

Inventory of Non-indigenous and Cryptogenic Marine Benthic Species of the South-East Adriatic Sea, Montenegro

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Abstract: We reviewed all available data on non-indigenous and cryptogenic marine benthic species of the South-East Adriatic Sea. Compilation of published literature and unpublished data revealed the presence of 23 species: five macroalgae and 18 zoobenthic species. Three species are considered as cryptogenic and 20 recognised as alien. The majority of the recorded species (16 taxa) were firstly recorded in the bay of Boka Kotorska (Kotor, Tivat, Herceg Novi). The lower number of species reported in the study region with respect to the neighbouring areas could be explained by differences in environmental conditions, the present migratory pathways, as well as the lack of experts and research efforts.

Key words: alien species, invertebrates, benthic species, South-East Adriatic Sea, Montenegro

Introduction

Over the last two centuries, the biodiversity of the Mediterranean Sea has been characterised by the introduction of new species. A major change took place with the opening of the Suez Canal in 1869, which connected the Indo-Pacific Ocean with the Mediterranean Sea and allowed the entry of many new species (ZENETOS et al. 2012, 2017, KATSANEVAKIS et al. 2013). Furthermore, rapid increase in shipping traffic, aquaculture and the development of the aquarium trade formed additional pathways for new species via fouling and ballast waters (SPAGNOLO et al. 2017). The introduction of non-native species is a permanent and complex process, with numbers increasing at a rate of one new record every two weeks (ZENETOS et al. 2012). As of now, 837 non-native species are recorded in the Mediterranean Sea (ZENETOS et al. 2017) and many changes in the marine ecosystem have already been observed (KATSANEVAKIS et al. 2016). Ecological impacts of invasive alien species range from single-species interactions and reduction in individual fitness of native species to population declines, local extinctions, changes in community composi-

tion and effects on entire ecosystem processes and wider ecosystem function (BLACKBURN et al. 2014, KATSANEVAKIS et al. 2014).

Situated in the Central Mediterranean Basin, the Adriatic Sea is an elongated, 800 km long, semi-closed basin, connected with the Ionian Sea by the Strait of Otranto, through which the circulation of water masses, nutrients' flow and species' migration takes place. Regarding the combination of depth, substratum type and temperature, the Adriatic Sea could be divided into three distinct sectors: northern, middle and southern (ZAVATARELLI et al. 1998). The south-eastern coast is considered as a pathway of warm water from the Mediterranean to the Adriatic Sea.

Although the problem of alien marine species affects the entire Adriatic Sea, the middle and northern sectors of the sea are considerably better studied (CROCETTA 2011, LIPEJ et al. 2012, PEĆAREVIĆ et al. 2013) in comparison to the southern. Recorded introduced species are more numerous in the Croatian part of the Adriatic Sea owing to the very extensively developed aquaculture and maritime traffic

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(PEĆAREVIĆ et al. 2013). Available relevant data from the South Adriatic Sea are fragmented and scarce (ZENETOS et al. 2011, KATSANEVAKIS et al. 2011, MAČIĆ et al. 2014, PETOVIĆ & MAČIĆ 2017).

Generating a list of the non-native species is a never-ending task for many reasons, such as the introduction of new species, some of which demonstrate established populations and others are never recorded after a certain period. As the current knowledge of the non-indigenous species from the South-Eastern Adriatic coast is far from being systematic and comprehensive, the present paper is an attempt to collect all available data regarding non-indigenous and cryptogenic benthic species, aiming at producing a first inventory of the region and deepening our knowledge on species' regional diversity.

Materials and Methods

The southern Adriatic Sea is the deepest part of the basin and can be considered a link between Ionian and Adriatic waters. The Montenegrin coast lies along the eastern part of the South Adriatic, which is under the strong impact of the Mediterranean currents. Within this broader region, the southern section close to the Albanian border is shallow, with fine sand bottoms, and is strongly influenced by the freshwater input of the Bojana River. To the north, the coast is steeper and rockier, including the bay of Boka Kotorska, a unique semi-enclosed fjord-like feature (Fig. 1).

For the needs of the present article we collected all available data regarding the non-native benthic species from the south-eastern part of the Adriatic Sea, including published scientific papers, technical reports and unpublished data (personal communications). The paper lists all species recognised as “alien” by EASIN (<http://easin.jrc.ec.europa.eu/>), although some of these are currently considered native species. Table 1 contains a list of all species present, together with an indication of the first finding (location, author/s and year of publication).

