



# INTERREG ITALY-CROATIA PROGRAMME 2021– 2027

Deliverable 1.1.2  
Database of NIS in  
Adriatic Sea and NIS  
report for the Pilot areas

(Version 1.0 - August 2024)

**ALIENA**ALLigning Efforts to control Non-indigenous species  
in the Adriatic sea

<b>WP 1</b>	<b>Review of non-indigenous species and causes determining their invasiveness in Adriatic Sea</b>
<b>Activity 1.1</b>	<b>Identification of non-indigenous species which can pose a threat to ecosystems and human activities in the Adriatic Sea</b>
<b>Deliverable 1.1.2</b>	<b>Database of NIS in Adriatic Sea and NIS report for the pilot areas</b>
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### 1. Introduction

Non-indigenous invasive species are globally acknowledged as one of the major threats to biodiversity, ecosystems and the services they provide (CBD, 2014; UNEP/MED, 2022). As a consequence, they constitute one of the elements that are taken into consideration when assessing the health of the environment and formulating management strategies in order to achieve and sustain good ecological status (UNEP/MED, 2022 and references therein). In particular, non-indigenous species (NIS, synonyms: exotic, non-native, allochthonous) are defined as species introduced outside of their natural range (past or present) and outside of their natural dispersal potential (Olenin et al., 2010). NIS are identified as “alien” when their presence in the given region is due to intentional or unintentional introduction resulting from human activities (UNEP/MED, 2022). Further invasive alien species (IAS) are a subset of established NIS which have spread, are spreading, or have demonstrated their potential to spread elsewhere. These species affect biological diversity and ecosystem functioning (by competing with and on some occasions replacing native species), socioeconomic values, and/or human health in invaded regions (Reg. EU n. 1143/2014 and n. 1141/2016). Nevertheless, it is essential to note that the term “invasive” may have various implications depending on the context. From a scientific perspective, “invasive” refers to the ability of the species to survive, reproduce and spread in the invaded region (Blackburn et al., 2011), whereas political frameworks, such as the EU Regulation (n. 1143/2014) on the prevention and management of the introduction and spread of IAS often connect invasiveness to impact (Zenetos et al., 2022b). The invasion process of NIS can be divided into a series of stages: transport to the new geographical area, introduction to the environment, establishment of self-sustaining populations and spread beyond the point of first introduction (Blackburn et al., 2011). Survival and reproduction in the new range may not suffice for establishment, which requires a positive long-term population growth. Scholars disagree on the number of introduced species which eventually manage to establish (Zenetos et al., 2022a). A first hypothesis posits that 10% of introduced species eventually appear in the wild (as casual species), 10% of these manage to establish, and 10% of established species become invasive (the so-called “tens rule”) (Williamson and Fitter, 1996). However, these figures may be too conservative, and more recent estimates suggest that 25% of introduced invertebrates and plants and 50% of vertebrates eventually manage to establish (Jeschke and Pyšek, 2018; Zenetos et al., 2022a).



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The advent of the European Union Marine Strategy Framework Directive (EU MSFD, Directive 2008/56/EC) promoted an ecosystem-based assessment approach introducing 11 Good Environmental Status (GES) descriptors. Among these, the Descriptor 2 (D2) “Non-indigenous species” states that “Non-indigenous species introduced by human activities are at level that not adversely alter the ecosystems” (Zenetos et al., 2020; Tsiamis et al., 2021). Similarly, at the Mediterranean level, the Integrated Monitoring and Assessment Programme (IMAP) of the United Nations Environment Programme evaluates NIS under Ecological Objective 2 (EO2) and requires refined, up-to-date inventories for the calculation of the relevant indicators (UNEP/MED, 2021; Zenetos et al., 2022a).

The avoidance of “adverse alteration” *sensu* D2 of the MSFD encompasses “the absence or minimal level of biopollution” (Olenin et al., 2010; Olenin et al., 2024), ascribed as the effects of IAS disturbing ecological quality at the individual, population, community, habitat or ecosystem levels (Elliott, 2003; Olenin et al., 2007, 2010, 2011). Olenin et al. (2024), in fact, suggested that “biological contamination” pertains to the introduction of NIS, while “biological pollution” is associated with IAS (a subset of NIS), implying some resulting harm (societal, economic, or ecological). On the basis of this assumption, NIS, introduced beyond their natural dispersal capacity due to human activities, are a human-induced component of an ecosystem, indicating contamination without implying pollution (Olenin et al., 2024). Once a NIS arrives, e.g. via ship ballast water, it is a potential contaminant and potential pollutant. Once it manages to get established, it is an actual contaminant but still a potential pollutant. Therefore, Olenin et al. (2024) emphasized that the term “contamination” is not making a quality judgement that the system is adversely affected, despite often taken to imply a status deterioration. Finally, if a NIS increases in abundance, spreads, and causes adverse effects, turning into IAS, the system becomes bio-polluted and the introduced species should be treated as a pollutant (Olenin et al., 2024).

Updated and validated NIS inventories represent a milestone for the implementation of the EU MSFD D2 and for any project concerning NIS, such as Project ALIENA. One of the first concerted efforts to collate and present comprehensive data about introduced species in the Mediterranean was initiated by the “Mediterranean Science Commission” (CIESM) with a publication of a series of atlases on exotic species in the early 2000s, addressing fishes, crustaceans, molluscs and, later, macrophytes (Galanidi et al., 2023 and references therein). Catalogues of NIS in the Mediterranean Sea have been addressed in a series of publications since 2005 (Zenetos et al., 2022a and references therein). Among the latest, Galanidi et al. (2023) published validated inventories of NIS for the four Mediterranean subregions:



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Eastern Mediterranean (EMED), Central Mediterranean (CMED), Adriatic Sea (ADRIA) and Western Mediterranean (WMED).

The aim of this Deliverable is to show a database with a catalogue of NIS in the Adriatic Sea and those recorded in every geographical territory of the pilot areas investigated in the project, which will be preparatory for the subsequent project activities.

### 2. Material and methods

A Mediterranean NIS catalogue was drawn on the basis of the following references data:

- Galanidi et al. (2023) "Validated inventories of Non-Indigenous Species (NIS) for the Mediterranean Sea as tools for regional policy and patterns of NIS spread" (<https://www.mdpi.com/article/10.3390/d15090962/s1>);
- Occhipinti Ambrogi and Marchini (2024) "Specie aliene presenti nei mari Italiani" (SIBM) (<https://www.sibm.it/public/document-files/SIBM-Specie-aliene-presenti-nei-mari-italiani.pdf>);
- "AquaNIS" Information system on aquatic non-indigenous and cryptogenic species (<https://aquanisresearch.com/>);
- Marine NIS by Marine Strategy Framework Directive regions – MSFD – (2008/56/EC) (<https://www.eea.europa.eu/en/datahub/datahubitem-view/8775b34c-bc10-4a6c-b446-f01b521bba85>);
- Marampouti et al. (2021) "Mediterranean alien harmful algal blooms: origins and impacts". *Environmental Science and Pollution Research* (2021) 28:3 837–3851. <https://doi.org/10.1007/s11356-020-10383-1>.
- EASIN base: European Commission - Joint Research Centre - European Alien Species Information Network (EASIN) <https://easin.jrc.ec.europa.eu/>
- Dulčić and Dragičević (2023) Handbook on alien decapod crustaceans and new fisher of the Adriatic Sea. Food and Agriculture Organization of the United Nations. Fisheries and Aquaculture Circular No. 1267. Rome, FAO. <https://doi.org/10.4060/cc7154en>
- Additional bibliographic sources

The database was organized in an Excel file having 6 sheets:

- The sheet "definitions" reports the specific definition and relative references of Non-Indigenous Species (NIS), Alien species, Invasive Alien Species (IAS), Cryptogenic species, Questionable



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species, Unresolved species and Likely alien species, as well as the references of the data are given;

- The sheet “database” lists the species following the alphabetical order;
- The sheet “AS” lists only the alien species following the alphabetical order;
- The sheet “Phyla” lists the species following the taxonomic rank;
- The sheet “Phyla Alien” lists only the alien species following the taxonomic rank;
- The sheet “Phyla IAS” lists only the Invasive Alien Species (IAS) following the taxonomic rank.

