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Marine alien species in Italy: a contribution to the implementation of descriptor D2 of the Marine Strategy Framework Directive

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Abstract

A re-examination of marine alien species or Non Indigenous Species (NIS) reported in Italian Seas, until December 2018, is provided, focusing on establishment success, year of first record, origin, potential invasiveness, and likely pathways, in particular. Furthermore, their distribution is assessed according to the marine subregions outlined by the European Union (EU) Marine Strategy Framework Directive: Adriatic Sea (ADRIA), Ionian Sea and Central Mediterranean Sea (CMED), and Western Mediterranean Sea (WMED). In Italy, 265 NIS have been detected with the highest number of species being recorded in the CMED (154 species) and the WMED (151 species) subregions, followed by the ADRIA (143) subregion. Most of these species were recorded in more than one subregion. One hundred and eighty (180 or 68%) NIS have established stable populations in Italian Seas among which 26 have exhibited invasive traits.

As regards the taxa involved, Macrophyta rank first with 65 taxa. Fifty-five of them are established in at least one subregion, mostly in the ADRIA and the CMED. Crustacea rank second with 48 taxa, followed by Polychaeta with 43 taxa, Mollusca with 29 taxa, and Fishes with 28 taxa, which were mainly reported from the CMED. In the period 2012-2017, 44 new alien species were recorded, resulting in approximately one new entry every two months. Approximately half of the NIS (~52%) recorded in Italy have most likely arrived through the transport-stowaway pathway related to shipping traffic (~28% as biofoulers, ~22% in ballast waters, and ~2% as hitchhikers). The second most common pathway is the unaided movement with currents (~19%), followed by the transport-contaminant on farmed shellfishes pathway (~18%). "Unaided" is the most common pathway for alien Fishes, especially in the CMED; escapes from confinement account for ~3% and release in nature for ~2%. The present NIS distribution hotspots for new introductions were defined at the first recipient area/location in Italy. In the ADRIA, the hotspot, Venice, accounts for the highest number of alien taxa introduced in Italy, with 50 newly recorded taxa. In the CMED subregion, the hotspots of introduction are the Taranto and Catania Gulfs, hosting 21 first records each. The Strait of Sicily represents a crossroad between alien taxa from the Atlantic Ocean and the Indo-Pacific area. In the WMED, bioinvasion hotspots include the Gulfs of Naples, Genoa and Livorno.

This review can serve as an updated baseline for future coordination and harmonization of monitoring initiatives under international, EU and regional policies, for the compilation of new data from established monitoring programs, and for rapid assessment surveys.

Keywords: Marine alien species; trends; MSFD; Italy; Mediterranean Sea.

Introduction

Biopollution, i.e. the redistribution of the Earth's species to habitats and ecosystems that were previously isolated from each other, is globally recognized as a menace to biodiversity, the economy, and human health (Vitousek *et al*., 1996). This phenomenon is so widespread to be considered a significant part of global environmental change (Vitousek *et al*., 1996; Ojaveer *et al*., 2015). From this perspective, at the 10th meeting of the Conference of the Parties held in 2010 in Nagoya, the Convention on Biological Diversity (CBD) adopted a new Strategic Plan for Biodiversity 2011-2020 and set 20 "Aichi targets", including Target 9 on alien species: "By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated and measures are in place to manage pathways to prevent their introduction and establishment". At European Union (EU) level, the Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC) has an overall goal to achieve a Good Environmental Status (GES) in the EU's marine waters by the year 2020, and one of its key descriptors for the initial marine strategy assessment is Descriptor D2, which addresses "Non Indigenous Species" (NIS), referred also here as alien species. The criteria for the assessment process towards a GES with respect to D2 will be based, amongst other information, on the abundance and spatial distribution of marine alien species, especially invasive ones, and on the environmental impact of the Non Indigenous Species (EU, 2017). The implementation of policies concerning the spread of alien species requires reliable data on the distribution, pathways, and impacts for each of them. In Italy, in order to satisfy this need, several attempts to review the recorded alien species have been made either at national scale covering all taxonomic groups (e.g. Occhipinti-Ambrogi *et al*., 2011; Marchini *et al*., 2013) or limited to particular groups and regions (e.g. alien Mollusca: Crocetta, 2012; Crocetta *et al*., 2013; alien Macrophyta: Cormaci *et al*., 2004). At local scale, comprehensive inventories of NIS concern particular areas such as the Venice Lagoon (Occhipinti-Ambrogi, 2000; Marchini *et al*., 2015), the Apulian coast (Gravili *et al*., 2010), the Calabrian coasts (Sperone *et al*., 2015), the Strait of Sicily (Azzurro *et al*., 2014), the Egadi Islands (Mannino *et al*., 2017), and a few others. Also, inventories of alien species, databases, and information systems have been implemented globally (e.g. GRIIS[1]), at European level (e.g. EASIN[2], AquaNIS[3], DAISIE[4]), and at national level (e.g. www.marinealien.sinanet.isprambiente.it). These systems operate by sharing their data over the web. For example, LifeWatch Alien Species VRE[5] is a platform that aims to develop supporting systems for experimental research on the arrival and spread of aquatic and terrestrial alien species; Oddfish[6] reports, through a Facebook page, observations and experiences of participating citizens regarding unusual captures and sightings of marine biota, in particular tropical fishes that reach the Italian shores, as in the case of *Sciaenops ocellatus* (Langeneck *et al*., 2017); Seawatchers[7] invasive species and Seawatchers Italia Alghe Aliene[8] are sea observatory networks that aim to map alien species in the Mediterranean by making use of citizen observations verified by scientists; the "Aliens in the Sea" Project[9], is a further initiative addressed to citizens, as well as the national campaign of monitoring/awareness-raising focusing on *Lagocephalus sceleratus* (Andaloro *et al*., 2016; Azzurro *et al*., 2016) and on *Pterois miles*. Citizen Science and Local Ecological Knowledge are increasingly employed to contribute with observations of Non Indigenous Species (Azzurro *et al*., 2018a), especially when evidence such as photos and videos can be reviewed and validated by researchers, and translated into geo-referenced information. Nevertheless, the spread of alien species is an on-going phenomenon, which requires accurate inventories based on continuous updates and scientific validation of the obtained data. This is of vital importance for the Mediterranean Sea, where the rate of introduction of new species kept increasing until 2010, when it reached a rate of approximately one new entry every two weeks (Zenetos, 2010), although this rate has slowed down recently (Zenetos, 2017; Zenetos *et al*., 2017).

Italy, with more than 7,000 km of coastline, has a prominent position in the Mediterranean Sea. Placed at the intersection of distinct basins, it has different hydrographic characteristics relevant to the spread of alien species in Italian seas. The most recent review enumerated 165 NIS

1 Global Register of Invasive Alien Species (http://www.griis.org).
2 European Alien Species Information Network (https://easin.jrc.ec.europa.eu/).
3 Information system on aquatic non-indigenous and cryptogenic species (http://www.corpi.ku.lt/databases/index.php/aquanis/).
4 Delivering Alien Invasive Species Inventories for Europe (http://www.europe-aliens.org).
5 LifeWatch Alien Species Virtual Environment (http://www.servicecentrelifewatch.eu/alien-species-vre).
6 Oddfish – Seawatchers – Exotic species: (https://www.facebook.com/groups/1714585748824288/).
7 http://www.observadoresdelmar.es/?idioma=en.
8 https://www.facebook.com/obsdelmar/.
9 http://www.unipa.it/dipartimenti/stebicef/.content/convegni/Poster-Progetto-Aliens-in-the-sea.pdf.

in Italy for the period 1945-2009 (Occhipinti-Ambrogi *et al*., 2011). This number was updated in 2013 with the addition of 11 species (Marchini *et al*., 2013). Yet, this is far from the 242 NIS reported by Andaloro *et al*. (2012) and EASIN (about 300 species). The aforementioned discrepancies can be attributed to the different periods involved, but mostly to definitions and related uncertainties. What is true, however, is that the number of NIS in Italian seas is increasing rapidly due to: a) increased scientific effort; b) the recent reassessments of the alien or cryptogenic status of some alien species (Zenetos *et al*., 2017); and c) the evolution of taxonomic approaches.

The re-examination of national alien species lists, their ecology, distribution, pathways of introduction, impacts, and control options is essential for efficient prevention, detection, and management of bioinvasions (Katsanevakis *et al*., 2015), especially within the framework of the recent invasive species policies, both internationally and under the MSFD. The aim of this paper is to present an updated inventory of alien species and their related potential pathways of introduction in each MSFD subregion located along the Italian coasts. Trends in introductions per 6-year periods (i.e. D2C1 of the MSFD – EU, 2017) and potential pathways are presented at both national and MSFD level as indicators, in view of the implementation of the MSFD in Italian waters.

Materials and Methods

A comprehensive bibliographic survey was performed to gather data for this review. Indexed and non-indexed journals, as well as grey literature, were researched since many historical and a few recent journals are not yet ISI indexed (e.g. *Archivio di Oceanografia e Limnologia, Bollettino Malacologico, Natura Milano, Oebalia, Thalassia Salentina*, to mention some important Italian journals). In addition, several old and recent obscure papers and books with first records of alien species in Italian waters have been used. Our survey also includes some new findings of yet unpublished occurrence records. Taxonomically, our survey follows the World Register of Marine Species (WoRMS)[10], Algaebase[11], and Catalog of Fishes[12].

Only NIS detected in marine and brackish waters were considered. The following data, as defined by the MSFD, are provided for each alien species belonging to multicellular and unicellular (Foraminifera) taxa, including subspecies, varieties, and genera, recorded and confirmed from Italian seas by December 2017 and reported in 2018:

1. distribution per MSFD subregion, namely, ADRIA, CMED, and WMED (EEA, 2015) - for details see study area;
2. native distribution range – i.e. putative native area. For the analysis, species such as those originating from the tropical western Pacific and tropical eastern Pacific were grouped together (Tropical Pacific); the same applies to those originating from the tropical western and eastern Atlantic (Tropical Atlantic). The Northern Pacific and North Atlantic include their respective eastern and western parts; the same applies to the South Pacific and South Atlantic that group together the respective eastern and western parts. Species characterized by a wider native distribution such as circum(sub)tropical and circumboreal species, were clustered together;
3. date of the first finding (year or range of years) for the different MSFD subregions;
4. establishment success. For each MSFD subregion the establishment success was defined on the basis of the following terminology:

- established (EST), a species with at least a self-maintaining population currently known to occur in the wild (including newly recorded species);
- invasive (INV), an established alien species that may change and threaten the native biodiversity of the invaded ecosystem or habitat;
- casual (CAS), a species that has never been able to spread nor reproduce in that area or with only a single or a few specimens recorded;
- unknown (UNK), a species whose establishment success is unknown. They are characterized by unconfirmed occurrence in a particular location, although previously recorded elsewhere in the Mediterranean, or species not validated because of incomplete documentation;

5. most plausible primary pathway/s, according to the Convention on Biological Diversity (CBD, 2014) see Supplement 1.

Species assigned to one of the following categories were excluded:

- species that cannot thrive in marine waters such as *Procambarus clarkii* (Girard, 1852), a truly fresh-water species, which was only occasionally recorded in slightly brackish estuarine habitats;
- cryptogenic species, a taxon that is not demonstrably native or introduced (Carlton, 1996);
- questionable species, a taxon whose presence in a certain area is not confirmed likely due to missing voucher material or published picture, although it has already been reported from other parts of the Mediterranean;
- species with unclear taxonomy; species with debatable status (species complexes/unconfirmed presence in the Mediterranean) such as *Eurythoe complanata* (Pallas, 1766), *Kyphosus* spp. (Mannino *et al*., 2015);
- species recorded merely on the basis of empty shells with no subsequent records such as the gastropod *Cymbium cucumis* Röding, 1798;
- records based on specimens released in the wild (e.g. for fishery/culture purposes of specimens) that did not survive such as *Pinctada imbricata radiata* (Leach, 1814), which was voluntarily introduced in the Fusaro Lagoon (Mazzarelli, 1923) or *Indothais lacera*

10 http://www.marinespecies.org.
11 http://www.algaebase.org.
12 http://www.calacademy.org/scientists/projects/catalog-of-fishes.

