populated both freshwater and marine habitats (Băcescu, 1967), and currently it is frequently present on rocky bottoms dominated by the Black Sea mussels *Mytilus galloprovincialis* (Lamarck, 1819). Extremely resistant to harsh environment conditions and its feeding behavior – predatory as well as scavenger or phytophagous – enabled it to become very efficient in exploiting certain ecological niches. Also, the large populations of this small crab make him a valuable trophic resource for native fishes.

Palaemon macrodactylus. This Asian prawn was recently reported from the northern part of Romanian Black Sea coast in large populations. This species is one of the most probable to spread all over the Black Sea shores (Micu & Niță, 2009).

In freshwater ecosystems, species like *Corbicula fluminea, Lepomis gibossus* and some Asian cyprinids became dominant in native pelagic or benthic associations. Species that had a low impact on native communities are *Eriocheir sinensis, Sinanodonta woodiana* and *Dreissena rostriformis bugensis*.

Corbicula fluminea, the Asian clam compared to other freshwater invaders, is a much more dynamic species. Having entered in the Danube River after the opening of the Rhine-Danube canal, it later established stabile populations in western part of Europe, from Great Britain (Elliott & zu Ermgassen, 2008) to the Balkans (Paunović et al., 2007). *Corbicula fluminea* has become rapidly a numerous species not only in the Danube and the Danube Delta, but also in the paramarine lakes or in the Danube-Black Sea Canal.

Freshwater fish species. *Lepomis gibbosus, Hypophthalmichthys molytrix*, *Ctenopharyngodon idella, Carassius gibelio* proved to be successful species in populating new habitats (Bănărescu, 1964; Staraș & Oțel, 1998). *Lepomis gibossus,* introduced in breeding farms, became a dominant species and the impact on fish communities was a major one. The Asian cyprinids also became dominant species, changing the structure of fish communities (Staraș & Oțel, 1998).

The bivalve *Teredo navalis*, the American blue crab *Callinectes sapidus* or the small gastropod *Corambe obscura* are the species that did not produce major modifications in the structure of native organisms' communities at the Romanian littoral.

Corambe obscura developed after acclimatization large populations. It is a predatory species that feeds exclusively on bryozoans and occupied an ecological niche with no efficient native competitors (Roginskaya & Grintsov, 1990; Gomoiu & Skolka, 1997).

Teredo navalis the shipworm occupies an exclusivist ecological niche and does not compete with any of the native species (Grossu, 1962; Skolka & Gomoiu, 2004).

Polydora cornuta became common in mussel communities on hard substrata. It resembles to other native *Polydora* species (Surugiu, 2008), and the impact on native communities is unclear.

In freshwater ecosystems, the same low ecological impact is proved by species like the gastropod *Potamopyrgus antipodarum,* the Chinese mitten crab *Eriocheir sinensis,* and *Sinanodonta woodiana*.

Potamopyrgus antipodarum became after acclimatization a widespread species in the Razelm – Sinoe lagoon complex (Grossu, 1986). This little gastropod knows a rapid expansion in the north-western part of the Black Sea littoral developing large populations at the Ukrainian Coast (Son, 2008).

Sinanodonta woodiana. The Chinese pond mussel is one of the freshwater bivalves accidentally introduced (Petro, 1984; Sarkany-Kiss, 1986), which spread out in Central Europe (Kiss & Petro, 1992; Beran, 2008). At the Romanian littoral, it was reported after 1990 in the Danube Delta (Skolka & Gomoiu, 2004; Popa et al., 2007) where it has developed populations alongside the native bivalve species *Anodonta cygnaea* (Linnaeus, 1758). Afterwards it spread north, being reported from Republic of Moldavia in 2003 (Munjiu & Shubernetski, 2008).

Eriocheir sinensis is present at the mouths of the Danube and in a number of lakes in the Danube Delta. The Chinese mitten crab is quite frequent in some areas (Oţel, 2004), but not abundant. The relationship between this species and the native crayfish *Astacus leptodactylus* (Eschscholtz, 1823) has not been studied yet.