Every species name reports the author(s) of the scientific name and the year it was published. In addition, every species is ranked on the basis of its Phylum, Class, Order and Family.

Every species is selected or not in the database when recorded in:

- Italy (on the basis of SIBM and MSFD catalogue);
- Puglia Region (when recorded, its presence is referred to Adriatic Sea, Ionian Sea or both);
- Gulf of Trieste (when recorded, its presence is referred to the Italian side of the Gulf of Trieste “FVG”, the Slovenian side of the Gulf “SLO” or both);
- Croatia;
- Istria (as the part of the Northern Adriatic);
- Northern, Central and South Adriatic of the Croatian area;
- Mediterranean Sea (Galanidi et al 2023, IMAP): ADRIA Adriatic Sea, WMED Western Mediterranean, CMED Central Mediterranean and EMED Eastern Mediterranean;
- “Named Expert” column reports those species inserted in the catalogue by expert judgement and/or additional bibliographic source, with a note in the adjacent column.

The column “Status (SIBM\_IMAP)” assigns to every species the status “alien”, “likely alien”, “questionable” and “unresolved” on the basis of the SIBM and IMAP catalogue;

The column “Status (Reg. EU n. 1143/2014)” assigns the status “non-indigenous”, “cryptogenic” and “unresolved” on the basis of the EU Regulation n. 1143/2014;

The column “Status IAS (UE Reg. n. 1141/2016\_rev08/2022)” assigns the status “invasive alien species” of Union Concern on the basis of the EU Regulation n. 1141/2016 updated in 2022;

The column “Invasiveness IUCN Other References” assigns the status of invasiveness or not, as well as those uncertain and unspecified, assigned by the International Union for Conservation of Nature (IUCN) and other reliable references sources;

Limited to the species recorded in the Adriatic Sea:

The column “year” reports the year of the first record in the Mediterranean Sea;

The column “country” reports the country of the first record in the Mediterranean Sea;

The column “full citation” reports the bibliographic source of the first record in the Mediterranean Sea;



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The column “Pathway” assignment follows the classification scheme of the Convention on Biological Diversity published in Galanidi et al. (2023): (1) “Release in nature” (intentional introduction into the natural environment including fishery in the wild and game fishing, intentional release in the wild of species kept in domestic aquaria and other intentional release); (2) “Escape from confinement” (accidental escape of live organisms from confinement, including aquaculture/mariculture, botanical gardens/zoos/aquaria—excluding domestic aquaria, live food and live bait); (3) “Transport-contaminant” (species transported by host/vector, including contaminant on animals, parasites on animals, contaminant on plants); (4) “Transport-stowaway” (including Ship/boat ballast water, Ship/boat hull fouling, Hitchhikers on ship/boat, Angling/fishing equipment, Organic packing material and Other means of transport); (5) “Corridor” (interconnected waterways/basins/seas); (6) “Unaided” (natural dispersal across borders of invasive alien species that have been introduced through all other pathways); (7) “Unknown”.

The species reported for each pilot area are represented by specimens recorded in the pilot area or in nearby areas that are connected to the pilot area and therefore potentially present in the latter. All records are represented by single or common specimens of established NIS derived from literature, technical reports, data sets or verified information.

### 3. Results

#### 3.1 Database

To date, 1189 species belonging to 25 phyla are reported in the database for the Mediterranean Sea: 1101 sp. are identified as non-indigenous (NIS), 6 sp. cryptogenic and 46 unresolved *sensu* Reg. EU n. 1143/2014 (see definitions in the database). On regard NIS, 1041 sp. are identified as alien *sensu* IMAP (Integrated Monitoring and Assessment Programme for the Mediterranean Sea) and SIBM (Società Italiana di Biologia Marina), 4 sp. likely alien and 56 as questionable. Among the alien species, 22 sp. are considered as Invasive Alien Species (IAS) *sensu* IUCN (International Union for Conservation of Nature) and other reliable references sources (e.g. Marampouti et al. (2021)), whereas 3 sp. are uncertain and 9 sp. unspecified.



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On regard the four Mediterranean subregions, EMED showed the highest number of NIS (829 sp.), followed by WMED (358 sp.), CMED (335 sp.) and ADRIA (216 sp.). IAS are mostly recorded in WMED and ADRIA, 15 and 14 sp. respectively, while CMED and EMED have 9 and 8 sp. respectively.

In Italy 273 sp. are recorded as NIS and 18 as IAS, while in Croatia 116 are NIS and 9 IAS. Taking into consideration the geographical areas comprising the pilot areas, 107 sp. are recorded in Puglia along both Adriatic and Ionian seas, 92 in the Gulf of Trieste on both Friuli Venezia Giulia and Slovenia, 59 in Istria of which 32 were identified by DNA barcode, 31 in northern area of Croatia (without considering those recorded in Istria by DNA barcode), 51 in the central and 38 in southern area (Table 1).

As far as the Chromista kingdom is concerned, the Myzozoa phylum is the most represented in terms of recorded NIS, especially in the Istria region, partly due to the DNA barcoding detection method used. The phylum Rhodophyta shows the highest number of records among the kingdom Plantae, especially in Puglia, the central Adriatic of the Croatian area and the Gulf of Trieste. NIS in the kingdom Animalia were mainly represented by the phyla Annelida, Arthropoda, Mollusca and Chordata (Table 1), the latter being mainly represented by the classes Ascidiacea and Actinopteri (fishes).

GEOGRAPHICAL AREA		Italy		Croatia			
		Puglia	Gulf of Trieste	Istria	North	Central	South
TOTAL NUMBER OF NIS		107	92	59	31	51	38
KINGDOM	PHYLUM						
Chromista	Foraminifera	0	0	2	0	0	0
	Ciliophora	0	0	0	0	0	2
	Heterokontophyta	1	1	7	0	1	1
	Myzozoa	3	5	19	6	6	4



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	Haptophyta	0	0	3	0	0	0
	Cryptista	0	0	2	0	0	0
	Ochrophyta	8	3	0	1	3	1
Plantae	Chlorophyta	6	3	2	3	3	2
	Rhodophyta	22	11	0	3	12	7
	Tracheophyta	1	0	0	0	0	0
Animalia	Porifera	1	1	0	1	1	1
	Cnidaria	7	3	3	0	1	5
	Ctenophora	1	2	1	1	0	1
	Platyhelminthes	0	0	0	0	0	0
	Nemertea	0	0	0	0	0	0
	Nematoda	0	0	0	0	0	0
	Annelida	10	13	5	1	3	2
	Arthropoda	19	18	4	7	7	7
	Mollusca	14	14	8	6	5	2
	Bryozoa	2	5	0	1	1	1
	Chaetognatha	0	0	0	0	0	1
	Echinodermata	0	0	0	0	0	0
	Chordata	12	13	3	1	8	9

Table 1. Total number of NIS recorded in each geographical area of the respective pilot area and distribution of NIS by phyla

Regarding IAS, 12 species have been recorded in at least one of the geographical area of the pilot areas. The brown algae *Rugulopterix okamurae* was recorded exclusively in the Adriatic side of Puglia Region, the crab *Hemigrapsus sanguineus* was recorded only in Istria and the dinoflagellate *Gymnodinium catenatum* was found in the northern area of Croatia. Conversely, the potentially toxic benthic microalgae *Ostreopsis* cfr. *ovata* has been recorded in all areas. The reef building polychaetae *Ficopomatus enigmaticus* has not yet been recorded in the Istrian region of Croatia, whereas the comb jelly *Mnemiopsis leidyi* has not been reported for the Croatian area of the Central Adriatic.