Results

The collection of all available existing data revealed the presence of 23 non-native marine benthic species in the South-East Adriatic Sea (Table 1). These species can be divided into two distinct groups: phyto-benthic and zoobenthic.

Introduced phytobenthic species

Antithamnion amphigeneum A.J.K. Millar, 1990 – collected on the Montenegrin coast at Tivat, Boka



Fig. 1. Map of the study area: South-Eastern Adriatic Sea, Montenegro

Kotorska Bay (MAČIĆ & BALLESTEROS 2016) as fouling organism from the pier in Porto Montenegro Marina. Filamentous algae, widespread in the Mediterranean Sea. This is the first record for the Adriatic Sea.

Caulerpa cylindracea (Sonder) Verlaque, Huisman & Boudouresque, 2004 – firstly recorded at Budva (MAČIĆ 2005), this alga, as one of the 100 most invasive species, has since propagated intensely and has disturbed the balance of benthic communities. In Montenegro, it has been recorded mostly in the area of o. Sv. Nikola near Budva, up to the Luštica Peninsula where it is widely distributed.

Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon, 1845 – red alga that is widespread in the Mediterranean Sea. Firstly recorded at Herceg Novi, Boka Kotorska Bay, in 2006 (ZENETOS et al. 2011).

Asparagopsis armata Harvey, 1855 – initially recorded from the entrance of the Boka Kotorska Bay (ŠPAN & ANTOLIĆ 1983). Currently, it is widespread in the Mediterranean Sea.

Womersleyella setacea (Hollenberg) R. E. Norris, 1992 – invasive red alga described for the Mediterranean Sea in 1987. Firstly registered along the Montenegrin coast in 2003 at the entrance of the Boka Kotorska Bay (Žanjice, Mamula) (BATTELI & RINDI 2008). Subsequently, it has become widespread (MAČIĆ 2008).

Introduced zoobenthic species

Paraleucilla magna Klautau, Monteiro & Borojevic, 2004 – initially recorded on the pier in the Porto

Table 1. Inventory of marine benthic non-indigenous and cryptogenic species recorded in South-Eastern Adriatic Sea, Montenegro.

Taxon	First record	Origin	Introduction pathway	Establishment success	Location	Reference and remarks
Rhodophyta						
<i>Antithamion amphigeneum</i>	2016	Indo Pacific	Shipping	Alien Casual	Tivat	MAČIĆ & BALLESTEROS (2016)
Chlorophyta						
<i>Caulerpa cylindracea</i>	2004	Indo West Pacific	Aquarium trade	Alien Invasive Established	Budva	MAČIĆ (2005)
<i>Asparagopsis taxiformis</i>	2006	Indo West Pacific	Suez/shipping	Alien Established	Herceg Novi	ZENETOS et al. (2011)
<i>Asparagopsis armata</i>		Western Australia	Aquaculture/shipping	Alien	Herceg Novi	ŠPAN & ANTOLIĆ (1987)
<i>Womersleyella setacea</i>	2003	Indo West Pacific	Shipping	Alien Casual	Herceg Novi	BATTELLI & RINDI (2008)
Porifera						
<i>Paraleucilla magna</i>	2016	South West Atlantic	Shipping?	Alien Established	Tivat	MAČIĆ & PETOVIĆ (2016)
Mollusca						
<i>Aphysia dactylomela</i>	2011	Circumtropical	Shipping?	Alien Established	Herceg Novi	MAČIĆ & KLJAJIĆ (2012)
<i>Bursatella leachi</i>	2009	Circumtropical	Suez/shipping	Alien Established	Herceg Novi	ZENETOS et al. (2011)
<i>Melibe viridis</i>	2003	Indo West Pacific	Suez/shipping	Alien Established	Herceg Novi	JANČIĆ (2004)
<i>Thecacera pennigera</i>	2017	Cosmopolitan	Shipping?	Cryptogenic	Tivat	PETOVIĆ & LIPEJ in GEROVASILEIOU et al. (2017)
<i>Anadara transversa</i>	2015	West Atlantic	Shipping	Alien Established	Kotor	PETOVIĆ et al. (2017)
<i>Arcuatula senhousia</i>	2014	Indo Pacific	Aquaculture/Shipping	Alien Established	Bar	PETOVIĆ et al. (2017)
<i>Ruditapes philippinarum</i>	2015	Indo Pacific	Aquaculture/Shipping	Alien Invasive	Bar	PETOVIĆ et al. (2017)
<i>Teredo navalis</i>	1967	Circumtropical	Shipping	Cryptogenic	Kotor	STJEPEČEVIĆ (1967)
<i>Pinctada imbricate radiata</i>	2016	Indo West Pacific	Suez/shipping	Alien Established	Tivat	PETOVIĆ & MAČIĆ (2017)
<i>Magallana gigas</i>	1977	Indo Pacific	Aquaculture	Alien Established	Kotor	STJEPEČEVIĆ et al. (1977)
Crustacea						
<i>Pennaeus aztecus</i>	2013	North West Atlantic	Shipping?	Alien Established	Tivat	MARKOVIĆ et al. (2013)
<i>Callinectes sapidus</i>	2006	West Atlantic	Shipping	Alien Established	Ulcinj, Jaz, Oblatno	ZENETOS et al. (2011)
<i>Amphibalanus eburneus</i>	1983	West Atlantic	Aquaculture/Shipping	Alien Established	Kotor	IGIĆ (1983)
Annelida						
<i>Hydroides dirampha</i>	2014	Circumtropical	Shipping	Alien	Bar	SPAGNOLO et al. (2018)
<i>Palola valida</i>	2014	Red Sea	Shipping	Alien	Bar	SPAGNOLO et al. (2018)
Bryozoa						
<i>Bugula neritina</i>	2014	Unknown	Shipping	Cryptogenic	Bar	SPAGNOLO et al. (2018)
Tunicata						
<i>Syella plicata</i>	2016	Western Atlantic	Aquaculture/Shipping	Alien	Tivat	Personal data