Casual species

For the marine ecosystems, 13 species were included in this category. The hydrozoans *Perigonimus megas* and *Rathkea octopunctata*, the bryozoan *Electra crustulenta* and the barnacle *Balanus perforatus* were not mentioned for a long period and their situation needs to be reconsidered. In the same situation is the small cirriped *Verruca spengleri*, mentioned only as larval stage (Porumb, 1959 a). *Lepas* sp. and *Sphaeroma walkeri*, both of them frequently present in fouling associations of marine ships (Skolka, unpublished data), have not been found in natural habitats. Species like *Musculista senhousia* and *Styela clava* were mentioned only as isolated specimens in the southern part of Constanţa harbor. Only one specimen of the Asian shore crab *Hemigrapsus sanguineus* was reported from the marina of Constanţa tourist harbor (Micu et al., 2010). Isolated specimens of *Callinectes sapidus* were encountered in the southern part of the Romanian littoral (Skolka, 1998; Petrescu et al., 2000). The big size of the American blue crab makes the occurrence of large populations little probable. Oysters like *Crassostrea virginica* and *Crassostrea gigas,* both species introduced for aquaculture, seem to be in the acclimatization period still (Zolotarev & Orlenko, 1999; Zolonitsky & Monina 1992; Ladigina & Pirkova, 2002; Skolka & Gomoiu, 2004).

For the freshwater ecosystems, only two species are included in this category: *Urnatella gracilis* and *Dreissena rostriformis*. *Urnatella gracilis*, a North-American species of Kamptozoa was mentioned for the first time in Romania in the 1950s. Since then, this species was reported only occasionally. Its situation should be reconsidered. The quagga mussel *Dreissena rostriformis bugensis* was reported in the lower Danube (Micu & Telembici, 2004; Popa & Popa, 2006) and it is also present in the Danube Delta (Orlova et al., 2004; Van der Velde & Platvoet, 2007). Its presence is difficult to assess due to the resemblance with the more common zebra mussel *D. polymorpha*.

Questionable species

In this category were included only freshwater fish species. The western mosquitofish *Gambusia affinis* was introduced in 1927 as pest-control in Mangalia Lake. No further data are available at present (Iacob & Petrescu-Mag, 2008). During the last decades, 31 fish species were introduced successfully in freshwater ecosystems for aquaculture. Acclimatized in artificial pounds, these species are

capable to develop self-sustaining populations in natural ecosystems (Iacob & Petrescu-Mag, 2008; DAISIE). Taking account of the current economic situation and of the uncontrolled development of aquaculture in private ponds, these species represent a real threat to biodiversity. Among these 31 species we consider as questionable, for freshwater ecosystems along the Black Sea coast and for the Danube Delta, the black bullhead *Ictalurus melas*, brown bullhead *Ictalurus nebulosus*, the Channel catfish *Ictalurus punctatus*, the black buffalo *Ictiobus niger*, the black carp *Mylopharyngodon piceus*, the white Amur bream *Parabramis pekinensis*, the black Amur bream *Megalobrama terminalis*, and the topmouth gudgeon *Pseudorasbora parva*.

Impact on native communities

In general terms, there are two major aspects: one is the obvious direct connection between the increased economical development of human society and bioinvasions, and the other is the effect of invasive species on economy and human health (Perrings et al., 2005). The economic impact of the alien invasive species at the Romanian littoral is insufficiently known. Most invasive species have had no visible economic effect but, in some cases, the effects on marine or freshwater ecosystems were reflected also on human economy. Some obvious examples are the species introduced for aquaculture (fish, crustaceans and bivalve mollusks) but the most relevant is that of *Mnemiopsis leidyi*. It had important economic effects in the Black, Azov and Caspian seas areas (Zaitsev & Ozturk, 2001; Nadolinski, 2004). Specialists are afraid that the same effects would repeat in the near future in the Baltic Sea following the rainbow comb jellies' intrusion in 2006. Several studies (Avsar, 1996 – 1997; Kideys, 1994; Lebedeva & Shushkina, 1994; Mutlu et al., 1994; Niermann et al., 1993, 1994; Petran & Moldoveanu, 1994 – 1995; Onciu et al., 2007; Shushkina et al., 1990, 2000; Shiganova & Bulgakova, 2000; Nadolinski, 2004) carried out in the so-called "*Mnemiopsis* period" showed that the stocks of many fish species decreased dramatically as a result of *M. leidyi* invasion. In 1960s, 26 species of fish were reported as economically valuable in the north-western part of the Black Sea. In the 1980s, the number decreased at six, and the total yield of 900,000 tones in the mid 1980s decreased to only 100,000 tones in 1992 (Avsar, 1996 – 1997). The stocks of predatory fish as mackerel, bluefish, bonito etc, were replaced by pelagic omnivorous feeders, species with low economical importance. The economic impact of *Mnemiopsis* for 1980 – 1990 period was estimated at 200,000,000 $/year (Caddy & Griffiths, 1990) for the entire Black Sea basin. Acclimatization of the nude ctenophore *Beroe ovata*, few years after the establishment of *M. leidyi*, had an indirect economic impact. Predation by *Beroe ovata* induces a general decrease of *M. leidyi* populations (Shiganova et al., 2001) therefore a predator – prey relationship established between the two species (Kideys, 2002; Abolmasova et al., 2002).