### 3.2 NIS in the pilot area “The rocky shore in Puglia Region between the territory of Molfetta (Bari) and Torchiarolo (Brindisi)”



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Currently, in the Apulian Adriatic Sea n. 66 Non-Indigenous Species (NIS) from n. 14 different phyla have been reported. The Phylum Arthropoda was the most represented with 15 NIS followed by Mollusca (8 NIS and 3 IAS), Annelida (6 NIS and 1 IAS), Rhodophyta (5 NIS and 2 IAS), Chlorophyta (4 NIS and 1 IAS), Chordata (4 NIS and 1 IAS), Myzozoa (2 NIS and 2 IAS), Ochrophyta (3 NIS and 1 IAS), Cnidaria (3), Bryozoa (1), Ctenophora (1 IAS), Heterokontophyta (1 IAS), Porifera (1) and Tracheophyta (1).

According to the just mentioned Phyla, the recorded NIS are:

Arthropoda - *Amphibalanus eburneus*, *Balanus trigonus*, *Callinectes sapidus* Rathbun, *Caprella scaura*, *Dyspanopeus sayi*, *Mesanthura romulea*, *Paracerceis sculpta*, *Paradella diana*, *Paranthura japonica*, *Penaeus japonicus*, *Percnon gibbesi*, *Procambarus clarkii*, *Scyllarus caparti*, *Sphaeroma walkeri*, *Stenothoe georgiana*.

Mollusca - *Anadara transversa*, *Anadara kagoshimensis*, *Arcuatula senhousia*, *Bursatella leachii*, *Cerithium scabridum*, *Fulvia fragilis*, *Littorina saxatilis*, *Magallana gigas*, *Rapana venosa*, *Ruditapes philippinarum*, *Saccostrea glomerata*.

Annelida - *Branchiomma boholense*, *Branchiomma luctuosum*, *Ficopomatus enigmaticus*, *Hydroides dirampha*, *Hydroides elegans*, *Lumbrineris perkinsi*, *Notomastus aberans*.

Rhodophyta - *Acrothamnion preissii*, *Aglaothamnion feldmanniae*, *Asparagopsis taxiformis*, *Chondria pygmaea*, *Gracilaria gracilis*, *Hypnea musciformis*, *Melanothamnus harveyi*.

Chlorophyta - *Caulerpa cylindracea*, *Caulerpa racemosa* var. *lamourouxii* f. *requienii*, *Codium fragile* subsp. *Fragile*, *Ulva australis*, *Ulvaria obscura*.

Chordata - *Fistularia commersonii*, *Lagocephalus sceleratus*, *Microcosmus squamiger*, *Pterois miles*, *Styela plicata*.

Myzozoa - *Coolia monotis*, *Gymnodinium catenatum*, *Ostreopsis ovata*, *Prorocentrum shikokuense*.

Ochrophyta - *Colpomenia peregrina*, *Pylaiella littoralis*, *Rugulopterix okamurae*, *Sargassum muticum*.

Cnidaria - *Aurelia coerulea*, *Clytia hummelincki*, *Eudendrium carneum*.

Bryozoa - *Amathia verticillata*.

Ctenophora - *Mnemiopsis leidyi*.

Heterokontophyta - *Pseudo-nitzschia multistriata*.

Porifera - *Paraleucilla magna*.

Tracheophyta - *Halophila stipulacea*.



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Among them, the Invasive Alien Species (IAS) *sensu* IUCN are: *Pseudo-nitzschia multistriata*, *Coolia monotis*, *Ostreopsis cf. ovata*, *Rugulopterix okamurae*, *Codium fragile subsp. fragile*, *Gracilaria gracilis*, *Hypnea musciformis*, *Mnemiopsis leidy*, *Ficopomatus enigmaticus*, *Arcuatula senhousia*, *Littorina saxatilis*, *Rapana venosa* and *Styela plicata*.

The full list of the marine NIS and IAS species recorded in the Apulian Adriatic Sea is reported in the following table.