(Born, 1778), discarded alive in Caprolace Lagoon (Bini, 1983);

- records based on erroneous identification/geographical distribution such as *Branchiomma bairdi* (McIntosh, 1885), reported by Arias *et al.* (2013), which is in fact *Branchiomma boholense* (Grube, 1870);
- native range expanding species, i.e. those species which may have arrived through natural expansion from another area of the Mediterranean Sea [e.g. southern Mediterranean species that expand along the Italian coasts according to the "meridionalization" phenomenon (Riera *et al*., 1995)] or from a neighbouring ocean (e.g. eastern Atlantic species, in particular fish). More precisely, an East Atlantic species recently entered the Mediterranean facilitated by climate change should not be considered "alien" *per se*, but only if it displays discontinuous dispersion; that is the case of an East Atlantic species found in the central or the eastern Mediterranean but not in the western. Taxa that arrived in Italian waters through phoresy and represent first records for the Mediterranean are also excluded, e.g. Cirripedia on sea turtles capable of wide migrations. *Chelonibia manati crenatibasis* Pilsbry, 1916, a tropical Atlantic species that lives on manatees and on turtles and that was found as an epibiont on a *Caretta caretta* in 2012 in Cesenatico (Rinaldi, 2017), is considered a range expanding species.
- Tethyan relicts such as the macrophytes *Acanthophora nayadiformis* (Delile) Papenfuss and *Ganonema farinosum* (J.V. Lamouroux) K.C. Fan & Yung C. Wang.

Study area, MSFD division

The main geographical, morphological and environmental characteristics of the Italian Seas are outlined below. The study area includes the Italian territorial seas, which belong to three MSFD subregions: the Adriatic (ADRIA), the central Mediterranean (CMED), and the western Mediterranean (WMED). The border between ADRIA and CMED is defined by a line that runs from Capo Santa Maria di Leuca (Italy) (39.8° N, 18.36666° E) to the west coas of Corfu (Greece) (39.75194° N, 19.62777° E); the border between CMED and WMED is defined by a line that joins Capo Bon (37.08333° N, 11.05° E) (Tunisia) with Capo Lilibeo (37.8° N, 12.43333° E) (Sicily, Italy); between Sicily and the mainland of Italy, the border of WMED is a line that connects Capo Peloro (North-East Sicily, Italy) (38.26666° N, 15.65° E) to Capo Paci (Calabria, Italy) (38.25° N, 15.7° E) on the mainland (Figure 1).

The three subregions present different hydrographic and environmental characteristics of both the coastline and the seabed in their Italian portion. ADRIA is characterized by sandy shores (except for limited rocky areas in the north-east, the Conero promontory, and a large part of the Apulian coast) and can be divided into three sectors (Marini *et al*., 2006): (i) northern Adriatic, with a 30 m average depth; (ii) central Adriatic, which is deeper and includes the 270 m deep Jabuka Pit; (iii) southern Adriatic, which is >1,200 m deep in its central part and ends at the Otranto Straits. CMED and WMED have mainly rocky coasts and a much more articulated seabed profile, with areas as deep as >4,100 and >3,700 m respectively, and a generally much narrower continental shelf in the Ionian Sea than in the two other subregions.

The average sea surface temperature is around 22-25°C in summer and 8-14°C in winter depending on the area, with a clear north-south gradient. The lowest temperatures are recorded in the North Adriatic (less than 8°C in winter, 22-23°C in summer) and the highest in the Ionian Sea (24-25°C) (Relini *et al*., 1999).

The currents follow a general large-scale cyclonic pattern in all subregions with the highest speed in the Strait of Sicily (Relini *et al*., 1999). Tidal amplitude of up to 1.5 m occurs in the northern Adriatic, which is amongst the highest in the Mediterranean (Airoldi *et al*., 2015).

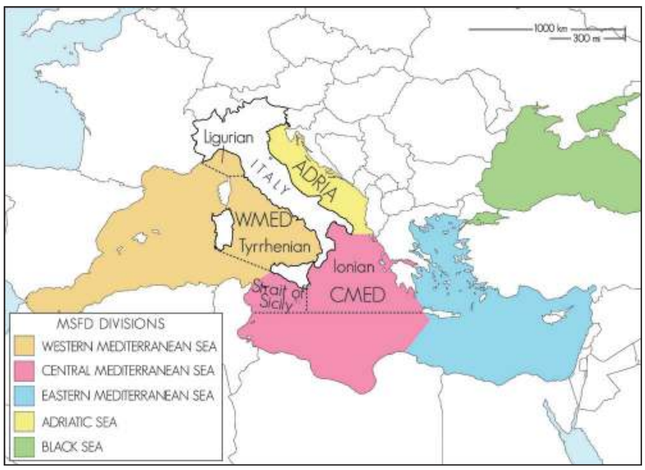

Fig. 1: Italian marine subregions according to the MSFD.

Results and Discussion

The core of this work is summarised in Table 1, which presents a list of the multicellular and unicellular (Foraminifera) NIS recorded along the coasts of Italy for each MSFD subregion. This section consists of seven parts. Parts 1 to 3 deal with the distribution of the alien species belonging to the seven systematic groups within each of the three MSFD subregions. The next three parts discuss the overall trends resulting from the data provided in Table 1. Finally, the seventh part is focused on the hotspots of introduction (i.e. the first recipient areas in Italian seas).

Table 1. Recorded marine alien species in Italian MSFD subregions. Species listed in alphabetic order per taxon within phyla, classes or orders.
Abbreviations: NDR=native distribution range: RS=Red Sea, **IO**=Indian Ocean, **IP**=Indo-Pacific, **PTW**=Pacific Tropical West, **PTE**=Pacific Tropical East, **PT**=Pacific Tropical, **PO**=Pacific Ocean, **PW**=Pacific West, **PN**=Pacific North, **PS**=Pacific South, **PSE**=Pacific Southeast, **PSW**=Pacific Southwest, **PNE**=Pacific Northeast, **PNW**=Pacific Northwest, **ASE**=Atlantic Southeast, **ASW**=Atlantic Southwest, **ANE**=Atlantic Northeast, **ANW**=Atlantic Northwest, **ATW**=Atlantic Tropical West, **ATE**=Atlantic Tropical East, **AT**=Atlantic Tropical, **AO**=Atlantic Ocean, **AW**=Atlantic West, **AN**=Atlantic North, **ArO**=Arctic Ocean, **CoC**=Cosmopolitan Circumtropical, **CoT**=Cosmopolitan Temperate, **UNK**=Unknown. **Year**=first detection year or year of publication of the first record when the year of actual finding is missing**; Success**=population success**; CAS**=casual**, EST**=established, **INV**=invasive, **UNK**=unknown; **Ref**=reference for first record (see: Supplementary material S2); **PP**=potential pathway/s, **REL/FISH**=RELEASE IN NATURE: Fishery in the wild, **REL/OTH**=RELEASE IN NATURE: Other intentional release, **ESC/AQ-MA**=ESCAPE FROM CONFINEMENT: Aquaculture/mariculture, **ESC/AQ**=ESCAPE FROM CONFINEMENT: Aquaria (excluding domestic aquaria), **ESC/DOM**=ESCAPE FROM CONFINEMENT: Domestic aquarium species (including live food for such species), **ESC/FO-BA**=ESCAPE FROM CONFINEMENT: Live food and live bait, **CONT/AN**=TRANSPORT-CONTAMINANT: Contaminant on animals (except parasites, species transported by host/vector), **CONT/PAR-AN**=TRANSPORT-CONTAMINANT: Parasites on animals (including species transported by host and vector), **ST/SH-HIT**=TRANSPORT-STOWAWAY: Hitchhikers on ship/boat (excluding ballast water and hull fouling), **ST/SH-BAL**=TRANSPORT-STOWAWAY: Ship/boat ballast water, **ST/SH-FOU**=TRANSPORT-STOWAWAY: Ship/boat hull fouling, **ST/PAC**=TRANSPORT-STOWAWAY: Organic packing material, **UNAI**=UNAIDED: Natural dispersal across borders.

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
FORAMINIFERA													
Amphistegina lobifera Larsen 1976	CoC	-	-	-	-	2005	INV	1	UNAI, ST/SH-BAL, CONT/AN	2017	INV	2	UNAI, ST/SH-BAL, CONT/AN
Amphistegina cf. *A. papillosa* Said, 1949	RS, IP, ATW	-	-	-	-	2005	EST	1	UNAI, ST/SH-BAL	2017	EST	2	UNAI, ST/SH-BAL
Amphistegina lessonii d'Orbigny in Guérin-Méneville, 1832	RS, IP, ATW	-	-	-	-	2005	INV	1	UNAI, ST/SH-BAL, CONT/AN	2017	INV	2	UNAI, ST/SH-BAL, CONT/AN
Coscinospira arietina (Batsch, 1791)	IP	-	-	-	-	-	-	-	-	2017	CAS	2	UNAI, ST/SH-BAL
Entosigmomorphina sp.	IP	-	-	-	-	2005	CAS	1	UNAI, ST/SH-BAL	-	-	-	-
Euthymonacha polita (Chapman, 1900)	IP	2013	CAS	3	UNAI, ST/SH-BAL	-	-	-	-	-	-	-	-
Loxostomina costulata (Cushman, 1922)	ATW, IP	2013	EST	3	UNAI, ST/SH-BAL	-	-	-	-	-	-	-	-
Sorites variabilis Lacroix, 1941	IP	-	-	-	-	-	-	-	-	2003	EST	4	UNAI, ST/SH-BAL
Spiroloculina antillarum (d'Orbigny, 1839)	ATW, IP	2013	EST	3	UNAI, ST/SH-BAL	-	-	-	-	-	-	-	-

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
MACROPHYTA													
Chlorophyta													
Batophora sp.	-	-	-	-	-	2003	CAS	5	UNK	-	-	-	-
Caulerpa cylindracea Sonder	IP	2000	INV	6	UNK	1993	INV	7	UNK	1993	INV	8	UNK
Caulerpa taxifolia (M.Vahl) C.Agardh	ATW	-	-	-	-	1993	EST	9	ESC/AQ	1992	EST	10	ESC/AQ
Caulerpa taxifolia var. *distichophylla* (Sonder) Verlaque, Huisman & Procaccini	IO	-	-	-	-	2007	INV	11	ESC/DOM, ST/SH-FOU	2013	EST	12	ESC/DOM, ST/SH-FOU
Codium fragile subsp. *fragile* (Suringar) Hariot	PNW	1978	EST	13	CONT/AN, ST/SH-FOU	≤1974 [B]	EST	14	CONT/AN, ST/SH-FOU	1972	EST	15	CONT/AN, ST/SH-FOU
Ulva australis Areschoug	PNW	2010	EST	16	CONT/AN	-	-	-	-	-	-	-	-
Ulva californica Wille	PNE	2011	EST	17	CONT/AN	-	-	-	-	-	-	-	-
Ulva ohnoi M.Hiraoka & S.Shimada	PNW	-	-	-	-	2011-13	UNK	18	UNK	-	-	-	-
Ulvaria obscura (Kützing) Gayral ex Bliding	ANE	2000	EST	19	CONT/AN	-	-	-	-	-	-	-	-
Uronema marinum Womersley	PSW	2008	EST	20	CONT/AN	-	-	-	-	-	-	-	-
Ochrophyta													
Ascophyllum nodosum (Linnaeus) Le Jolis	AO	-	-	-	-	2009	CAS	21	ST/PAC	-	-	-	-
Botrytella parva (Takamatsu) H.S.Kim	PNW	1996	EST	22	CONT/AN	-	-	-	-	-	-	-	-
Chrysonephos lewisii (W.R.Taylor) W.R.Taylor	ATW	-	-	-	-	-	-	-	-	1992	EST	23	ST/SH-FOU
Cladosiphon zosterae (J.Agardh) Kylin	AO	≤1978	CAS	13	CONT/AN	≤1975	EST	24	CONT/AN	1980	EST	25	CONT/AN
Colpomenia peregrina Sauvageau	ANE	1975	EST	26	CONT/AN	≤1976	EST	27	CONT/AN	1939	EST	28	CONT/AN