Other species have not had such a visible economic impact: *Eriocheir sinensis* was considered a harmful species because the adults damaged the river banks with their underwater shelters and fed with fish caught in fishing nets. Fouling organisms, like barnacles or the polychaete *Ficopomatus aenigmaticus,* are harmful because their biomass increases the fuel consumption of the ships. Such organisms also increase the corrosion rate of metallic submerged structures.

Mya arenaria, dominant species on sandy bottoms, induced structural changes in native associations previously dominated by the bivalve *Lentidium mediterraneum* (Costa, 1829). Since the tiny *Lentidium mediterraneum* is a food

resource for the juveniles of many native bottom fish species while the juveniles of *Mya arenaria* are consumed by the adults of the same species (Zaitsev, 2001), the economic impact may be considered somewhat balanced. Juveniles and adults of the white fingered mud crab *Rhithropanopeus harrisii* represent an additional food resource for native fish species like gobies, sturgeons, turbot and flounder.

Rapana venosa, as top predator for bivalve associations contributed to the disappearance of large oyster banks in the Black Sea. After 1980, the commercial exploitation of this species began over the entire Black Sea littoral, leading to a decrease of *Rapana venosa* stocks (Zaitsev & Ozturk, 2001). This is the only case in which a notable decrease of the population of an invasive species with major impact was registered as a direct result of human activities and had a positive economic impact at the same time.

Potential invasions – perspectives

Predicting future invasions in one definite area is a real challenge for scientists. Despite the low number of alien invasive species with radical impact on native ecosystems, the effects of these species are irreversible and so unexpected that human society has to take measures in order to stop, prevent or at least predict what invasive species could establish in a given area. The climate changes reflected in global warming represent another opportunity for invasive species to spread out (Gollasch & Nehring, 2006).

Potentially invasive species in marine ecosystems

The development of Constanța Harbor and the increasing commercial activities in the area (Fig. 6; APM Constanța) represent further opportunities for other alien species, already reported from other parts of Europe, to become invasive at the Romanian Black Sea coast. It is quite obvious that the number of invasive species at the Romanian littoral will increase in the future. As in the case of alien invasive species already acclimatized in the Black Sea area, the most likely invasive species would be benthic species introduced in fouling associations or for mariculture, and pelagic species introduced with ballast water.

a. Benthic species in the infralittoral zone

Several types of organisms can be introduced in this category: crustaceans, polychaetes, bivalves. Some of these potential invasive species are cirripeds like *Balanus amphitrite* (Darwin, 1854) or *Balanus crenatus* (Bruguiére, 1789) – both of them mentioned from other parts of Black Sea basin – and the southern Pacific barnacle *Elimnius modestus* (Darwin, 1854), very common now in western Europe (Crisp, 1958; Barnes & Stone, 1972). An obstacle in the way of their establishment is *Balanus improvisus*, which dominates very efficiently its ecological niche. In the European waters, there are a number of species whose ecological preferences match the general characteristics of the Black Sea. The barnacles have proven several times extremely plastic species from an ecological point of view. Almost all these barnacles have proven to be successful invasive species (Kerckhof, 2002). Other species are successful invaders in other parts of the globe, like the overbite clam *Potamocorbula amurensis* (Schrenck, 1861) native from the Far East, an invasive species on the Pacific coasts of the USA. The polychaeta fauna of the western Black Sea coast is relatively well known (Marinov, 1966, 1977, 1990; Surugiu, 2008) but it is possible that a number of species already reported in other parts of the Black Sea like *Ancistrosyllis tentaculata* (Treadwell, 1941), *Streblospio shrubsolii*