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PHYLUM	NIS SPECIES	IAS sensu IUCN
Heterokontophyta	<i>Pseudo-nitzschia multistriata</i> (Takano) Takano	IAS
Myozoa	<i>Coolia monotis</i> Meunier, 1919	IAS
	<i>Gymnodinium catenatum</i> H.W.Graham, 1943	
	<i>Ostreopsis ovata</i> Y.Fukuyo 1981	IAS
	<i>Proocentrum shikokuense</i> Y.Hada, 1975	
Ochrophyta	<i>Colpomenia peregrina</i> Sauvageau, 1927	
	<i>Pylaiella littoralis</i> (Linnaeus) Kjellman, 1872	
	<i>Rugulopterix okamurae</i> (E.Y.Dawson) I.K.Hwang, W.J.Lee & H.S.Kim, 2009	IAS
Chlorophyta	<i>Sargassum muticum</i> (Yendo) Fensholt, 1955	
	<i>Caulerpa cylindracea</i> Sonder, 1845	
	<i>Caulerpa racemosa</i> var. <i>lamourouxii</i> f. <i>requienii</i> (Montagne) Weber Bosse 1913	
	<i>Codium fragile</i> sub sp. <i>fragile</i> (Suringar) Hariot, 1889	IAS
Rhodophyta	<i>Ulva australis</i> Areschoug	
	<i>Ulvaria obscura</i> (Kützting) P.Gayral ex C.Bliding	
	<i>Acrothamnion preissii</i> (Sonder) E.M. Wollaston	
	<i>Aglaothamnion feldmanniae</i> Halos, 1965	
	<i>Asparagopsis taxiformis</i> (Delille) Trevisan de Saint-Léon, 1845	
	<i>Chondria pygmaea</i> Garbary & Vandermeulen, 1990	
Tracheophyta	<i>Gracilaria gracilis</i> (Stackhouse) Steentoft, L.M.Irvine & Farnham, 1995	IAS
	<i>Hypnea musciformis</i> (Wulfen) J.V.Lamouroux, 1813	IAS
	<i>Melanothamnus harveyi</i> (Bailey) Diaz-Tapia & Maggs, 2017 ex Neosiphonia harveyi	
	<i>Halophila stipulacea</i> (Forsskål) Ascherson, 1867	
Porifera	<i>Paraleucilla magna</i> Klautau, Monteiro & Borojevic, 2004	
Cnidaria	<i>Aurelia coerulea</i> von Lendenfeld, 1884	
	<i>Clytia hummelincki</i> (Leloup, 1935)	
	<i>Eudendrium carneum</i> Clarke, 1882	
Ctenophora	<i>Mnemiopsis leidyi</i> A. Agassiz, 1865	IAS
Annelida	<i>Branchioma boholense</i> (Grube, 1878)	
	<i>Branchioma luctuosum</i> (Grube, 1870)	
	<i>Ficopomatus enigmaticus</i> (Fauvel, 1923)	IAS
	<i>Hydroides dirampha</i> Mörch, 1863	
	<i>Hydroides elegans</i> (Haswell, 1883)	
	<i>Lumbrineris perkinsi</i> Carrera-Parra, 2001	
Arthropoda	<i>Notomastus aberans</i> Day, 1957	
	<i>Amphibalanus eburneus</i> (Gould, 1841)	
	<i>Balanus trigonus</i> Darwin, 1854	
	<i>Callinectes sapidus</i> Rathbun, 1896	
	<i>Caprella scaura</i> Templeton, 1836	
	<i>Dyspanopeus sayi</i> (Smith, 1869)	
	<i>Mesanthura romulea</i> Poore & Lew Ton, 1986	
	<i>Paracerceis sculpta</i> (Holmes, 1904)	
	<i>Paradella dianae</i> (Menzies, 1962)	
	<i>Paranthura japonica</i> Richardson, 1909	
	<i>Penaeus japonicus</i> Spence Bate, 1888	
	<i>Percnon gibbesi</i> (H. Milne Edwards, 1853)	
	<i>Procambarus clarkii</i> (Girard, 1852)	
	<i>Scyllarus caparti</i> Holthuis, 1952	
<i>Sphaeroma walkeri</i> Stebbing, 1905		
<i>Stenothoe georgiana</i> Bynum & Fox, 1977		
Mollusca	<i>Anadara transversa</i> (Say, 1822)	
	<i>Anadara kagoshimensis</i> (Tokunaga, 1906)	
	<i>Arcuatula senhousia</i> (Benson, 1842)	IAS
	<i>Bursatella leachii</i> Blainville, 1817	
	<i>Cerithium scabridum</i> Philippi, 1848	
	<i>Fulvia fragilis</i> (Forsskål in Niebuhr, 1775)	
	<i>Littorina saxatilis</i> (Olivé, 1792)	IAS
	<i>Megallana gigas</i> (Thunberg, 1793)	
	<i>Rapana venosa</i> (Valenciennes, 1846)	IAS
<i>Ruditapes philippinarum</i> (Adams & Reeve, 1850)		
<i>Saccostrea glomerata</i> (Gould, 1850)		
Bryozoa	<i>Amathia verticillata</i> (delle Chiaje, 1822)	
Chordata	<i>Fistularia commersonii</i> Rüppell, 1838	
	<i>Lagocephalus sceleratus</i> (Gmelin, 1789)	
	<i>Microcosmus squamiger</i> (Michaelsen, 1927)	
	<i>Pterois miles</i> (Bennett, 1828)	
	<i>Styela plicata</i> (Lesueur, 1823)	IAS



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### 3.3 NIS in the pilot area “The rocky shore in the Gulf of Trieste and 1 or 2 marine sites”

Currently in the Gulf of Trieste n. 92 Non-Indigenous Species (NIS) from 13 different phyla have been reported. The Phylum Arthropoda was the most represented 18 NIS followed by Mollusca (14 NIS), Chordata (13 NIS), Annelida (12 NIS and 1 IAS), Rhodophyta (10 NIS and 1 IAS), Myzozoa (3 NIS and 2 IAS), Bryozoa (5), Ochrophyta (3), Chlorophyta (2 and 1 IAS), Cnidaria (3), Ctenophora (1 NIS and 1 IAS), Heterokontophyta (1 IAS) and Porifera (1).

According to the just mentioned Phyla, the recorded NIS are:

Arthropoda - *Acartia tonsa*, *Paracartia grani*, *Pseudodiaptomus marinus*, *Oithona davisae*, *Caprella scaura*, *Jassa marmorata*, *Jassa slatteryi*, *Stenothoe georgiana*, *Dyspanopeus sayi*, *Rhithropanopeus harrisi*, *Callinectes sapidus*, *Processa macrodactyla*, *Paranthura japonica*, *Paracerceis sculpta*, *Megabalanus tintinnabulum*, *Amphibalanus improvisus*, *Amphibalanus eburneum* and *Balanus trigonus*.

Mollusca - *Anadara kagoshimensis*, *Anadara transversa*, *Arcuatula senhousia*, *Brachidontes pharaonis*, *Perna perna*, *Xenostrobus securis*, *Magallana gigas*, *Ruditapes philippinarum*, *Bursatella leachii*, *Haloa japonica*, *Rapana venosa*, *Cuthona perca*, *Polycera hedpethi*, *Polycerella emertoni*, *Thecacera pennigera* and *Melibe viridis*.

Chordata - *Clavelina oblonga*, *Didemnum vexillum*, *Asciidiella adspersa*, *Ciona robusta*, *Botrylloides violaceus*, *Styela plicata*, *Terapon theraps*, *Chrysiptera cyanea*, *Epinephelus coioides*, *Oplegnathus fasciatus*, *Abudefduf saxatilis*, *Tylosurus crocodilus* and *Stephanolepis diaspros*.

Annelida - *Chaetozone corona*, *Desdemona ornata*, *Ficopomatus enigmaticus*, *Hydroides elegans*, *Lumbrineris perkinsi*, *Notomastus aberans*, *Palola valida*, *Polydora cornuta*, *Pseudopolydora paucibranchiata*, *Leiochrides australis*, *Metasychis gotoi*, *Neopseudocapitella brasiliensis* and *Pista unibranchiata*.

Rhodophyta - *Colaconema codicola*, *Asparagopsis armata*, *Bonnemaisonia hamifera*, *Aglaothamnion feldmanniae*, *Melanothamnus harveyi*, *Agardhiella subulata*, *Caulacanthus okamurae*, *Hypnea musciformis*, *Hypnea spinella*, *Solieria filiformis* and *Gracilaria gracilis*.

Myzozoa - *Dinophysis acuminata*, *Alexandrium taylori*, *Coolia monotis*, *Lingulodinium polyedra* and *Ostreopsis cf. ovata*.

Bryozoa - *Amathia verticillata*, *Arbopercula tenella*, *Celleporaria brunnea*, *Tricellaria inopinata* and *Watersipora arcuata*.



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Ochrophyta - *Cutleria multifida*, *Cladosiphon zosterae* and *Scytosiphon dotyi*.

Chlorophyta - *Caulerpa cylindracea*, *Codium fragile* susp. *fragile* and *Uronema marinum*.

Cnidaria - *Diadumene lineata*, *Aurelia solida* and *Mawia benovici*.

Ctenophora - *Beroe ovata* and *Mnemiopsis leidyi*.

Heterokontophyta - *Pseudo-nitzschia multistriata*.

Porifera - *Paraleucilla magna*.

Among them, the Invasive Alien Species (IAS) *sensu* IUCN are: *Pseudo-nitzschia multistriata*, *Coolia monotis*, *Ostreopsis cf. ovata*, *Codium fragile* subsp. *fragile*, *Gracilaria gracilis*, *Mnemiopsis leidyi* and *Ficopomatus enigmaticus*.

The full list of the marine NIS and IAS species recorded in the Gulf of Trieste is reported in the following table.