Montenegro marina (Tivat, Boka Kotorska Bay) during winter and spring in 2016 (MAČIĆ & PETOVIĆ 2016). Subsequently, it has been found in many locations across the Boka Kotorska Bay, mainly at mariculture sites as a fouling species on ropes and nets.

Aplysia dactylomela (Rang, 1828) – firstly recorded at Herceg Novi, Boka Kotorska Bay (MAČIĆ & KLJAJIĆ 2012), although subsequent surveys found no specimens. This species has wide distribution in tropical and warm temperate waters. It is common in tropical Indian and Pacific Oceans, also quite well represented in the Caribbean and near Atlantic islands, located along the west coast of Africa.

Bursatella leachi de Blainville, 1817 – a gastropod species with a worldwide distribution in warm temperate and tropical waters. Along the coast of Montenegro, initially found at Sv. Nedjelja, Boka Kotorska Bay (ZENETOS et al. 2011) and has since been recorded in many localities inside the bay (personal data).

Melibe viridis Kelaart, 1858 – an Indo-Pacific gastropod species recorded along all Mediterranean coasts. First record from Montenegrin coast in 2003 near Herceg Novi, Boka Kotorska Bay (JANČIĆ 2004). Subsequently, many specimens have been observed during field research throughout the bay (personal data).

Thecacera pennigera (Montagu, 1813) – a nudibranch gastropod; a specimen was recorded on 17th April 2017 during a biological monitoring program focused on fouling communities, performed in Porto Montenegro (Tivat, Boka Kotorska) marina by SCUBA diving (PETOVIĆ & LIPEJ 2017).

Anadara transversa (Say, 1822) – native to North-west Atlantic, from Cape Cod to Texas, introduced to the Aegean and Adriatic Seas. Specimens have been collected from the Boka Kotorska Bay (PETOVIĆ et al. 2017).

Arcuatula senhousia (Benson in Cantor, 1842) – a mussel species native to the Pacific Ocean from Siberia to Singapore, accidentally introduced and now invasive in numerous other areas worldwide. It has been recorded for the first time in the study region as a fouling organism in the Port of Bar (PETOVIĆ et al. 2017).

Ruditapes philippinarum (Adams & Reeve, 1850) – native to South-Eastern Asia (Indo-Pacific), introduced for commercial purposes in the Mediterranean Sea (although only in the Adriatic Sea and tentative aquaculture in the Tyrrhenian Sea). Collected from soft-bottom open-sea sites (PETOVIĆ et al. 2017).

Teredo navalis (Linnaeus, 1758) – the so-called

naval shipworm is a saltwater clam. It has been recorded for the first time in the study region by STJEPČEVIĆ (1967) in the Boka Kotorska Bay; later, STJEPČEVIĆ & PARENZAN (1980) and PETOVIĆ et al. (2017) have reported it from open-sea sites.