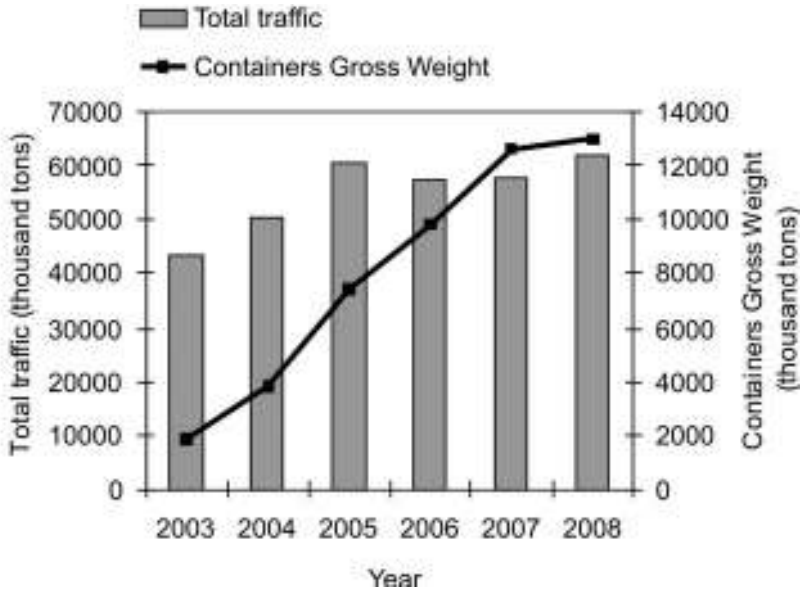

Fig. 6 - Commercial trades in Constanța harbor between 2003 and 2008.

(Buchanan, 1890), *Glycera capitata* (Örsted, 1843), *Streptosyllis varians* (Webster and Benedict, 1885) are present at the Romanian littoral as well. For now, only species like *Ficopomatus aenigmaticus* and *Polydora cornuta* are reported invasive for the Romanian Black Sea Coast (Surugiu, 2008). There is a high possibility for the occurrence of North American species *Marenzelleria neglecta* (Sikorski et Bick, 2004). Very efficient in populating different types of benthic habitats, *M. neglecta* became one of the dominant invasive species in the Baltic Sea basin (Gollasch & Leppäkoski, 1999; Leppäkoski et al., 2002).

b. Benthic species introduced through mariculture

This category includes a number of bivalves, and crustaceans. Breeding in controlled conditions usually leads to acclimatization and sometimes to the stabilization of these species in natural habitats. Three species of Asian shrimps: the Hokkai shrimps *Pandalus latirostris* (Rathbun, 1902) and *Pandalus kessleri* (Czerniavsky, 1878), and the Kuruma prawn *Marsupenaeus japonicus* (Bate, 1888) were introduced on the north-eastern part of the Black Sea (Băcescu, 1967; CIESM official data).

c. Pelagic species

Studies carried out all over the world are showing that ballast water is a major source of new invasions and the incidence of new invasions via ballast water is continuing to increase (Gollasch et al., 2000). The microalgae and copepods are most suitable groups to be transported with ballast water.

Potentially invasive species in freshwater ecosystems

For the freshwater ecosystems, future invaders would possibly be introduced as species with economic interest and several examples exist all over Europe. Fish and crustacean species are the most suitable candidates as potential invaders.

a. Aquaculture

A number of Asian cyprinids have proven very competitive as they were introduced on a large scale. The spiny-cheek crayfish, *Orconectes limosus* (Rafinesque, 1817) was mentioned in 2009 (Pârvulescu et al., 2009) from the south-western part of Romania in the Danube, after his introduction in Hungary. Other north-American crayfish species could be new invaders in freshwater habitats in the Romanian littoral zone such as *Orconectes virilis* (Hagen, 1870), *Orconectes juvenilis* (Hagen, 1870), *Procambarus clarcki* (Girard, 1852) and *Pacifastacus leniusculus* (Peckny & Pöckl, 2000) (Holdich et al., 1999; Ahern et al., 2008; Chucholl & Daudey, 2008; Semenchenko et al., 2009).