PHYLUM	NIS SPECIES	IAS <i>sensu</i> IUCN
Heterokontophyta	<i>Pseudo-nitzschia multistriata</i> (Takano) Takano	IAS
Myzozoa	<i>Dinophysis acuminata</i> Claparède & Lachmann, 1859	
	<i>Alexandrium taylori</i> Balech, 1994	
	<i>Coolia monotis</i> Meunier, 1919	IAS
	<i>Lingulodinium polyedra</i> (F.Stein) J.D.Dodge, 1989	
	<i>Ostreopsis ovata</i> Y.Fukuyo 1981	IAS
Chlorophyta	<i>Caulerpa cylindracea</i> Sonder, 1845	
	<i>Codium fragile</i> subsp. <i>fragile</i> (Suringar) Hariot, 1889	IAS
	<i>Uronema marinum</i> Womersley	
Ochrophyta	<i>Cutleria multifida</i> (Turner) Greville, 1830	
	<i>Cladosiphon zosterae</i> (J.Agardh) Kylin, 1940	
	<i>Scytosiphon dotyi</i> M.J.Wynne, 1969	
Rhodophyta	<i>Colaconema codicola</i> (Børgesen) H.Stegenga, J.J.Bolton, & R.J.Anderson, 1997	
	<i>Asparagopsis armata</i> Harvey, 1855	
	<i>Bonnemaisonia hamifera</i> Hariot, 1891	
	<i>Aglaothamnion feldmanniae</i> Halos, 1965	
	<i>Melanothamnus harveyi</i> (Bailey) Díaz-Tapia & Maggs, 2017 ex <i>Neosiphonia harveyi</i>	
	<i>Agardhiella subulata</i> (C. Agardh) Kraft & M.J. Wynne	
	<i>Caulacanthus okamurae</i> Yamada, 1933	
	<i>Hypnea musciformis</i> (Wulfen) J.V.Lamouroux, 1813	
<i>Hypnea spinella</i> (C.Agardh) Kützinger, 1847		



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	<i>Solieria filiformis</i> (Kützing) P.W.Gabrielson, 1985	
	<i>Gracilaria gracilis</i> (Stackhouse) Steentoft, L.M.Irvine & Farnham, 1995	IAS
Porifera	<i>Paraleucilla magna</i> Klautau, Monteiro & Borojevic, 2004	
Cnidaria	<i>Diadumene lineata</i> (Verrill, 1869)	
	<i>Aurelia solida</i> Browne, 1905	
	<i>Mawia benovici</i> (Piraino, Aglieri, Scorrano & Boero, 2014)	
Ctenophora	<i>Beroe ovata</i> Bruguière, 1789	
	<i>Mnemiopsis leidyi</i> A. Agassiz, 1865	IAS
Annelida	<i>Chaetozone corona</i> Berkeley & Berkeley, 1941	
	<i>Desdemona ornata</i> Banse, 1957	
	<i>Ficopomatus enigmaticus</i> (Fauvel, 1923)	IAS
	<i>Hydroides elegans</i> (Haswell, 1883)	
	<i>Lumbrineris perkinsi</i> Carrera-Parra, 2001	
	<i>Notomastus aberans</i> Day, 1957	
	<i>Palola valida</i> (Gravier, 1900)	
	<i>Polydora cornuta</i> Bosc, 1802	
	<i>Pseudopolydora paucibranchiata</i> Okuda, 1937	
	<i>Leiochrides australis</i> Augener, 1914	
	<i>Metasychis gotoi</i> (Izuka, 1902)	
	<i>Neopseudocapitella brasiliensis</i> Rullier & Amoureux, 1979	
	<i>Pista unibranchia</i> Day, 1963	
Arthropoda	<i>Acartia (Acanthacartia) tonsa</i> Dana, 1849	
	<i>Paracartia grani</i> Sars G.O., 1904	
	<i>Pseudodiaptomus marinus</i> Sato, 1913	
	<i>Oithona davisae</i> Ferrari F.D. & Orsi, 1984	
	<i>Caprella scaura</i> Templeton, 1836	
	<i>Jassa marmorata</i> Holmes, 1905	
	<i>Jassa slatteryi</i> Conlan, 1990	
	<i>Stenothoe georgiana</i> Bynum & Fox, 1977	
	<i>Dyspanopeus sayi</i> (Smith, 1869)	
	<i>Rhithropanopeus harrisi</i> (Gould, 1841)	
	<i>Callinectes sapidus</i> Rathbun, 1896	
	<i>Processa macrodactyla</i> Holthuis, 1952	
	<i>Paranthura japonica</i> Richardson, 1909	
	<i>Paracerceis sculpta</i> (Holmes, 1904)	
	<i>Megabalanus tintinnabulum</i> (Linnaeus, 1758)	
	<i>Amphibalanus improvisus</i> (Darwin, 1854)	
	<i>Amphibalanus eburneus</i> (Gould, 1841)	
	<i>Balanus trigonus</i> Darwin, 1854	
Mollusca	<i>Anadara kagoshimensis</i> (Tokunaga, 1906)	
	<i>Anadara transversa</i> (Say, 1822)	
	<i>Arcuatula senhousia</i> (Benson, 1842)	
	<i>Brachidontes pharaonis</i> (P. Fischer, 1870)	
	<i>Perna perna</i> (Linnaeus, 1758)	
	<i>Xenostrobus securis</i> (Lamarck, 1819)	
	<i>Magallana gigas</i> (Thunberg, 1793)	
	<i>Ruditapes philippinarum</i> (Adams & Reeve, 1850)	
	<i>Haloa japonica</i> (Pilsbry, 1895)	
	<i>Rapana venosa</i> (Valenciennes, 1846)	
	<i>Cuthona perca</i> (Er. Marcus, 1958)	
	<i>Polycera hedgpethi</i> Er. Marcus, 1964	
	<i>Polycerella emertoni</i> A. E. Verrill, 1880	
	<i>Melibe viridis</i> (Kelaart, 1858)	
<i>Thecacera pennigera</i> (Montagu, 1813)		
Bryozoa	<i>Amathia verticillata</i> (delle Chiaje, 1822)	



	<i>Arbopercula tenella</i> (Hincks, 1880)	
	<i>Celleporaria brunnea</i> (Hincks, 1884)	
	<i>Tricellaria inopinata</i> d'Hondt & Occhipinti Ambrogi, 1985	
	<i>Watersipora arcuata</i> Banta, 1969	
Chordata	<i>Clavelina oblonga</i> Herdman, 1880	
	<i>Didemnum vexillum</i> Kott, 2002	
	<i>Asciella aspersa</i> (Müller, 1776)	
	<i>Ciona robusta</i> Hoshino & Tokioka, 1967	
	<i>Botrylloides violaceus</i> Oka, 1927	
	<i>Styela plicata</i> (Lesueur, 1823)	
	<i>Tylosurus crocodilus</i> (Péron & Lesueur, 1821)	
	<i>Oplegnathus fasciatus</i> (Temminck & Schlegel, 1844)	
	<i>Terapon theraps</i> Cuvier, 1829	
	<i>Abudefduf saxatilis</i> (Linnaeus, 1758)	
	<i>Chrysiptera cyanea</i> (Quoy & Gaimard, 1825)	
	<i>Epinephelus coioides</i> (Hamilton, 1822)	
	<i>Stephanolepis diaspros</i> Fraser-Brunner, 1940	

### 3.4 NIS in the pilot area “The western Istrian coast & Northern Adriatic: several sites on rocky shore and RV001 station 1 nm from coast”

Currently, in the Istrian marine area n. 59 Non-Indigenous Species (NIS) from n. 12 different phyla have been reported. The Phylum Myzozoa was the most represented with 18 NIS and 1 IAS followed by Mollusca (8 NIS), Heterokontophyta (7 NIS), Annelida (5 NIS), Arthropoda (3 NIS and 1 IAS), Haptophyta (3 NIS), Chordata (3 NIS), Cnidaria (3 NIS), Foraminifera (2 NIS), Cryptista (2 NIS), Chlorophyta (2 NIS) and Ctenophora (1 IAS).