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Cutleria multifida (Turner) Greville	ANE	1847	EST	29	CONT/AN	1904	EST	30	CONT/AN	1842	EST	31	CONT/AN
Halothrix lumbricalis (Kützing) Reinke	ANE	1992	UNK	32	CONT/AN	1978	EST	33	CONT/AN	-	-	-	-
Leathesia marina (Lyngbye) Decaisne	ANE	1996	EST	34	CONT/AN	1996	EST	35	CONT/AN	-	-	-	-
Padina boergesenii Allender & Kraft	ATW, IP	-	-	-	-	1963-66	EST	36	UNAI	-	-	-	-
Punctaria tenuissima (C.Agardh) Greville	ANE	1998	EST	34	CONT/AN	-	-	-	-	-	-	-	-
Sargassum muticum (Yendo) Fensholt	PNW	1992	EST	37	CONT/AN	-	-	-	-	-	-	-	-
Scytosiphon dotyi M.J.Wynne	PNE	1960-77	EST	13	CONT/AN	-	-	-	-	-	-	-	-
Undaria pinnatifida (Harvey) Suringar	PNW	1992	EST	38	ST/PAC	1998	CAS	39	ST/PAC	-	-	-	-
Rhodophyta													
Acrothamnion preissii (Sonder) E.M.Wollaston	IP	2007	EST	40	ST/SH-FOU, ESC/DOM	1997	EST	41	ST/SH-FOU, ESC/DOM	1969	INV	42	ST/SH-FOU, ESC/DOM
Agardhiella subulata (C.Agardh) Kraft & M.J.Wynne	ANW	2003	EST	43	CONT/AN	1987	EST	44	CONT/AN	-	-	-	-
Aglaothamnion feldmanniae Halos	ANE	2000	EST	45	ST/SH-FOU	-	-	-	-	1975	EST	46	ST/SH-FOU
Aglaothamnion halliae (F.S.Collins) N.E.Aponte, D.L. Ballantine & J.N.Norris	ATW	2016	CAS	47	CONT/AN	-	-	-	-	-	-	-	-
Antithamnion amphigeneum A.Millar	PSW	-	-	-	-	2005	UNK	48	ST/SH-FOU	1995	EST	49	ST/SH-FOU
Antithamnion hubbsii E.Y.Dawson	PNE	1994	EST	50	CONT/AN, ST/SH-FOU	-	-	-	-	-	-	-	-

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Asparagopsis armata Harvey	IO	≤1978	EST	13	ST/SH-FOU	1965-66	INV	51	ST/SH-FOU	1880	EST	52	ST/SH-FOU
Asparagopsis taxiformis (Delile) Trevisan – lineage 2	IP	-	-	-	-	2014	EST	53	ST/SH-FOU	1993	EST	54	ST/SH-FOU
Bonnemaisonia hamifera Hariot	PNW	1995	EST	55	ST/SH-FOU	1973	EST	56	ST/SH-FOU	2001-02	UNK	57	ST/SH-FOU
Botryocladia madagascariensis G.Feldmann	IO	1997	EST	58	ST/SH-FOU, UNAI	1978	EST	59	ST/SH-FOU, UNAI	1991	EST	60	ST/SH-FOU, UNAI
Ceramium strobiliforme G.W.Lawson & D.M.John	ATE	1997	CAS	58	ST/SH-FOU	-	-	-	-	1991	EST	59	ST/SH-FOU
Chondria curvilineata Collins & Hervey	ATW	-	-	-	-	2015	EST	61	ST/SH-FOU	-	-	-	-
Chondria polyrhiza Collins & Hervey	ATW	-	-	-	-	1992	UNK	62	ST/SH-FOU	-	-	-	-
Chondria pygmaea Garbary & Vandermeulen	RS	1997	EST	58	UNAI	1991	UNK	59	UNAI	1995	UNK	63	UNAI
Dasysiphonia japonica (Yendo) H.-S.Kim	PNW	1999	EST	64	CONT/AN	-	-	-	-	-	-	-	-
Gracilaria vermiculophylla (Ohmi) Papenfuss	PNW	2008	EST	65	CONT/AN	-	-	-	-	-	-	-	-
Grateloupia minima P.Crouan & H.Crouan	ANE	-	-	-	-	2010	EST	66	CONT/AN	-	-	-	-
Grateloupia turuturu Yamada	PNW	1987	EST	67	CONT/AN	2007	EST	68	CONT/AN	-	-	-	-
Grateloupia yinggehaiensis H.W.Wang & R.X.Luan	PTW	2008	EST	69	CONT/AN	-	-	-	-	-	-	-	-
Griffithsia corallinoides (Linnaeus) Trevisan	ANE	-	-	-	-	1963-66	UNK	36	CONT/AN, ST/SH-FOU	1963-64	EST	70	CONT/AN, ST/SH-FOU

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Hypnea cornuta (Kützing) J.Agardh	ATE	-	-	-	-	2000	EST	71	CONT/AN, ST/SH-FOU, UNAI	-	-	-	-
Hypnea cervicornis J.Agardh	IO, ATW	2009	EST	72	CONT/AN, ST/SH-FOU	-	-	-	-	-	-	-	-
Hypnea spinella (C.Agardh) Kützing	ATW	-	-	-	-	1985	EST	73	ST/SH-FOU, UNAI	1990	EST	74	ST/SH-FOU, UNAI
Hypnea valentiae (Turner) Montagne	RS	2000	CAS	19	CONT/AN	-	-	-	-	-	-	-	-
Lomentaria hakodatensis Yendo	PNW	2000	EST	75	CONT/AN	-	-	-	-	-	-	-	-
Lophocladia lallemandii (Montagne) F.Schmitz	RS	≤1978	EST	13	ST/SH-FOU, UNAI	1969	INV	76	ST/SH-FOU, UNAI	1971	UNK	77	ST/SH-FOU, UNAI
Melanothamnus harveyi (Bailey) Díaz-Tapia & Maggs	ANW	1998	EST	34	CONT/AN, ST/SH-FOU	1990-91	UNK	78	CONT/AN, ST/SH-FOU	1971	UNK	79	CONT/AN, ST/SH-FOU
Melanothamnus japonicus (Harvey) Díaz-Tapia & Maggs	PNW	2016	EST	47	CONT/AN	-	-	-	-	-	-	-	-
Pachymeniopsis lanceolata (K.Okamura) Y.Yamada ex S.Kawabata	PNW	-	-	-	-	1982	UNK	80	CONT/AN	-	-	-	-
Palisada maris-rubri (K.W.Nam & Saito) K.W.Nam	RS	-	-	-	-	1991	CAS	81	UNAI	-	-	-	-
Phrix spatulata (E.Y.Dawson) M.J.Wynne, M.Kamiya & J.A.West	PNE	-	-	-	-	1999	UNK	82	ST/SH-FOU	1992	EST	83	ST/SH-FOU
Plocamium secundatum (Kützing) Kützing	PSW	-	-	-	-	≤1991	CAS	84	ST/SH-FOU	-	-	-	-
Polysiphonia morrowii Harvey	PNW	1999	EST	85	CONT/AN	2012	EST	86	CONT/AN	-	-	-	-

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Polysiphonia paniculata Montagne	PSE	-	-	-	-	1971	CAS	51	ST/SH-FOU	1980	CAS	25	ST/SH-FOU
Polysiphonia schneideri B.Stuercke & D.W.Freshwater	ANW	2016	EST	47	ST/SH-FOU	-	-	-	-	-	-	-	-
Pyropia suborbiculata (Kjellman) J.E.Sutherland, H.G.Choi, M.S.Hwang & W.A.Nelson	PNW	2014	EST	87	CONT/AN, ST/SH-FOU	-	-	-	-	-	-	-	-
Pyropia yezoensis (Ueda) M.S.Hwang & H.G.Choi	PNW	2010	EST	88	CONT/AN, REL/FISH	-	-	-	-	-	-	-	-
Solieria filiformis (Kützing) P.W.Gabrielson	ATW	2003	EST	43	ST/SH-FOU	1922	CAS	89	ST/SH-FOU	-	-	-	-
Spermothamnion cymosum (Harvey) De Toni	IO	2010	EST	88	ST/SH-FOU	-	-	-	-	-	-	-	-
Symphyocladia marchantioides (Harvey) Falkenberg	PSW	-	-	-	-	-	-	-	-	1984	EST	90	ST/SH-FOU
Womersleyella setacea (Hollenberg) R.E.Norris	PTW	1997	EST	58	ST/SH-FOU, ESC/AQ	1993	INV	91	ST/SH-FOU, ESC/AQ	1986	INV	92	ST/SH-FOU, ESC/AQ
Tracheophyta													
Halophila stipulacea (Forsskål) Ascherson	RS	-	-	-	-	1998	EST	93	UNAI	1995	EST	63	UNAI
POLYCHAETA													
Axionice medusa (Savigny, 1822)	RS	-	-	-	-	1987	EST	94	ST/SH-BAL, ST/SH-FOU, UNAI	-	-	-	-
Branchiomma boholense (Grube, 1878)	IP	2012	INV	95	UNAI	2007 [B]	INV	96	UNAI	2004	INV	95	UNAI
Branchiomma luctuosum (Grube, 1870)	RS, IO	2000	INV	97	ST/SH-BAL, ST/SH-FOU	1988	INV	98	ST/SH-BAL, ST/SH-FOU	1978-79	INV	99	ST/SH-BAL, ST/SH-FOU

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Chaetozone corona Berkeley & Berkeley, 1941	PNE, AW	2006	EST	100	ST/SH-BAL	2010	CAS	101	ST/SH-BAL	2016	EST	102	ST/SH-BAL
Desdemona ornata Banse, 1957	IO	1992	EST	103	ST/SH-BAL	-	-	-	-	1983-84	EST	104	ST/SH-BAL
Diopatra hupferiana hupferiana (Augener, 1918)	AT	-	-	-	-	1975	CAS	105	ST/SH-BAL	-	-	-	-
Diopatra hupferiana monroi (Day, 1957)	IO	-	-	-	-	1977	CAS	106	ST/SH-BAL	-	-	-	-
Erinaceusyllis serratosetosa (Hartmann-Schröder, 1982)	PO	2006	CAS	107	ST/SH-BAL	-	-	-	-	-	-	-	-
Fabriciola ghardaqa Banse, 1959	RS	1986-94	CAS	108	ST/SH-BAL	-	-	-	-	-	-	-	-
Ficopomatus enigmaticus (Fauvel, 1923)	IO	1934	INV	109	UNAI	1955	INV	110	UNAI	1919	INV	111	UNAI
Hesionura serrata (Hartmann-Schröder, 1960)	RS	2010	CAS	112	UNAI	-	-	-	-	-	-	-	-
Hydroides dirampha Mörch, 1863	Co(sub)C	2014	CAS	113	ST/SH-FOU	2013-14	EST	114	ST/SH-BAL, ST/SH-FOU	1868-69	EST	115	ST/SH-BAL, ST/SH-FOU
Hydroides elegans (Haswell, 1883)	IP	1938	INV	109	ST/SH-BAL, ST/SH-FOU	≤1965	INV	116	ST/SH-BAL, ST/SH-FOU	1888	INV	117	ST/SH-BAL, ST/SH-FOU
Hydroides sanctaecrucis Krøyer in Mörch, 1863	ATW	2016	UNK	118	UNAI [A]	-	-	-	-	-	-	-	-
Leiochrides australis Augener, 1914	PO	≤1996	EST	119	ST/SH-BAL, ST/SH-FOU	≤1996	EST	119	ST/SH-BAL, ST/SH-FOU	≤1996	EST	119	ST/SH-BAL, ST/SH-FOU
Leodice antennata Savigny in Lamarck, 1818	IP	-	-	-	-	≤1993	CAS	120	UNAI	-	-	-	-
Linopherus canariensis Langerhans, 1881	AO	-	-	-	-	2006-09 [B]	EST	121	ST/SH-BAL, ST/SH-FOU	-	-	-	-