Pinctada imbricata radiata (Leach, 1814) – known as the ‘pearl oyster’, widespread in shallow waters of tropical and subtropical continental shelf regions, particularly abundant in the Indo-Pacific. Considered the first Lessepsian bivalve species reported for the Mediterranean Sea (MONTEROSATO 1878). In Montenegro, this species is, very numerous in the Porto Montenegro Marina (Tivat, Boka Kotorska Bay) (PETOVIĆ & MAČIĆ 2017) and at many other sites across the Boka Kotorska Bay (personal data).

Magallana gigas (Thunberg, 1793) – Pacific or Japanese oyster, native to the Pacific coast of Asia, introduced in North America, Australia, Europe and New Zealand. It has been introduced in the Boka Kotorska Bay for aquaculture purposes (STJEPČEVIĆ et al. 1977). However, no shells have been observed in the area for the last ten years (personal data).

Penaeus aztecus (Ives, 1891) – a species native to the western Atlantic coast. The first record in the Adriatic Sea was from the Boka Kotorska Bay (MARKOVIĆ et al. 2014). It is tolerant to a wide range of temperatures and salinities.

Callinectes sapidus Rathbun, 1896 – first specimen collected from Ulcinj (Port Milena), Jaz and Oblatno (ZENETOS et al. 2011), later in the Boka Kotorska Bay at Tivat (MARKOVIĆ & DJUROVIĆ 2014). Currently, it is widely distributed and very abundant along the Montenegrin coast (personal data).

Amphibalanus eburneus (Gould, 1841) – a species occurring on the east coast of North America as well as from the Caribbean Sea and Gulf of Mexico. In Montenegro, it has been recorded as a fouling organism on aquaculture equipment (IGIĆ 1983).

Hydroides dirampha Mörch, 1863 – a polychete species, firstly collected from the Port of Bar as a fouling organism on piers (SPAGNOLO et al. 2017).

Palola valida (Gravier, 1900) – firstly recorded in the Port of Bar (SPAGNOLO et al. 2017).

Bugula neritina (Linnaeus, 1758) – widespread in port waters and mariculture sites across the study area as a fouling species. First record in the Port of Bar (SPAGNOLO et al. 2017).

Styela plicata (Lesueur, 1823) – numerous on piers in the Porto Montenegro Marina (Tivat-Boka Kotorska Bay) and on mariculture equipment (personal data).

Discussion

The collection of all available published and unpublished data on non-indigenous marine benthic species from the South-Eastern Adriatic coast produced a total of 23 species, including five macroalgal and 18 zoobenthic species (one taxon of Porifera, ten taxa of Mollusca, three of Crustacea, two of Polychaeta, one of Bryozoa and one of Ascidia).

The majority of the recorded species (16) were first observed in the Boka Kotorska Bay, an area characterised by specific environmental conditions (STJEPČEVIĆ & PARENZAN 1980), with well-developed aquaculture (MANDIĆ et al. 2014) and extensive nautical tourism. These activities have opened the door to non-indigenous and cryptogenic species. Fourteen new species have been recorded since 2010, primarily in ports that can be considered “hot points” for alien species (SPAGNOLO et al. 2017). Nevertheless, the number of the recorded species is significantly lower than the one in the Croatian part of the Adriatic Sea, where 60 introduced benthic species have been recorded (PEĆAREVIĆ et al. 2013), as well as the total of 190 alien species calculated for the whole Adriatic Sea (ZENETOS et al. 2012). There are many possible reasons that could explain this difference. As the rest of the Adriatic Sea is characterised by more intensive shipping traffic and more developed aquaculture, the main pathways are well established and there is more potential for the introduction of new species (SPAGNOLO et al. 2017). In addition, other Adriatic countries, that are already EU members, currently pay more attention on the subject and have made big efforts to conduct research on alien species and their impact on the ecosystems (KATSANEVAKIS et al. 2016).

Examination of the spatial patterns of alien marine species across the Ionian-Adriatic boundary (KATSANEVAKIS et al. 2011) has revealed fewer species than expected. Possible explanations for this include the presence of lower temperatures that restrict the northward expansion of the thermophilic alien species, as well as a low salinity layer that could act as a barrier for some species.

Although this number may increase and the list could be improved, for the moment a lack of both experts and financial support for further research is impeding such efforts. Nevertheless, we hope that the present study can act as a starting point for future work on this very important scientific field.

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