According to the just mentioned Phyla, the recorded NIS are:

**Myzozoa** - *Amphidinium massartii*, *Phalacroma porodictyum*, *Gonyaulax ellegaardiae*, *Alexandrium affine*, *Alexandrium tamarense*, *Amylax triacantha*, *Protoceratium reticulatum*, *Fragilidium mexicanum*, *Fragilidium subglobosum*, *Lepidodinium chlorophorum*, *Cucumeridinium coeruleum*, *Dissodinium pseudolunula*, *Karlodinium veneficum*, *Balechina gracilis*, *Blastodinium manginii*, *Blastodinium spinulosum*, *Ostreopsis cf. ovata*, *Pelagodinium bei* and *Kofooidinium cf. pavillardii*.

**Mollusca** - *Anadara natalensis*, *Arcuatula senhousia*, *Brachidontes pharaonis*, *Pinctada imbricata radiata*, *Magallana gigas*, *Ruditapes philippinarum*, *Halgerda willeyi* and *Godiva quadricolor*.

**Heterokontophyta** - *Bacteriastrum jadrantum*, *Chaetoceros eibonii*, *Leptocylindrus aporus*, *Pseudonitzschia pseudodelicatissima*, *Meuniera membranacea*, *Rhizosolenia formosa* and *Mediolabrus comicus*.



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Annelida - *Lysidice collaris*, *Pileolaria berkeleyana*, *Spirorbis (Spirorbis) marioni*, *Neanthes agulhana* and *Neopseudocapitella brasiliensis*.

Arthropoda - *Callinectes sapidus*, *Hemigrapsus sanguineum*, *Megabalanus tintinnabulum* and *Balanus trigonus*.

Haptophyta - *Gephyrocapsa oceanica*, *Phaeocystis globosa* and *Pavlova pinguis*.

Chordata - *Oplegnathus fasciatus*, *Pampus argenteus* and *Lagocephalus sceleratus*.

Cnidaria - *Clytia linearis*, *Aurelia solida* and *Mawia benovici*.

Foraminifera - *Elphidium striatopunctatum* and *Planispirinella exigua*.

Cryptista - *Teleaulax amphioxeia* and *Teleaulax gracilis*.

Chlorophyta - *Tetraselmis marina* and *Bathycoccus prasinos*.

Ctenophora - *Mnemiopsis leidyi*.

Among them, the Invasive Alien Species (IAS) *sensu* IUCN are: *Ostreopsis cf. ovata*, *Mnemiopsis leidyi* and *Hemigrapsus sanguineus*.

The full list of the marine NIS and IAS species recorded in the Istrian marine area is reported in the following table.

PHYLUM	NIS SPECIES	IAS <i>sensu</i> IUCN
Foraminifera	<i>Elphidium striatopunctatum</i> (Fichtel & Moll, 1798)	
	<i>Planispirinella exigua</i> (Brady, 1879)	
Heterokontophyta	<i>Bacteriastrium jadrantum</i> Godrijan, Maric & Pfannkuchen (2012)	
	<i>Chaetoceros eibonii</i> Grunow (1882)	
	<i>Leptocylindrus aporus</i> (F.W.French & Hargraves) D.Nanjappa & A.Zingone (2013)	
	<i>Pseudo-nitzschia pseudodelicatissima</i> (Hasle) Hasle 1993	
	<i>Meuniera membranacea</i> (Cleve) P.C.Silva 1996	
	<i>Rhizosolenia formosa</i> H.Peragallo 1888	
	<i>Mediolabrus comicus</i> (H.Takano) Yang Li 2020	
Myzozoa	<i>Amphidinium massartii</i> Biecheler 1952	
	<i>Phalacroma porodictyum</i> F.Stein 1883	
	<i>Ostreopsis ovata</i> Y.Fukuyo 1981	IAS
	<i>Gonyaulax ellegaardiae</i> Mertens, Aydin, Takano, Yamaguchi & Matsuoka 2015	
	<i>Alexandrium affine</i> (H.Inoue & Y.Fukuyo) Balech 1995	
	<i>Alexandrium tamarense</i> (Lebour) Balech (1995)	
	<i>Amylax triacantha</i> (Jørgensen) Sournia 1984	
	<i>Protoceratium reticulatum</i> (Claparède & Lachmann) Bütschli 1885	
	<i>Fragilidium mexicanum</i> Balech 1988	
	<i>Fragilidium subglobosum</i> (Stosch) Loeblich III 1980	
	<i>Lepidodinium chlorophorum</i> (Elbrächter & Schnepf) Gert Hansen, Botes & Salas 2007	
	<i>Cucumeridinium coeruleum</i> (Dogiel) F.Gomez, P.López-García, H.Takayama & D.Moreira 2015	
	<i>Dissodinium pseudolunula</i> Swift ex Elbrächter & Drebes 1978	
	<i>Karlodinium veneficum</i> (D.Ballantine) J.Larsen 2000	
	<i>Balechina gracilis</i> (Bergh) F.Gómez, Artigas & Gast 2021	
<i>Blastodinium manginii</i> Chatton 1908		



	<i>Blastodinium spinulosum</i> Chatton 1912	
	<i>Pelagodinium bei</i> (H.J.Spero) Siano, Montresor, Probert & Vargas 2010	
	<i>Kofoidinium cf. pavillardii</i> J.Cachon & M.Cachon 1967	
Haptophyta	<i>Gephyrocapsa oceanica</i> Kamptner 1943	
	<i>Phaeocystis globosa</i> Scherffel 1899	
	<i>Pavlova pinguis</i> J.C.Green 1967	
Cryptista	<i>Teleaulax amphioxeia</i> (W.Conrad) D.R.A.Hill 1992	
	<i>Teleaulax gracilis</i> Laza-Martinez 2012	
Chlorophyta	<i>Tetraselmis marina</i> (Cienkowski) R.E.Norris, Hori & Chihara 1980	
	<i>Bathycoccus prasinos</i> Eikrem & Throndsen 1990	
Cnidaria	<i>Clytia linearis</i> (Thorneley, 1900)	
	<i>Aurelia solida</i> Browne, 1905	
	<i>Mawia benovici</i> (Piraino, Aglieri, Scorrano & Boero, 2014)	
Ctenophora	<i>Mnemiopsis leidyi</i> A. Agassiz, 1865	IAS
Annelida	<i>Lysidice collaris</i> Grube, 1870	
	<i>Pileolaria berkeleyana</i> (Rioja, 1942)	
	<i>Spirorbis (Spirorbis) marioni</i> Caullery & Mesnil, 1897	
	<i>Neanthes agulhana</i> (Day, 1963)	
	<i>Neopseudocapitella brasiliensis</i> Rullier & Amoureux, 1979	
Arthropoda	<i>Callinectes sapidus</i> Rathbun, 1896	
	<i>Hemigrapsus sanguineus</i> (De Haan, 1835)	IAS
	<i>Megabalanus tintinnabulum</i> (Linnaeus, 1758)	
	<i>Balanus trigonus</i> Darwin, 1854	
Mollusca	<i>Anadara natalensis</i> (Krauss, 1848)	
	<i>Arcuatula senhousia</i> (Benson, 1842)	
	<i>Brachidontes pharaonis</i> (P. Fischer, 1870)	
	<i>Pinctada imbricata radiata</i> (Leach, 1814)	
	<i>Magallana gigas</i> (Thunberg, 1793)	
	<i>Ruditapes philippinarum</i> (Adams & Reeve, 1850)	
	<i>Halgerda willeyi</i> Eliot, 1904	
	<i>Godiva quadricolor</i> (Barnard, 1927)	
Chordata	<i>Oplegnathus fasciatus</i> (Temminck & Schlegel, 1844)	
	<i>Pampus argenteus</i> (Euphrasen, 1788)	
	<i>Lagocephalus sceleratus</i> (Gmelin, 1789)	