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Lumbrinerides neogesae Miura, 1981	ASE	≤1991	CAS	122	ST/SH-BAL	-	-	-	-	≤1991	CAS	122	ST/SH-BAL
Lumbrineris acutiformis Gallardo, 1968	PO	-	-	-	-	1987	CAS	94	ST/SH-BAL	-	-	-	-
Lumbrineris perkinsi Carrera-Parra, 2001	IP	-	-	-	-	2013	EST	123	ST/SH-BAL	1975-76	EST	124	ST/SH-BAL
Lysidice collaris Grube, 1870	PO, RS	2000	EST	125	UNAI	1961	EST	126	ST/SH-BAL, ST/SH-FOU, UNAI	1971	EST	127	ST/SH-BAL, ST/SH-FOU, UNAI
Metasychis gotoi (Izuka, 1902)	RS	1934-36	CAS	128	UNAI	≤2008	EST	103	UNAI	1999-2009	EST	129	UNAI
Naineris setosa (Verrill, 1900)	ATW	2003	CAS	130	CONT/AN	-	-	-	-	2010	EST	131	CONT/AN
Neanthes agulhana (Day, 1963)	ASE	2008	EST	132	UNAI	2008	EST	132	UNAI	2011	EST	132	UNAI
Nereis jacksoni Kinberg, 1866	IP	≤2015	CAS	133	UNK	-	-	-	-	1983-84	CAS	134	UNAI
Notomastus aberans Day, 1957	RS	≤1990 [C D]	EST	135	UNAI	1992 [C]	EST	136	UNAI	1976-77	EST	137	UNAI
Notopygos crinita Grube, 1855	AO	-	-	-	-	1977	EST	138	ST/SH-BAL, ST/SH-FOU	-	-	-	-
Ophryotrocha diadema Åkesson, 1976	PNE	-	-	-	-	2006	EST	139	CONT/AN, ST/SH-BAL	-	-	-	-
Ophryotrocha japonica Paxton & Åkesson, 2010	PN	1999	EST	140	CONT/AN, ST/SH-BAL	1999	EST	140	CONT/AN, ST/SH-BAL	1999	EST	140	CONT/AN, ST/SH-BAL
Paramphitrite birulai (Ssolowiew, 1899)	ArO, ANE	2013	EST	141	UNK	-	-	-	-	-	-	-	-
Pileolaria berkeleyana (Rioja, 1942)	PTE	-	-	-	-	≤2008 [D]	EST	103	ST/SH-FOU	≤1995 [D]	EST	142	ST/SH-FOU
Pista unibranchia Day, 1963	IO	≤2008	EST	103	UNK	1977	EST	143	UNK	≤2008	EST	103	UNK
Podarkeopsis capensis (Day, 1963)	ANE, ASE	≤2008	EST	103	UNK	≤2008	EST	103	UNK	1982	EST	144	UNK

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Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Polydora colonia Moore, 1907	AO	2009	CAS	145	UNK	-	-	-	-	-	-	-	-
Polydora cornuta Bosc, 1802	AO, PO	2009	EST	146	ST/SH-BAL	-	-	-	-	-	-	-	-
Prionospio pygmaeus Hartman, 1961	ANE, PNE	-	-	-	-	-	-	-	-	1987	CAS	147	UNK
Pseudonereis anomala Gravier, 1900	RS	-	-	-	-	2013	CAS	148	ST/SH-BAL	-	-	-	-
Pseudopolydora paucibranchiata (Okuda, 1937)	ANE, PW, PNE	-	-	-	-	-	-	-	-	1977	EST	149	UNK
Spirobranchus tetraceros (Schmarda, 1861)	IO, PSW, PT, ATW	-	-	-	-	2016	CAS	150	ST/SH-BAL, ST/SH-FOU, CONT/AN	-	-	-	-
Spirorbis (Spirorbis) marioni Caullery & Mesnil, 1897	PTE, ANE	-	-	-	-	≤2008	UNK	103	ST/SH-FOU	1977	EST	151	ST/SH-FOU
Streblosoma comatus (Grube, 1859)	IO	2000	CAS	152	ST/SH-BAL	-	-	-	-	1975-76	EST	124	ST/SH-BAL
Syllis hyllebergi (Licher, 1999)	RS, ASW	-	-	-	-	2008 [B]	EST	153	CONT/AN	-	-	-	-
Syllis pectinans Haswell, 1920	PTE, PS, ANE	-	-	-	-	-	-	-	-	2013	CAS	154	UNK
CRUSTACEA													
Amphipoda													
Caprella scaura Templeton, 1836	IO	1994-95	EST	155	CONT/AN	≤2004	EST	156	CONT/AN	2003-04	EST	157	CONT/AN
Grandidierella japonica Stephensen, 1938	PNW	2015	EST	158	ST/SH-FOU, CONT/AN	-	-	-	-	2013	EST	159	ST/SH-FOU, CONT/AN
Photis lamellifera Schellenberg, 1928	IO	-	-	-	-	1990	CAS	160	UNAI	-	-	-	-
Stenothoe georgiana Bynum & Fox, 1977	AW	-	-	-	-	2016	EST	150	ST/SH-FOU, CONT/AN	2013	EST	161	ST/SH-FOU, CONT/AN

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Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Cirripedia Thoracica													
Amphibalanus improvisus (Darwin, 1854)	ANW	1969	EST	162	CONT/AN, ST/SH-FOU	1951	EST	163	CONT/AN, ST/SH-FOU	1970	EST	164	CONT/AN, ST/SH-FOU
Balanus trigonus Darwin, 1854	PT	≤1968	EST	165	ST/SH-BAL, ST/SH-FOU	1927	EST	166	CONT/AN, ST/SH-BAL, ST/SH-FOU	≤1962	EST	167	ST/SH-FOU
Megabalanus tintinnabulum (Linnaeus, 1758)	IP	≤1900	UNK	168	ST/SH-BAL, ST/SH-FOU	1986	EST	169	ST/SH-BAL, ST/SH-FOU	1791 [D]	CAS	170	ST/SH-BAL, ST/SH-FOU
Copepoda													
Acartia (Acanthacartia) tonsa Dana, 1849	CoC, CoT	1987	EST	171	ST/SH-BAL	2009-10 [B]	EST	172	CONT/AN	1986	EST	173	ST/SH-BAL
Calanopia elliptica (Dana, 1849)	IP	-	-	-	-	-	-	-	-	1891	UNK	174	ST/SH-BAL, UNAI
Metacalanus acutioperculum Ohtsuka, 1984	PNW	2002	CAS	175	ST/SH-BAL	-	-	-	-	1995	EST	176	ST/SH-BAL
Oithona davisae Ferrari F.D. & Orsi, 1984	PNE	2014	EST	177	ST/SH-BAL	2014 [B]	INV	178	ST/SH-BAL, CONT/AN	-	-	-	-
Paracartia grani Sars G.O., 1904	AO	2003	EST	179	ST/SH-BAL	2016	EST	180	ST/SH-BAL	≤1995	EST	181	ST/SH-BAL
Pseudodiaptomus marinus Sato, 1913	IP	2007	EST	182	ST/SH-BAL, CONT/AN	2008 [B]	INV	183	ST/SH-BAL, CONT/AN	2008	EST	184	ST/SH-BAL, CONT/AN
Triconia hawii (Böttger-Schnack & Boxshall, 1990)	RS	-	-	-	-	-	-	-	-	2004	EST	185	ST/SH-BAL, UNAI
Triconia rufa (Boxshall & Böttger, 1987)	RS	-	-	-	-	-	-	-	-	2004	EST	185	ST/SH-BAL, UNAI

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Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Triconia umerus (Böttger-Schnack & Boxshall, 1990)	RS	-	-	-	-	-	-	-	-	2004	EST	185	ST/SH-BAL, UNAI
Decapoda													
Actumnus globulus Heller, 1861	IO	-	-	-	-	-	-	-	-	1978	CAS	186	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU
Calappa pelii Herklots, 1851	ATE	-	-	-	-	1993	CAS	187	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	-	-	-	-
Callinectes danae Smith, 1869	ASW, ATW	1981	CAS	188	ST/SH-BAL	-	-	-	-	-	-	-	-
Callinectes sapidus Rathbun, 1896	AW	1949	EST	189	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU, UNAI	1999	EST	190	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU, UNAI	1964	EST	191	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU, UNAI
Charybdis (Charybdis) feriata (Linnaeus, 1758)	IP	-	-	-	-	-	-	-	-	2015	CAS	192	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU
Charybdis (Charybdis) japonica (A. Milne-Edwards, 1861)	PNW, PTW	2006	CAS	193	ST/SH-FOU	-	-	-	-	-	-	-	-
Charybdis (Charybdis) lucifera (Fabricius, 1798)	IP	2006	CAS	194	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	-	-	-	-	-	-	-	-

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Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Dyspanopeus sayi (Smith, 1869)	ANW	1992	EST	195	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	2011	EST	196	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	2011	EST	197	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU
Eriocheir sinensis H. Milne Edwards, 1853	PNW	2005	CAS	198	ESC/FO-BA, ST/SH-BAL	-	-	-	-	-	-	-	-
Glabropilumnus laevis (Dana, 1852)	IO, IP	-	-	-	-	-	-	-	-	1956	CAS	199	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU
Herbstia nitida Manning & Holthuis, 1981	ATE	2002	CAS	200	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	-	-	-	-	-	-	-	-
Menaethius monoceros (Latreille, 1825)	IO, PTW	-	-	-	-	-	-	-	-	1978	CAS	201	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU
Palaemon macrodactylus Rathbun, 1902	PNW	2011	EST	202	ST/SH-BAL	-	-	-	-	-	-	-	-
Paralithodes camtschaticus (Tilesius, 1815)	PN, ArO	-	-	-	-	2008	CAS	203	UNK	-	-	-	-
Penaeus aztecus Ives, 1891	ANW, ATW	2016	EST	204	ST/SH-BAL, UNAI	2014	EST	205	ST/SH-BAL, UNAI	2014	EST	206	ST/SH-BAL, ESC/AQ-MA
Penaeus japonicus Spence Bate, 1888	PNW	1985	CAS	207	REL/FISH	-	-	-	-	-	-	-	-

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Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Percnon gibbesi (H. Milne Edwards, 1853)	AT, PTE	2007	EST	208	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	1999	EST	209	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	2000	EST	210	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU
Plagusia squamosa (Herbst, 1790)	IO, RS, PW	1907	CAS	211	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	-	-	-	-	-	-	-	-
Portunus segnis (Forsskål, 1775)	IO	-	-	-	-	1966	EST	212	UNAI, ST/SH-BAL, ST/SH-FOU	2004	CAS	213	UNAI, ST/SH-BAL, ST/SH-FOU
Rhithropanopeus harrisii (Gould, 1841)	ANW	1994	EST	214	CONT/AN, ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	-	-	-	-	2013	EST	215	CONT/AN, ST/SH-HIT, ST/SH-BAL, ST/SH-FOU
Scyllarus caparti Holthuis, 1952	ATE	1977	CAS	216	REL/OTH, ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	-	-	-	-	-	-	-	-
Sternodromia spinirostris (Miers, 1881)	ATE	-	-	-	-	1969-72	CAS	217	ST/SH-HIT, ST/SH-BAL, ST/SH-FOU	-	-	-	-
Thalamita gloriensis Crosnier, 1962	IP, PTW	-	-	-	-	-	-	-	-	1977	CAS	218	ST/SH-FOU