b. Aquarium and pet trade industry

Accidental releases from aquarium industry represent another major threat, especially for freshwater ecosystems from the Romanian littoral. Many of these species are characterized by ecological particularities such as high competitivity, asexual reproduction, polyphagy etc. In the last years, the aquarium industry knew a large-scale development all over Romania, and the number of commercialized ornamental species increased. Aquarium species with potential invasive risk are coelenterates like *Craspedacusta sowerbyi* (Lancester, 1880), gastropods like *Ampularia* species, *Physella heterostropha* (Say, 1817), *Ferrissia fragilis* (Tryon, 1863) mentioned in European Union countries (Gollasch & Nehring, 2006) or in Belarus and Ukraine (Alexandrov et al., 2007; Semenchenko et al., 2009). Vertebrates like the Chinese firebelly newt *Cynops orientalis* (David, 1873), the oriental fire-bellied toad *Bombina orientalis* (Boulenger, 1890) or crustaceans like the Asian shrimps in *Caridina* or *Neocaridina* genera are potential invaders for freshwater ecosystems also. The North American tortoise *Trachemis scripta* is already reported from some aquatic habitats in Romania (DAISIE).

c. Parasite species

Parasites represent a particular category of present and potential invasive species insufficiently studied. Certain parasite species can penetrate new habitats with their invasive hosts. Their number is quite high and they are often ignored. Some of the most common parasites introduced with freshwater fish are the ciliate *Trichodina reticulata* (Hirschmann et Partsch, 1955), the monogen flatworm *Eudiplozoon nipponicum* (Goto, 1891) and tapeworm *Bothriocephalus acheilognathii* (Yamaguti, 1934), species with East Asian origin (Lom & Dykova, 1992). *Trichodina reticulata* is ectocommensal on several invertebrates and Cyprinids, feeding on bacteria.

Conclusions

In terms of future bioinvasions at the Romanian coastal area, the data accumulated so far allows us to draw some conclusions and to estimate the evolution of the phenomenon. Thus, analyzing the way alien species arrived into the Black Sea basin, two major acclimatization "waves" in the Black Sea can be observed: one between 1950 and 1959 and a second one between 1980 and 1989. The first wave can be associated to the intensification of commercial exchanges in the post-war period, especially to the increased traffic in the former Soviet harbors and Constanța harbor. The second wave of "immigrants" can be associated to the radical eutrophication phenomena that affected the entire Black Sea basin and caused structural modifications of the marine communities in coastal waters. Intentional

introductions of species for aquaculture is another major pathway, over 20 species (one having a major impact) being introduced in the Black Sea area. Considering these disturbances, the intrusion and acclimatization of invasive species occurred more easily. The phenomenon was observed also in other parts of the world.

Considering the evolution of the invasive species phenomenon at European level, we can make some predictions for the western Black Sea coast. The intrusion of new alien species is expected to continue in the future, at a comparable rate to that recorded in the last decade. Usually, every 5-6 years, a new alien species is recorded at the Romanian littoral (Skolka & Gomoiu, 2004), a phenomenon in direct connection with the commercial trades performed in the coastal zone. The development of Constanța South-Agigea harbor area and increased traffic will generate a higher risk for new invasive species arrivals. The current global economic crisis will only slow down the introduction rate of new species.

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SPECII INVAZIVE LA LITORALUL ROMÂNESC AL MĂRII NEGRE – PREZENT ŞI PERSPECTIVE

REZUMAT

Speciile invazive reprezintă una dintre problemele cele mai complexe cu care se confruntă societatea contemporană. Nu întotdeauna corect înțeles, acest fenomen produce în primul rând prejudicii de ordin ecologic. Speciile invazive afectează biodiversitatea ecosistemelor unde se instalează în urma acțiunii directe sau indirecte a omului prin simpla lor prezență, fără a mai fi nevoie să apreciem efectele economice sau de altă natură. În lucrarea de față, autorii încearcă să ofere o sinteză asupra situației speciilor animale invazive în ecosistemele marine din zona litorală românească și din ecosistemele dulcicole din dreptul coastei, inclusiv din Delta Dunării.

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Marius Skolka
Universitatea "Ovidius" Constanţa, Catedra de Biologie – Ecologie, Aleea Universităţii Nr. 1, Corp B, RO-900470, Constanţa, România.
e-mail: mskolka@gmail.com

Cristina Preda
Universitatea "Ovidius" Constanţa, Catedra de Biologie – Ecologie, Laboratorul de Inventarierea Biodiversităţii, Aleea Universităţii Nr. 1, Corp B, RO-900470, Constanţa, România
e-mail: cristina.preda@stiintele-naturii.ro