### 3.5 NIS in the pilot area “Several sites in Kaštela Bay and Šibenik Bay area”

Currently, for this pilot area as part of the Croatian Middle Adriatic n. 51 Non Indigenous Species (NIS) from 12 different phyla have been reported. The Phylum Rhodophyta was the most represented with 12 NIS followed by Chordata (8 NIS), Arthropoda (7 NIS), Myzozoa (4 NIS and 2 IAS), Mollusca (5 NIS), Ochrophyta (3 NIS), Chlorophyta (1 NIS and 2 IAS), Annelida (2 NIS and 1 IAS), Bryozoa (1 NIS), Porifera (1 NIS), Heterokontophyta (1 IAS) and Cnidaria (1 NIS).

According to the just mentioned Phyla, the recorded NIS are:

Rhodophyta - *Colaconema codicola*, *Asparagopsis armata*, *Asparagopsis taxiformis*, *Bonnemaisonia hamifera*, *Acrothamnion preissii*, *Aglaothamnion feldmanniae*, *Antithamnion amphigeneum*, *Antithamnion*



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*hubbsii*, *Antithamnion nipponicum*, *Lophocladia lallemandii*, *Womersleyella setacea* and *Hypnea spinella*.

Chordata - *Styela plicata*, *Holacanthus ciliaris*, *Pagrus major*, *Bregmaceros nectabanus*, *Elates ransonnettii*, *Pterois miles*, *Paranthias furcifer* and *Lagocephalus sceleratus*.

Arthropoda - *Parvocalanus crassirostris*, *Pseudodiaptomus marinus*, *Penaeus aztecus*, *Percnon gibbesi*, *Callinectes sapidus*, *Amphibalanus eburneus* and *Balanus trigonus*.

Myzozoa - *Dinophysis acuminata*, *Alexandrium ostenfeldii*, *Alexandrium taylori*, *Coolia monotis*, *Lingulodinium polyedra* and *Ostreopsis cf. ovata*.

Mollusca - *Arcuatula senhousia*, *Pinctada imbricata radiata*, *Magallana gigas*, *Lamprohaminoea ovalis* and *Melibe viridis*.

Ochrophyta - *Dictyota cyanoloma*, *Styopodium schimperi* and *Colpomenia peregrina*.

Annelida - *Ficopomatus enigmaticus*, *Hydroides elegans* and *Lysidice collaris*.

Bryozoa - *Amathia verticillata*

Porifera - *Paraleucilla magna*

Heterokontophyta – *Pseudo-nitzschia multistriata*

Cnidaria - *Oculina patagonica*

Among them, the Invasive Alien Species (IAS) *sensu* IUCN are: *Pseudo-nitzschia multistriata*, *Coolia monotis*, *Ostreopsis cf. ovata*, *Caulerpa taxifolia*, *Codium fragile subsp. fragile* and *Ficopomatus enigmaticus*.

The full list of the marine NIS and IAS species recorded for this area is reported in the following table.

PHYLUM	NIS SPECIES	IAS <i>sensu</i> IUCN
Heterokontophyta	<i>Pseudo-nitzschia multistriata</i> (Takano) Takano	
Myzozoa	<i>Dinophysis acuminata</i> Claparède & Lachmann, 1859	
	<i>Alexandrium ostenfeldii</i> (Paulsen) Balech & Tangen, 1985	
	<i>Alexandrium taylori</i> Balech, 1994	
	<i>Coolia monotis</i> Meunier, 1919	IAS
	<i>Lingulodinium polyedra</i> (F.Stein) J.D.Dodge, 1989	
	<i>Ostreopsis ovata</i> Y.Fukuyo 1981	IAS
Chlorophyta	<i>Caulerpa cylindracea</i> Sonder, 1845	IAS
	<i>Caulerpa taxifolia</i> (M.Vahl) C.Agardh, 1817	IAS
	<i>Codium fragile subsp. fragile</i> (Suringar) Hariot, 1889	
Ochrophyta	<i>Dictyota cyanoloma</i> Tronholm, De Clerck, A.Gómez-Garreta & Rull Lluch	
	<i>Styopodium schimperi</i> (Kützing) Verlaque & Boudouresque, 1991	
	<i>Colpomenia peregrina</i> Sauvageau, 1927	
Rhodophyta	<i>Colaconema codicola</i> (Børgesen) H.Stegenga, J.J.Bolton, & R.J.Anderson, 1997	
	<i>Asparagopsis armata</i> Harvey, 1855	
	<i>Asparagopsis taxiformis</i> (Delile) Trevisan de Saint-Léon, 1845	



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	<i>Bonnemaisonia hamifera</i> Hariot, 1891	
	<i>Acrothamnion preissii</i> (Sonder) E.M. Wollaston	
	<i>Aglaothamnion feldmanniae</i> Halos, 1965	
	<i>Antithamnion amphigeneum</i> A.Millar, 1990	
	<i>Antithamnion hubbsii</i> E.Y.Dawson, 1962	
	<i>Antithamnion nipponicum</i> Yamada & Inagaki	
	<i>Lophocladia lallemandii</i> (Montagne) F.Schmitz, 1893	
	<i>Womersleyella setacea</i> (Hollenberg) R.E.Norris	
	<i>Hypnea spinella</i> (C.Agardh) Kützing, 1847	
Porifera	<i>Paraleucilla magna</i> Klautau, Monteiro & Borojevic, 2004	
Cnidaria	<i>Oculina patagonica</i> de Angelis, 1908	
Annelida	<i>Ficopomatus enigmaticus</i> (Fauvel, 1923)	IAS
	<i>Hydroides elegans</i> (Haswell, 1883)	
	<i>Lysidice collaris</i> Grube, 1870	
Arthropoda	<i>Parvocalanus crassirostris</i> (Dahl F., 1894)	
	<i>Pseudodiaptomus marinus</i> Sato, 1913	
	<i>Penaeus aztecus</i> Ives, 1891	
	<i>Percnon gibbesi</i> (H. Milne Edwards, 1853)	
	<i>Callinectes sapidus</i> Rathbun, 1896	
	<i>Amphibalanus eburneus</i> (Gould, 1841)	
	<i>Balanus trigonus</i> Darwin, 1854	
Mollusca	<i>Arcuatula senhousia</i> (Benson, 1842)	
	<i>Pinctada imbricata radiata</i> (Leach, 1814)	
	<i>Magallana gigas</i> (Thunberg, 1793)	
	<i>Lamprohaminoea ovalis</i> (Pease, 1868)	
Bryozoa	<i>Melibe viridis</i> (Kelaart, 1858)	
	<i>Amathia verticillata</i> (delle Chiaje, 1822)	
Chordata	<i>Styela plicata</i> (Lesueur, 1823)	
	<i>Holacanthus ciliaris</i> (Linnaeus, 1758)	
	<i>Pagrus major</i> (Temminck & Schlegel, 1843)	
	<i>Bregmaceros nectabanus</i> Whitley, 1941	
	<i>Elates ransonnettii</i> (Steindachner, 1876)	
	<i>Pterois miles</i> (Bennett, 1828)	
	<i>Paranthias furcifer</i> (Lichtenstein, 1822)	
<i>Lagocephalus sceleratus</i> (Gmelin, 1789)		