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Trachysalambria palaestinensis (Steinitz, 1932)	IO	-	-	-	-	2016	CAS	219	ST/SH-BAL, UNAI	-	-	-	-
Isopoda													
Ianiropsis serricaudis Gurjanova, 1936	PNW	2012	EST	220	ST/SH-FOU, CONT/AN	-	-	-	-	2014	EST	221	ST/SH-FOU, CONT/AN
Mesanthura cf. *romulea* Poore & Lew Ton, 1986	CoC	-	-	-	-	2004	EST	222	ST/SH-FOU	2000	EST	222	ST/SH-FOU
Paracerceis sculpta (Holmes, 1904)	PNW	1981	EST	223	ST/SH-FOU	1983	EST	224	ST/SH-FOU	1983	EST	224	ST/SH-FOU
Paradella dianae (Menzies, 1962)	PNE	-	-	-	-	-	-	-	-	≤1985	EST	224	ST/SH-FOU
Paranthura japonica Richardson, 1909	PNW	2005	EST	225	CONT/AN, ST/SH-FOU	2013	EST	226	CONT/AN	2010	EST	225	CONT/AN, ST/SH-FOU
Sphaeroma walkeri Stebbing, 1905	IO	-	-	-	-	-	-	-	-	2010	CAS	227	ST/SH-FOU
Stomatopoda													
Erugosquilla massavensis (Kossmann, 1880)	IO	-	-	-	-	2017	CAS	228	ST/SH-BAL, UNAI	-	-	-	-
Anostraca													
Artemia franciscana Kellog, 1906	PNE, PTE, ATW	2004	EST	229	REL/FISH	-	-	-	-	-	-	-	-
MOLLUSCA													
Bivalvia													
Anadara kagoshimensis (Tokunaga, 1906)	PNW	~1966	INV	230	ST/SH-BAL	1976	CAS	231	ST/SH-BAL	1977	CAS	231	ST/SH-BAL

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Anadara transversa (Say, 1822)	ANW	1970s	INV	232	ST/SH-BAL, ST/SH-FOU, CONT/AN	2003	EST	233	CONT/AN	2005	CAS	234	CONT/AN
Arcuatula senhousia (Benson, 1842)	PNW	1992	INV	235	ST/SH-BAL, ST/SH-FOU, CONT/AN	1988	INV	236	ST/SH-BAL, ST/SH-FOU	2000	INV	237	CONT/AN
Brachidontes pharaonis (P. Fischer, 1870)	IP, RS	2009	CAS	238	ST/SH-BAL, ST/SH-FOU	1969	INV	239	ST/SH-BAL, ST/SH-FOU, UNAI	1977	INV	231	ST/SH-FOU, UNAI
Fulvia fragilis (Forsskål, 1775)	IO, RS, ATE	-	-	-	-	2007	EST	234	ST/SH-FOU, UNAI	2003	EST	240	ST/SH-FOU, UNAI
Crassostrea/Magallana sp./spp.	UNK	~1964	INV	241	REL/FISH, CONT/AN,								
ESC/AQ-MA	1966	UNK	242	REL/FISH	1966	UNK	242	REL/FISH					
Mercenaria mercenaria (Linnaeus, 1758)	ANW	2002	CAS	243	CONT/AN	-	-	-	-	1978	CAS	244	ST/SH-BAL?
Mya arenaria Linnaeus, 1758	PNE, ArO	2008	EST	245	REL/FISH, CONT/AN	-	-	-	-	-	-	-	-
Pinctada imbricata radiata (Leach, 1814)	CoC	≤2012	CAS	246	UNAI	≤1917	EST	247	UNAI	1967	EST	248	UNAI
Ruditapes philippinarum (Adams & Reeve, 1850)	PNW	1983	INV	249	REL/FISH	≤1990	EST	250	REL/FISH	1985	EST	251	REL/FISH
Saccostrea glomerata (Gould, 1850)	IO	1984	CAS	249	ESC/AQ-MA	-	-	-	-	-	-	-	-
Theora lubrica Gould, 1861	PNW	-	-	-	-	-	-	-	-	2001	EST	252	ST/SH-BAL

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Xenostrobus securis (Lamarck, 1819)	IO	1991	INV	253	ST/SH-BAL, ST/SH-FOU, CONT/AN	-	-	-	-	2006	EST	254	ST/SH-BAL, ST/SH-FOU
Cephalopoda													
Tremoctopus gracilis (Souleyet, 1852)	IP	-	-	-	-	-	-	-	-	2002	CAS	255	UNAI
Gastropoda													
Cerithium scabridum Philippi, 1848	IO, RS	2005	EST	256	ST/SH-BAL, UNAI	1972	EST	231	ST/SH-BAL, UNAI	1999	EST	257	ST/SH-BAL, UNAI
Biuve fulvipunctata (Baba, 1938)	IO, PW	-	-	-	-	2015 [B]	EST	258	ST/SH-BAL, UNAI	-	-	-	-
Chromodoris quadricolor (Rüppell & Leuckart, 1830)	RS, IO	-	-	-	-	-	-	-	-	1982	CAS	259	ST/SH-BAL, ESC/DOM
Crepidula fornicata (Linnaeus, 1758)	ANW	-	-	-	-	≤1970 [D]	CAS	260	ST/SH-BAL, ST/SH-FOU	≤2005 [D]	CAS	261	ST/SH-BAL, ST/SH-FOU
Cuthona perca (Er. Marcus, 1958)	AW	1976-77	CAS	253	ST/SH-BAL, ST/SH-FOU	-	-	-	-	-	-	-	-
Godiva quadricolor (Barnard, 1927)	IO	2011	CAS	262	ST/SH-BAL, ST/SH-FOU	2016 [B]	EST	263	ST/SH-BAL, ST/SH-FOU	1985-86	EST	264	ST/SH-BAL, ST/SH-FOU
Haminoea cyanomarginata Heller & Thompson, 1983	RS	-	-	-	-	2007	EST	265	ST/SH-BAL, UNAI	2008	EST	266	ST/SH-BAL, UNAI
Haminoea japonica Pilsbry, 1895	PNW	1992	INV	267	CONT/AN	-	-	-	-	2007	INV	268	CONT/AN
Littorina saxatilis (Olivi, 1792)	AN	≤1792	EST	269	ST/SH-FOU	-	-	-	-	-	-	-	-

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Lottia sp.	UNK	-	-	-	-	2015	EST	270	ST/SH-BAL, ST/SH-FOU	-	-	-	-
Melibe viridis (Kelaart, 1858)	IO	-	-	-	-	1991	EST	271	ST/SH-BAL, UNAI	2007	EST	272	ST/SH-BAL, UNAI
Polycera hedgpethi Er. Marcus, 1964	UNK	2005	EST	273	ST/SH-BAL, ST/SH-FOU	2012 [B]	EST	274	ST/SH-BAL, ST/SH-FOU	1986	EST	275	ST/SH-BAL, ST/SH-FOU
Polycerella emertoni A. E. Verrill, 1880	AO	-	-	-	-	-	-	-	-	1964	EST	276	ST/SH-BAL, ST/SH-FOU
Rapana venosa (Valenciennes, 1846)	PNW	1973	INV	277	ST/SH-BAL, CONT/AN	≤1988	CAS	233	ST/SH-BAL, CONT/AN	1978	EST	278	ST/SH-BAL, CONT/AN
Syphonota geographica (A. Adams & Reeve, 1850)	CoC	-	-	-	-	1999	EST	279	ST/SH-BAL, ST/SH-FOU, UNAI	-	-	-	-
MISCELLANEA INVERTEBRATA													
Cnidaria/Anthozoa													
Diadumene cincta Stephenson, 1925	ANE	1993	EST	280	ST/SH-BAL ST/SH-FOU CONT/AN	-	-	-	-	-	-	-	-
Diadumene lineata (Verrill, 1869)	CoT	1925	EST	281	ST/SH-FOU CONT/AN	-	-	-	-	-	-	-	-
Cnidaria/Hydrozoa													
Clytia hummelincki (Leloup, 1935)	ATW, CoC	2002	EST	282	ST/SH-FOU	1996	EST	283	ST/SH-FOU	2003	EST	282	ST/SH-FOU
Clytia linearis (Thorneley, 1900)	IP, CoC	1996	EST	284	UNAI	≤1961	EST	285	UNAI	1957	EST	285	UNAI

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Eudendrium carneum Clarke, 1882	ANW, CoC	-	-	-	-	2004	EST	286	ST/SH-FOU	1985	EST	287	ST/SH-FOU
Eudendrium merulum Watson, 1985	IP	2004	EST	288	ST/SH-FOU, ST/SH-BAL	2004	EST	286	ST/SH-FOU, ST/SH-BAL	1984	EST	287	ST/SH-FOU, ST/SH-BAL
Filellum serratum (Clarke, 1879)	ATW, CoC	-	-	-	-	-	-	-	-	≤1923	EST	289	UNAI?
Garveia franciscana (Torrey, 1902)	PNE, CoC	1978	EST	290	ST/SH-FOU	-	-	-	-	-	-	-	-
Gonionemus vertens A. Agassiz, 1862	PNE, CoC	1918	EST	291	ST/SH-BAL	-	-	-	-	≤1959	EST	292	ST/SH-BAL
Scolionema suvaense (Agassiz & Mayer, 1899)	PSW, IP	-	-	-	-	-	-	-	-	1961-63	EST	293	ST/SH-BAL
Cnidaria/Scyphozoa													
Aurelia coerulea von Lendenfeld, 1884	IP, PN	2011	EST	294	ST/SH-BAL, CONT/AN	-	-	-	-	2011?	EST	294	ST/SH-BAL, CONT/AN
Aurelia solida Browne, 1905	IP	2015	EST	294	ST/SH-BAL	2015	EST	294	ST/SH-BAL	-	-	-	-
Cassiopea andromeda (Forsskål, 1775)	IP	-	-	-	-	2014	EST	295	UNAI, ST/SH-BAL, ST/SH-FOU	2014	EST	296	UNAI, ST/SH-BAL, ST/SH-FOU
Phyllorhiza punctata von Lendenfeld, 1884	PTW	-	-	-	-	2011	CAS	297	UNAI	2009	INV	298	UNAI
Rhopilema nomadica Galil, 1990	RS	-	-	-	-	2015	CAS	299	UNAI	2015	CAS	300	UNAI
Bryozoa													
Amathia verticillata (delle Chiaje, 1822)	UNK	≤1867	INV	301	ST/SH-FOU	≤1958	INV	302	ST/SH-FOU	≤1822	INV	303	ST/SH-FOU
Arachnoidella protecta Harmer, 1915	IP	-	-	-	-	-	-	-	-	1992	EST	304	UNK

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Arbopercula tenella (Hincks, 1880)	AT	-	-	-	-	1990	CAS	305	ST/SH-FOU	2011	EST	306	ST/SH-FOU
Celleporaria brunnea (Hincks, 1884)	PTE, PN	-	-	-	-	2010	EST	307	ST/SH-FOU, CONT/AN	2010	EST	307	ST/SH-FOU, CONT/AN
Celleporella carolinensis Ryland, 1979	AT, ANW	1993	EST	308	ST/SH-FOU	-	-	-	-	-	-	-	-
Crepidacantha poissonii (Audouin, 1826)	CoC	-	-	-	-	1982	CAS	309	ST/SH-FOU	-	-	-	-
Crisularia serrata (Lamarck, 1816)	IP	-	-	-	-	-	-	-	-	1986	EST	310	ST/SH-FOU
Microporella coronata (Audouin, 1826)	RS	-	-	-	-	1991	CAS	311	ST/SH-FOU	-	-	-	-
Parasmittina egyptiaca (Waters, 1909)	IP	-	-	-	-	2016	UNK	150	ST/SH-FOU	-	-	-	-
Pherusella brevituba Soule, 1951	PNE	-	-	-	-	-	-	-	-	1996	EST	312	ST/SH-FOU
Smittina nitidissima (Hincks, 1880)	RS	-	-	-	-	2014	CAS	313	UNAI	-	-	-	-
Tricellaria inopinata d´Hondt & Occhipinti Ambrogi, 1985	PN	1982	EST	314	ST/SH-FOU	-	-	-	-	2010	EST	315	ST/SH-FOU
Watersipora arcuata Banta, 1969	PTE	-	-	-	-	2013-14	EST	114	ST/SH-FOU	2013	EST	316	ST/SH-FOU
Chordata/Ascidiacea													
Botrylloides violaceus Oka, 1927	PNW	1991	EST	317	CONT/AN	-	-	-	-	-	-	-	-
Clavelina oblonga Herdman, 1880	ATW, ANW	-	-	-	-	2003-04	EST	318	ST/SH-FOU	≤1929	EST	319	ST/SH-FOU
Didemnum vexillum Kott, 2002	PN	2012	EST	320	ST/SH-FOU, CONT/AN	-	-	-	-	-	-	-	-

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Distaplia bermudensis Van Name, 1902	AT	-	-	-	-	2000	EST	321	ST/SH-FOU, CONT/AN	-	-	-	-
Microcosmus squamiger Michaelsen, 1927	IP	-	-	-	-	1977	EST	322	ST/SH-FOU	1971	EST	322	ST/SH-FOU
Perophora multiclathrata (Sluiter, 1904)	CoC	1973	UNK	323	ST/SH-FOU	2013-14	CAS	114	ST/SH-FOU	-	-	-	-
Polyandrocarpa zorritensis (Van Name, 1931)	PSE	-	-	-	-	2001	EST	324	ST/SH-FOU, CON/AN	1974	EST	325	ST/SH-FOU
Styela plicata (Lesueur, 1823)	PN	1877	EST	326	ST/SH-FOU	1948	EST	327	ST/SH-FOU	≤1883	EST	328	ST/SH-FOU
Symplegma brakenhielmi (Michaelsen, 1904)	PTE, AT	-	-	-	-	-	-	-	-	2003	EST	329	ST/SH-FOU, CONT/AN
Ctenophora													
Mnemiopsis leidyi A. Agassiz, 1865	ANW	2016	INV	330	UNAI	2009	INV	298	UNAI	2009	INV	298	UNAI
Arthropoda/Pycnogonida													
Ammothea hilgendorfi (Böhm, 1879)	PN	1979	EST	331	CONT/AN	-	-	-	-	-	-	-	-
Anoplodactylus californicus Hall, 1912	CoC	-	-	-	-	-	-	-	-	1965	EST	332	ST/SH-FOU
Porifera													
Paraleucilla magna Klautau, Monteiro & Borojevic, 2004	AT	2007	EST	333	CONT/AN, ST/SH-FOU	2001	EST	334	CONT/AN, ST/SH-FOU	2004	EST	333	ST/SH-FOU, CONT/AN
Sipuncula													
Phascolion (Isomya) convestitum Sluiter, 1902	IP	-	-	-	-	-	-	-	-	1977 D	CAS	335	ST/SH-FOU
Platyhelminthes													

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Allolepidapedon fistulariae Yamaguti, 1940	IP	-	-	-	-	-	-	-	-	2005	CAS	336	CONT/ PAR-AN
FISH													
Actinopterygii													
Abudefduf vaigiensis (Quoy & Gaimard, 1825)	IP	-	-	-	-	-	-	-	-	1957	CAS	337	ST/SH-BAL
Acanthurus chirurgus (Bloch, 1787)	AT, ANW	-	-	-	-	-	-	-	-	2012	CAS	338	ESC/DOM
Acropoma japonicum Günther, 1859	IP	-	-	-	-	-	-	-	-	1987	CAS	339	UNAI, ST/ SH-BAL
Cephalopholis taeniops (Valenciennes, 1828)	AO	-	-	-	-	2009	EST	340	SH/SH-BAL, ST/ SH-FOU	-	-	-	-
Chaetodon auriga Forsskål, 1775	IP	-	-	-	-	-	-	-	-	2015	CAS	341	ESC/DOM
Chlorurus rhakoura Randall & Anderson, 1997	IP	-	-	-	-	2017	CAS	342	SH/SH-HIT, ST/ SH-FOU	-	-	-	-
Elates ransonnettii (Steindachner, 1876)	PTW	-	-	-	-	2005	CAS	343	ST/SH-BAL, ESC/ DOM	-	-	-	-
Epinephelus coioides (Hamilton, 1822)	IP	1998	CAS	344	UNAI	-	-	-	-	-	-	-	-
Etrumeus golanii DiBattista, Randall & Bowen, 2012	RS	-	-	-	-	2005	CAS	345	UNAI	-	-	-	-
Fistularia commersonii Rüppell, 1838	IP	2006	EST	346	UNAI	2002	EST	347	UNAI	2003	EST	348	UNAI
Hemiramphus far (Forsskål, 1775)	IP	-	-	-	-	2013	EST	349	UNAI	-	-	-	-
Hyporhamphus affinis (Günther, 1866)	IP	2008	CAS	350	UNK	-	-	-	-	-	-	-	-

(continued)

Table 1. (continued)

TAXA	NDR	ADRIA				CMED				WMED			
		Year	Success	Ref.	PP	Year	Success	Ref.	PP	Year	Success	Ref.	PP
Lagocephalus sceleratus (Gmelin, 1789)	IP	2013	EST?	351	UNAI	2013	EST	352	UNAI	2016	CAS	353	UNAI
Lutjanus jocu (Bloch & Schneider, 1801)	AO	-	-	-	-	-	-	-	-	2005	CAS	354	ST/SH-BAL
Lutjanus sebae (Cuvier, 1816)	IP	-	-	-	-	-	-	-	-	2016	CAS	355	UNK
Ophioblennius atlanticus (Valenciennes, 1836)	ANW, ATW	-	-	-	-	2017	CAS	356	SH/SH-BAL, ST/SH-FOU	-	-	-	-
Oplegnathus fasciatus (Temminck & Schlegel, 1844)	PO	2015	CAS	357	ST/SH-BAL	-	-	-	-	-	-	-	-
Pinguipes brasilianus Cuvier, 1829	AW	-	-	-	-	1990	CAS	358	ST/SH-BAL	1990	CAS	359	ST/SH-BAL
Platycephalus indicus (Linnaeus, 1758)	IP	-	-	-	-	1978	CAS	360	UNAI	-	-	-	-
Pomadasys stridens (Forsskål, 1775)	IO	-	-	-	-	-	-	-	-	1968	CAS	361	UNAI
Pterois miles (Bennett, 1828)	IO	-	-	-	-	2016	CAS	362	UNAI	-	-	-	-
Saurida lessepsianus Russell, Golani & Tikochinski, 2015	RS	-	-	-	-	1978	CAS	360	UNAI	-	-	-	-
Sciaenops ocellatus (Linnaeus, 1766)	ANW	-	-	-	-	2016	CAS	363	UNK	-	-	-	-
Siganus luridus (Rüppell, 1829)	IO	2010	CAS	364	UNAI	2003	EST	365	UNAI	2004	EST	366	UNAI
Siganus rivulatus Forsskål, 1775	IO	-	-	-	-	2015	CAS	367	UNAI	-	-	-	-
Stephanolepis diaspros Fraser-Brunner, 1940	IO	-	-	-	-	1967	EST	368	UNAI	1983	EST	369	UNAI
Upeneus pori Ben-Tuvia & Golani, 1989	IO	-	-	-	-	2017	CAS	370	UNAI	-	-	-	-
Zebrasoma xanthurum (Blyth, 1852)	IO	-	-	-	-	-	-	-	-	2015	CAS	371	ESC/DOM

[A] Unaided pathway through floating litter. [B] Species found in Faro coastal lake which is connected with both the western and the central Mediterranean. [C] Bedulli *et al.* (1986) reported this species in several locations of an area comprised between Bari (Adriatic Sea) and the Gulf of Taranto (Ionian Sea) but without specifying the exact localities. In the North Adriatic, its presence was later reported from Ravenna by Crema *et al*. (1993), and in the South and central Adriatic by Castelli *et al*. (2008). [D] The exact location of the finding is unknown.

1. MSFD ADRIATIC

Foraminifera

So far, only three alien benthic foraminiferans have been recorded, namely, *Euthymonacha polita, Loxostomina costulata*, and *Spiroloculina antillarum*. All of them were recently collected (2013) in *Posidonia* meadows and on sandy patches outside the harbour of Otranto (Huth & Langer, unpublished data). *Amphistegina lobifera*, the most prolific and productive symbiont-bearing foraminifer, has recently invaded the southern coast of Albania (Langer & Mouanga, 2016) but has not yet colonized the Italian coast, or simply went overlooked so far. The number of invasive species currently present in the Adriatic Sea is considerably lower than in the eastern Mediterranean (EMED), as reported by Hyams-Kaphzan *et al*. (2008); this may be the reason why so few species have been recorded for the area so far. Winter sea surface temperature has been identified as a key variable controlling the spatial distribution of symbiont-bearing foraminiferans in the Mediterranean (Langer & Hottinger, 2000, Langer *et al*., 2012), while counter-clockwise migratory range expansion patterns prevail among the taxa considered to have entered the Mediterranean via the Suez Canal from the Red Sea (Langer, 2008).

Macrophyta

Overall, 43 alien macrophytes have been recorded (Table 1). Their most significant potential pathway is represented by shellfish aquaculture as contaminants on animals, although maritime traffic (hull fouling) seems to have played an important role also. There are 38 established species, while four species, namely, *Aglaothamnion halliae*, *Ceramium strobiliforme, Cladosiphon zosterae,* and *Hypnea valentiae* are just casual findings. The establishment success of *Halothrix lumbricalis* is unknown. Of the established taxa, only one is invasive in the West Adriatic: *Caulerpa cylindracea*, originating from SW Australia and recorded for the first time in this area in Cerano, Brindisi (Costantino *et al*., 2002 as *Caulerpa racemosa*). According to Athanasiadis (2009), the findings of *Antithamnion pectinatum* and *Antithamnion nipponicum* in the Mediterranean can be attributed to *Antithamnion hubbsii*, recorded for the first time in Italy from Venice (Curiel *et al*., 1996 as *A. pectinatum*), where it is established. This is the reason why these two taxa were not included in our work.

Most of the taxa originate from the North Pacific (17) and from the North Atlantic (10), while the remaining taxa come from the Indo-Pacific region (including the Indian Ocean and Red Sea) or other areas of the Atlantic and Pacific. Based on their main pathway of introduction (i.e. shellfish trade) and boreal affinity, most of the alien Macrophyta were found in the northern Adriatic, i.e. 38 species (88% of the total macrophytes recorded in ADRIA). Of these, 30 were in Venice, representing 79% of the northern Adriatic records, likely in connection with the presence of prominent oyster, mussel, and clam farming (Zenetos *et al*., 2010).

Polychaeta

Twenty-six alien polychaetes have been locally recorded. Most of them originate from the Pacific, Indo-Pacific, Indian Ocean, or Red Sea, while six species from the Atlantic. There are 15 established species, of which four are also invasive, namely, *Branchiomma boholense*, *Branchiomma luctuosum*, *Ficopomatus enigmaticus*, and *Hydroides elegans*. While *B. boholense* and *F. enigmaticus* may have reached the Adriatic Sea unaided, the remaining invaders have probably arrived through maritime traffic (ballast water or hull fouling). *Branchiomma boholense* was originally described from the Philippines and introduced to the Mediterranean in 1927 (Knight-Jones *et al*., 1991; Del Pasqua *et al*., 2018); this species, previously misidentified as the Bermudian *B. bairdi*, is particularly abundant in confined zones and areas degraded by anthropogenic impacts (Arias *et al*., 2013). The casual records amount to 10 species, among which *Naineris setosa*, which was recorded in Brindisi (from an aquaculture farm), but the population became extinct (Blake & Giangrande, 2011); nevertheless, *N. setosa* was recorded in the Tyrrhenian from 2010 to 2014 (Atzori *et al*., 2016), where it has established permanent populations. Species such as *Hesionura serrata* (two specimens were retrieved during a survey conducted in October 2010 along the coast of Apulia) (Delos & Giangrande in Eleftheriou *et al*., 2011), *Erinaceusyllis serratosetosa*, *Fabriciola ghardaqa*, *Paramphitrite birulai*, *Polydora colonia*, and *Polydora cornuta* have been found only along the coasts of the Adriatic Sea in Italian waters, although the record of *P. colonia* from Torre Guaceto (Apulia) (Occhipinti Ambrogi *et al*., 2011) lacks a specimen description.