#### 4. Discussion

At the Mediterranean level, the different taxonomic groups are variable represented in the four subregions. Macrophytes are the most dominant group in the ADRIA and WMED, primarily as contaminants in shellfish consignments towards the shellfish culture areas of the northern Adriatic (Galanidi et al., 2023). Mollusca, Arthropoda and fishes are the main taxa groups in EMED, with more than 140 species each. Many of these are species of Indo-Pacific origin and warm water affinity. Annelida almost invariably constitutes approximately 10% of the NIS found, regardless of subregion, while Osteichthyes (fishes) is the most common taxon reported in the CMED. Foraminifera are



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represented by 44 species in the EMED (or 5%) but much lower species numbers (between 6 and 8 or 2–3%) in the other subregions (Galanidi et al., 2023).

About half of NIS in the Mediterranean have Corridor as their primary pathway of introduction, i.e., have most likely entered through the Suez Canal. This number reaches 57% in the EMED, but this pathway is not applicable as we move westward and northward to the other subregions, where Lessepsian migrants primarily spread through natural dispersal (Unaided pathway). CMED has the largest proportion of Unaided species, as it receives naturally dispersing NIS propagules from all other subregions. It is also noteworthy the higher percentage of contaminant species in ADRIA (21%) and the WMED (22%), which are inadvertently transported through aquaculture activities, while Escapes have their largest representation in ADRIA, with 6% of the species assumed to have escaped from mariculture or from non-domestic aquaria. Intentional releases from domestic aquaria represent only 1–2% of all introductions, with the highest number of species appearing in the WMED and the EMED. Transport—stowaway, including the two main shipping vectors (i.e., ballast water and hull fouling), represents the primary pathway for almost one third of the NIS entering the Mediterranean but as high as 49% of the NIS present in the ADRIA (Galanidi et al., 2023).

There was a general increase in the yearly rate of new NIS introductions after the late 1990s, which appears to be slowing down in the last decade, but this may be confounded by reporting lags and differential research efforts. Between 1970 and 2020 there has been a steep increase in the proportion of shared species present throughout all four Mediterranean subregions, which are predominantly transported via shipping and recreational boating. While Lessepsian species are gradually spreading westwards and northwards (Galanidi et al., 2023).

The notable increase in new NIS records for the entire Mediterranean after the mid-1990s has been attributed to a basin scale temperature regime shift in the late 1990s, shifts in driving forces such as the increased global trade and the associated shipping traffic, shellfish culture, as well as the increase in dedicated research efforts and citizen science initiatives targeting NIS in the last decade (Galanidi and Zenetos, 2022).

To date a limited number of papers about NIS introduction have focused on the Adriatic Sea. Most of these studies refer to new records and individual introductions or invasions at a particular site, not being focused on introduction pathway (Slišković et al., 2021 and references therein). In addition, most of the papers are focused on the Italian coastal area of the Adriatic Sea and none provides a comprehensive



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analysis of NIS likely introduced by shipping into the Adriatic region entirely, including its eastern part (Slišković et al., 2021 and references therein). Zenetos et al. (2012) suggested that a total of 190 NIS were introduced into the Adriatic through all identified pathways, while Tsiamis et al. (2019) reported a total of 155 NIS in this area. The ALIENA database, based on the last catalogue published by Galanidi et al. (2023) and adopted by EASIN, reported 216 NIS in the Adriatic.

From the NIS recorded in the Adriatic Sea, 13 NIS were commonly found in more than one pilot area: *Ostreopsis cf. ovata* (IAS), *Caulerpa cylindracea*, *Codium fragile* (IAS), *Paraleucilla magna*, *Mnemiopsis leidyi* (IAS), *Arcuatula senhousia* (IAS uncertain) and *Magallana gigas*, *Ficopomatus enigmaticus* (IAS), *Amphibalanus eburneus*, *Balanus trigonus*, *Callinectes sapidus*, *Amathia verticillata*, and *Styela plicata* (IAS). In particular, *O. cf. ovata* is categorized as Harmful Algal Bloom (HAB) species and potentially dangerous for human health; the green alga *C. cylindracea* is considered highly invasive, with severe impacts demonstrated on native biodiversity, community and habitat structure, and the ecosystem functioning of sensitive habitats (Galanidi et al., 2023); the green alga *Codium fragile* is one of the most important invasive marine algae becoming a dominant component of the invaded habitats with dramatic ecological consequences on native understory assemblages (Bellissimo et al., 2018). *Paraleucilla magna* shows its invasive character with the ability to colonize different environments with high abundance (Cvitković 2013). *Mnemiopsis leidyi* is one of the world's worst invaders; after arriving in the Black Sea, this holoplanktonic and hermaphroditic species has dramatically increased its population causing deleterious effects on fisheries and ecosystems (Budiša et al., 2023). The Asian mussel *M. senhousia* can influence the sediment features as well as the species composition and abundance of local infauna (Scirocco and Urbano, 2018); the Pacific oyster *M. gigas* is considered historically established species in the Adriatic Sea and it was introduced for aquaculture purposes. *Ficopomatus enigmaticus* is an alien invasive serpulid tubeworm with unknown origin with a global distribution. It can cause habitat changes by forming large reef-like colonies on formerly bare sediments and can create fouling problems on boats, pilings and pontoons. The barnacles *Balanus trigonus* and *Amphibalanus eburneus* may compete with other benthic invertebrates and the latter fouls cultured oysters. The bluecrab *C. sapidus* is highly invasive mainly in the transitional environments of the Adriatic Sea, causing severe impacts also on the fishery and aquaculture activities.



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The bryozoan *Amathia verticillata* has listed on the Global Invasive Species database as an impacting species (www. issg.org, Accessed Jan 17, 2015), specifically causes extensive fouling on *Zostera* spp. in summer, contributing to its decline (Marchini et al., 2015). The ascidian *Styela plicata* is non-native but widely established in the Mediterranean Sea where it reproduces throughout the year. It may impact native invertebrates by outcompeting them for resources (Huhn, 2024).

The database ALIENA provides all fundamental information regarding the NIS recorded in the pilot areas, in the Adriatic and Mediterranean Sea and represents a useful tool for the selection of target species in subsequent project activities. However, due to continuous changes in the checklists as a result of updates in species nomenclature (Slišković et al., 2021 and references therein) and heterogeneous experience between areas regarding taxonomic identification, each list could be called a 'provisional list'. Therefore, the ALIENA database has to be continuously revised and updated, but today it represents the most complete catalogue of NIS in the Adriatic Sea and its pilot areas.

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