Crustacea

In total, 28 alien crustaceans have been found, of these 18 are established, nine are casual, and one is of unknown establishment success. The taxa recorded belong to Decapoda (14 species), Copepoda (five species), Cirripedia (three species), Isopoda (three species), Amphipoda (two species), and Anostraca (one species).

Alien Decapoda mostly originate from the Atlantic, while six species originate from the Indo-Pacific, Pacific, or Red Sea. The oldest alien crab (*Plagusia squamosa*) captured in the area dates back to 1907 (Stiasny, 1908); only after more than forty years the western Atlantic portunid *Callinectes sapidus* was found for the first time off Caorle (Giordani Soika, 1951 as *Neptunus pelagicus*). It probably reached the Gulf of Venice via on vessels and it is well established now in the ADRIA subregion. *Penaeus aztecus* represents the latest alien decapod caught in Italy, in 2016 off Termoli (Zava *et al*., 2018); it probably arrived through ballast waters or unaided from other areas of introduction. Casual findings are represented by *Callinectes danae*, *Charybdis (Charybdis) japonica*, *Charybdis (Charybdis) lucifera*, *Eriocheir sinensis*, *Herbstia nitida*, *Penaeus japonicus*, *Plagusia squamosa*, and *Scyllarus caparti.* The adults of the Chinese mitten crab *E. sinensis* live in rivers, but their life cycle is completed only in a marine habitat. In 2009, fisheries inspectors of the Italian Coast Guard obtained evidence of illegal import of live crabs from Northern Europe to meet the market demand of the large Chinese community present in Italy (Froglia & Marchini, 2014), and its recent records in the North Adriatic lagoons may well be attributed to improper storage.

Amongst Copepoda, the alien species found in ADRIA are *Acartia (Acanthacartia) tonsa,* recorded in 1987 (Farabegoli *et al*., 1989), *Metacalanus acutioperculum*, reported from Grotta di Ciolo, Cape of Leuca (Moscatello & Belmonte, 2007)*, Paracartia grani*, found in the Gulf of Trieste (De Olazabal *et al*., 2006; Mazzocchi & Di Capua, 2010), *Pseudodiaptomus marinus* recorded in Rimini (De Olazabal & Tirelli, 2011), and lastly *Oithona davisae*, detected in Venice (Vidjak *et al*., 2018). These species are mostly native to the Indo-Pacific.

Regarding Cirripedia, *Megabalanus tintinnabulum*, a worldwide distributed barnacle presumably originating from the Indo-Pacific, is of unknown establishment success. In fact, it was recorded in Trieste in the early 20th century (Graeffe, 1900) where it probably arrived through shipping, and represents the earliest alien crustacean reported in the area. However, despite the monitoring surveys that have been carried out in ADRIA (Venice Lagoon and other parts of the northern Adriatic), it was never recorded again after 1950. Other alien cirripeds locally recorded are the barnacles *Amphibalanus improvisus*, first found in Rimini and Ancona (Relini, 1969), and *Balanus trigonus*, first found in Trieste (Relini, 1968).

Alien Amphipoda are native to the Indian and NW Pacific Oceans, while alien Isopoda found in the ADRIA subregion probably originate from the NW Pacific. The "American colonizer" *Artemia franciscana* is the only alien Anostraca recorded and its introduction in the Margherita di Savoia Salterns (Mura *et al*., 2006) is likely attributed to deliberate release in nature.

Mollusca

Eighteen alien molluscan taxa have been recorded. Of these, 12 are established and six are casual records (four bivalves and two gastropods). Casual bivalve sightings include *Brachidontes pharaonis*, recorded from Piallassa Baiona (Ravenna) (Rinaldi, 2012; Crocetta *et al*. in Lipej *et al*., 2017), *Mercenaria mercenaria*, recorded from north Adriatic lagoons (Turolla, 2006)*, Saccostrea glomerata,* recorded from Venice Lagoon (Cesari & Pellizzato, 1985), and *Pinctada imbricata radiata.* The latter was only recently recorded by Scuderi & Terlizzi (2012) from Torre Guaceto (Brindisi), although it is not known whether this record is based on a specimen or a shell. Gastropods recorded on the basis of just a few sightings comprise *Cuthona perca*, recorded from Venice Lagoon (Cesari, 1994; Perrone, 1995), and *Godiva quadricolor*, sighted in Piallassa Baiona (Ravenna) (Rinaldi, 2012). The majority of the established species are of boreal affinity, among which the North Atlantic taxon *Littorina saxatilis* is the oldest Italian record, being known from Venice Lagoon since at least 1792, when it was described as a new species by Olivi (1792). The tropical molluscs are represented by *Xenostrobus securis*, native to Australia and New Zealand, and *Cerithium scabridum*, native to the wider Indo-Pacific area. Species displaying invasive traits are the most numerous, and include: the NW Pacific bivalves *Anadara kagoshimensis*, *Arcuatula senhousia*, and *Ruditapes philippinarum*, the NW Atlantic *Anadara transversa*, *Crassostrea/Magallana* oysters, and *X. securis*; among gastropods, *Haminoea japonica* and *Rapana venosa*, both native to the NW Pacific, are also considered invasive. The invasiveness of *R. philippinarum* has often been a matter of debate; however, there is no scientific evidence to support its ability to displace the native *R. decussatus* (Turolla, 2008). On the other hand, the introduction of *R. philippinarum* is considered the most relevant socio-economic event in Italian shellfish farming. In fact, with a harvest of 50,000 tons/year, Italy ranks second (after China) in the global production of Manila clams, representing 90% of the production in Europe (Turolla, 2008), whereas the Italian production of the native *R. decussatus* is less than 1,000 tons/year (Turolla, 2007). On the other hand, the Asian date mussel *A. senhousia* proved to be a nuisance species in clam farming: it builds a dense mat with sediment, macroalgae, and bivalves (>10,000 specimens/m^2), thus constituting a barrier that prevents water to reach the underlying clams, with subsequent death (Turolla, 1999).

Miscellaneous Invertebrata

With regards to Cnidaria, nine NIS were recorded. Five are Hydrozoa, namely *Clytia hummelincki*, *Clytia linearis*, *Eudendrium merulum*, *Garveia franciscana*, and *Gonionemus vertens*, most of them having a tropical/subtropical native distribution. The first alien cnidarian recorded dates back to 1918 (Joseph, 1919) and refers to *G. vertens*, an estuarine species, native to the NE Pacific and thriving in temperate waters (Zenetos *et al*., 2010). Two alien Anthozoa, *Diadumene cincta,* a NE Atlantic species, and *Diadumene lineata*, a circum-temperate species were recorded in Venice lagoon and are established. The alien Scyphozoa are represented by *Aurelia coerulea*, reported from Varano Lagoon, and *Aurelia solida*, sighted in the Gulf of Trieste (Scorrano *et al*., 2017); both species are established.

Only three alien Bryozoa have been reported in the western Adriatic, out of 13 recorded along the Italian coasts, all with established populations. The latest Adriatic finding is *Celleporella carolinensis*, a species reported exclusively from this area. It was recorded in Venice [Occhipinti - Ambrogi & d' Hondt, (1995) 1996] and is characterized by an Atlantic (tropical to tempetrate) distribution.

Alien Tunicata Ascidiacea comprise four species, namely *Botrylloides violaceus*, *Didemnum vexillum*, *Perophora multiclathrata*, and *Styela plicata*. Three species originate from the North Pacific, while *P. multiclathrata* is a circumtropical species. Among them, *S. plicata* is a species naturalized in almost the entire Mediterranean basin, while *D. vexillum* is the latest reported species, probably introduced via on vessels and/or as a contaminant with aquaculture products (Tagliapietra *et al*., 2012). *Botrylloides violaceus* is an established species in Venice Lagoon, found for the first time in 1991 (Zaniolo *et al*. 1993; Brunetti, R., pers. communication), while *P. multiclathrata* is an accidental species (Brunetti & Menin, 1977).

Among alien Ctenophora, *Mnemiopsis leidyi* has invaded the Italian Adriatic since 2016 (Malej *et al*., 2017), introduced to the Mediterranean from the Black Sea via the Dardanelles. Exclusively found in the Adriatic, the alien pycnogonid *Ammothea hilgendorfi* is a temperate northern Pacific species (Krapp & Sconfietti, 1983). The only alien Porifera reported in Italy, *Paraleucilla magna*, was found for the first time in Brindisi (Longo *et al*., 2007), where it likely arrived as a contaminant on animals (i.e. through shellfish aquaculture) or via maritime traffic.

Fishes

Six alien Fishes have been recorded in the area so far. The Pacific barred knifejaw *Oplegnathus fasciatus* was recently caught in Trieste (Ciriaco & Lipej in Crocetta *et al*., 2015), and another observation of this species (30 miles out of Ravenna in December 2017) has been posted by recreational fishermen on the "Oddfish"[13] Facebook page. Both specimens have presumably arrived through ship transport. Apart this taxon, the majority of Lessepsian fishes recorded in the area reached it unaided from already established Mediterranean populations. Multiple records in the western Adriatic only exist for two species: *Fistularia commersonii*, recorded in Tricase, Lecce (Dulčić *et al*., 2008) and *Lagocephalus sceleratus*, recorded twice in Bari and Molfetta (Apulia) (Andaloro *et al*., 2016; Azzurro *et al*., 2018a). Nevertheless, the occurrence of established populations of the aforementioned species in the western Adriatic is still questionable.

2. MSFD CENTRAL MEDITERRANEAN

Foraminifera

Alien foraminiferans include *Amphistegina lobifera*, *Amphistegina lessonii*, *Amphistegina* cf. *A. papillosa*, and *Entosigmomorphina* sp. (Langer, 2008; Caruso & Cosentino, 2014). The main vectors driving their introduction include transport via maritime traffic (ballast water), ichtyoendochory, and biofouling (Koukousioura *et al*., 2010; Langer, unpubl. data). All taxa have established self-maintaining populations, except for *Entosigmomorphina* sp. Among them, *A. lobifera* and *A. lessonii* have the capability to reach high abundances and to cause a negative impact on the diversity of native biotas and modify local habitats. For symbiont-bearing taxa, range expansions are fuelled by rapidly rising temperatures in the Mediterranean (Langer *et al*., 2013; Langer & Mouanga, 2016). Species distribution modelling has indicated that climate-driven range expansions will likely shift the current range front towards the Adriatic and the Tyrrhenian Sea via the Straits of Otranto, Sicily, and Messina (Langer *et al*., 2012). Weinmann *et al*. (2013a, b) forecasted that the average range expansion rate till the year 2,100 will be approximately 12.5 km per year (for the Mediterranean Sea), a rather conservative estimate that appears to have increased as shown by new occurrence records from Tunisia and Sicily (Guastella, Mancin & Langer, unpubl. data).

Macrophyta

Forty alien macrophytes were recorded, representing 61.5% of the Macrophyta recorded in Italy. The main pathways of introduction are represented by maritime traffic (hull fouling), aquaculture (contaminant on cultured bivalves) and, to a lesser extent, the unaided pathway; the most affected localities are the Taranto and Catania Gulfs. Twenty-five of them are established, five of which are also ranked as invasive (*Asparagopsis armata*, *Caulerpa cylindracea, Caulerpa taxifolia* var. *distichophylla*, *Lophocladia lallemandii*, and *Womersleyella setacea*). Among the established species, the Japanese *Codium fragile* subsp. *fragile* was recorded for the first time in Lake Faro (Furnari, 1974, as *Codium fragile*); in the Mar Piccolo of Taranto, the taxon was observed for the first time with a few specimens in 2001; subsequently, it disappeared and then, since 2012, it has become a permanent presence (Petrocelli *et al*., 2013). Seven NIS are casual; they include *Ascophyllum nodosum*, *Batophora* sp., *Palisada maris-rubri*, *Plocamium secundatum*, *Polysiphonia paniculata*, *Solieria filiformis*, and *Undaria pinnatifida*. The latter was recorded in the Mar Piccolo of Taranto from 1998 to 2009, but since 2010 has never been found again (Cecere *et al*., 2000; Cecere *et al*., 2016a).

The establishment success of the remaining eight species is unknown. Among them, the Bermudian *Chondria polyrhiza* was recorded in Taranto with small specimens, although it was also found in Greece (Cecere *et al*., 1996). NIS native to cold/temperate regions are generally slightly more numerous than species with a tropical/subtropical affinity. In particular, eight taxa are native to the NW Pacific and eight to the NE Atlantic. Ten taxa originate from the Indian Ocean, Indo-Pacific or Red Sea; six of them are likely Lessepsian immigrants, such as *Chondria pygmaea*, *Halophila stipulacea*, and *Palisada maris-rubri*, which arrived through unaided spreading.

13 https://www.facebook.com/groups/1714585748824288/search/?query=fasciatus.

Polychaeta

Twenty-eight polychaeta taxa (actually 27 species, one of which represented by 2 subspecies) are known from the area, the majority of which are established. *Spirorbis (Spirorbis) marioni*, recorded in eastern Sicily (Castelli *et al*., 2008), is of unknown establishment success. Among the polychaetes that have formed stable populations, the Lessepsian *Notomastus aberans* was mentioned in a publication by Bedulli *et al*. (1986), but the authors did not specify the exact locations of the findings between Bari (Adriatic Sea) and Taranto (Ionian Sea). It was later recorded in 1992 in the Strait of Messina (Cosentino & Giacobbe, 2006). Four invasive NIS, all found also in the other MSFD subregions (Table 1), are mostly reported from Taranto, Messina (Lake Faro and Lake Ganzirri), and Siracusa. *Branchiomma luctuosum,* found in the Ionian, but not in the Strait of Sicily, has invaded the majority of the Italian coasts and is considered a pest (Licciano *et al*., 2002). Recently, the Indo-Pacific *H. elegans,* also included on the Worst Invasive species list as it is able to create thick aggregations in polluted waters (Streftaris & Zenetos, 2006), and the putative Lessepsian *B. boholense* have reached the Strait of Sicily, being recorded in Licata (Ulman *et al*., 2017) and Lampedusa (Biodivalue, 2016), respectively. *Ficopomatus enigmaticus* was found for the first time in Lake Ganzirri (Rullier, 1955). The first records for the Mediterranean Sea consist of five taxa, namely, *Diopatra hupferiana hupferiana*, *Diopatra hupferiana monroi*, *Lumbrineris acutiformis*, *Notopygos crinita*, and *Ophryotrocha diadema*; the first records for Italy retrieved from the CMED include *Linopherus canariensis*, *Pseudonereis anomala*, *Syllis hyllebergi*, the Lessepsian *Leodice antennata*, and the latest recorded *Spirobranchus tetraceros* (Ulman *et al*., 2017). Of these, *L. acutiformis* and *O. diadema* were recorded from the Strait of Sicily by Albertelli *et al*. (1995) and Simonini *et al*. (2009), respectively.

Crustacea

Overall, 23 alien crustaceans have been found, of which 17 established and six casual.

Established alien Decapoda, such as *C. sapidus*, *Dyspanopeus sayi*, *P. aztecus* and *Percnon gibbesi*, are reported with self-maintaining populations as in all the other MSFD subregions, while *Portunus segnis*, a putative Lessepsian species originating in the Indian Ocean, was recorded in Augusta (Siracusa, Sicily) (Torchio, 1967; Ghisotti, 1966 as *C. sapidus*, misidentification) but it has not reached the Adriatic Sea yet. Apparently, *D. sayi* and *P. segnis* have not expanded to the Strait of Sicily. Casual Decapoda records, as well as first findings in Italy, include *Calappa pelii* originating from the tropical East Atlantic and recorded in Metaponto (Matera) (Pastore, 1995), the boreal red king crab *Paralithodes camtschaticus* caught off Le Cannella, Isola di Capo Rizzuto (Calabria) (Faccia *et al*., 2009), and *Sternodromia spinirostris* reported from Lido Bruno, Gulf Taranto (Pastore, 1976 as *Dromidiopsis spinirostris*); all three were found along the Ionian coast. The Lessepsian *Trachysalambria palaestinensis,* native to the Indian Ocean, was recorded in 2016 off Ragusa (Sicily) (Insacco *et al*., 2017).

Smaller alien Crustacea include three Cirripedia, namely, *A. improvisus, B. trigonus* and *M. tintinnabulum*, all well established in Ionian waters (Berdar & Riccobono, 1986; Berdar *et al*., 1996). Data on cirripeds in the Strait of Sicily are scanty, due to lack of previous studies in the area.

Among alien Amphipoda, *Caprella scaura* originates from the Indian Ocean (Krapp *et al*., 2006), *Photis lamellifera* represents a first record in Italy (Krapp-Schickel, 1993), and *Stenothoe georgiana* was recently found in Siracusa and Licata (Ulman *et al*., 2017).

Alien Isopoda include the circumtropical *Mesanthura* cf. *romulea*, recorded as *Mesanthura* sp. in the Ionian and in the WMED (Lorenti *et al*., 2009), and *Paracerceis sculpta* and *Paranthura japonica,* the latter being sighted recently in the Mar Piccolo of Taranto and in the Strait of Sicily as well (Lorenti *et al*., 2016; Ulman *et al*., 2017). There are four established Copepoda, namely, *P. grani*, *P. marinus, A. (Acanthacartia) tonsa,* and *O. davisae*.

The Lessepsian species *Erugosquilla massavensis* reported in 2017 from the CMED off Brucoli, SE Sicily (Corsini-Foka *et al*., 2017) is the only alien Stomatopoda found in Italian waters.

Mollusca

Similarly to the Adriatic subregion, 18 alien molluscan taxa were sighted, of which 14 established, three casual, and *Crassostrea/Magallana* oysters of unknown establishment success. Circumtropical, Indian Ocean, Red Sea, and Indo-Pacific species may have arrived unaided and represent 27% of the species; around 56% may have arrived via maritime traffic, and three species (~19%) through aquaculture activities or for fishery purposes. *Pinctada imbricata radiata,* the rayed pearl oyster, was first recorded in Lampedusa by Monterosato (1917) (although unknown if alive or dead), and subsequently by Bombace (1967); in the Ionian, just loose valves were initially retrieved (Paccagnella, 1967). Subsequently, it was recorded alive and with stable populations in the same regional sea (Crocetta *et al*., 2009a). The established *C. scabridum* was first recorded with dead specimens in Brucoli (Siracusa) and subsequently found alive by Di Natale (1982). From the temperate regions of the planet, only few molluscs have been reported in CMED; specifically, *A. kagoshimensis*, *A. senhousia*, *R. philippinarum*, and *R. venosa* from the NW Pacific, and *A. transversa* and *Crepidula fornicata* from the NW Atlantic. *Anadara transversa* was first recorded with dead specimens in Sant' Isidoro (Apulia) (Trono, 2006, date in Albano *et al*. 2009), and was subsequently found alive and established in the area (Crocetta *et al*., 2009b). *Crepidula fornicata* was first reported from Sicily, presumably in the Ionian Sea (Parenzan, 1970), with specimens of unknown vitality, constituting just a casual sighting. Among the recorded species only one is ranked as invasive, namely *A. senhousia,* first found in Italy in Siracusa (Brancato & Reitano, 2009, just one valve). Living specimens were reported later by Mastrototaro *et al*. (2003) from the Gulf of Taranto. The northern Pacific *R. philippinarum* was first sighted in the Gulf of Taranto (Cesari & Pellizzato, 1990 as *Tapes philippinarum*). *Brachidontes pharaonis*, a species of Indo-Pacific origin, was recorded for the first time in Italy from Vendicari (Siracusa, Sicily) (Di Geronimo, 1971). Among the latest findings, the gastropod *Biuve fulvipunctata* (described from the Indian Ocean and W Pacific) was reported from Lake Faro (Malaquias *et al*., 2016), where it has already formed self-sustaining populations. The first Mediterranean records include the alien limpet *Lottia* sp., whose native distribution is yet to be determined, found in 2015 in the Ionian Sea (Scuderi & Eernisse, 2016), with permanent populations already established in Catania harbour and nearby areas, and the circumtropical gastropod *Syphonota geographica,* found in 1999 in Reggio Calabria (Turano & Neto, 2001).

Miscellaneous Invertebrata

In the CMED, eight alien Cnidaria have been identified. Among these, four alien scyphozoans were reported, i.e. *Aurelia solida* (Scorrano *et al*., 2017), the Indo-Pacific *Cassiopea andromeda*, recorded in Baia di Augusta (Piraino S., Catalano D., unpublished), the invasive *Phyllorhiza punctata* (Deidun *et al*., 2017) and *Rhopilema nomadica* (Balistreri & Ghelia in Crocetta *et al*., 2015), although the latter two are still casual in Italy. Just four hydrozoans were sighted: the western tropical Atlantic *Clytia hummelincki* (Gravili *et al*., 2008), the NW Atlantic *Eudendrium carneum*, and the two Indo-Pacific species *E. merulum* (Gravili *et al*., 2015; S. Piraino, pers. observ.) and *C. linearis* (Rossi, 1961, as *Clytia gravieri*), all established in the CMED (Gravili *et al*., 2015). *Clytia hummelincki* and *C. linearis* are also two successful invaders in the Mediterranean. The former arrived only recently and it often creates a "belt" in urchin barrens in shallow waters; the latter, native to the Indo-Pacific, is a very common hydrozoan found on shallow hard bottoms of the Mediterranean and probably constitutes the first successful Lessepsian cnidarian, having already been reported in the Mediterranean in the 1950s (Boero *et al*., 2005; Gravili, 2017).

Alien Bryozoa include eight species (the majority of the species recorded in Italy). Most of the species are circumtropical, such as *Crepidacantha poissonii*. There are three NIS originating from the Indo-Pacific/Red Sea, one from the tropical Atlantic, and one from the tropical and North Pacific, while for *Amathia verticillata* the origin is unknown.

Six alien ascidians, i.e. *Clavelina oblonga*, *Distaplia bermudensis*, *Microcosmus quamiger*, *Polyandrocarpa zorritensis*, *P. multiclathrata*, and *S. plicata*, were found in the area. Their native distribution ranges include the Atlantic, Indo-Pacific, and Pacific Oceans. The northern Pacific species *S. plicata* is established in all Italian seas, while the circumtropical *P. multiclathrata* was found in Taranto by Lezzi *et al*. (2018). Although the description of *P. multiclathrata* is missing in Lezzi *et al.* (2018), this species was already reported by Monniot & Monniot (1987) along the Corsican coast (France). *Distaplia bermudensis* was recorded for the first time in Italy in the Ionian Sea, in the Gulf of Taranto (Mastrototaro & Brunetti, 2006).

The alien ctenophore *M. leidyi* was recorded off Isola di Capo Rizzuto (Ionian Sea) by Boero *et al*. (2009), where it is established as in every Italian MSFD subregion.

Among alien Porifera, *P. magna,* was seen for the first time in Italy in 2001, in Mar Piccolo and Mar Grande of Taranto (Longo *et al*., 2007).

Fishes

More than 60% of the alien fish recorded in Italian waters (17 species out of 28) have been reported from the CMED subregion, of which 11 are casual sightings and six can be considered as established. Four established fish species are characterized by repeated sightings; these are *Siganus luridus, F. commersonii, L. sceleratus*, and *Stephanolepis diaspros*, while *Hemiramphus far* was reported only once but with 70 specimens (Falautano *et al*., 2014). These species, after settling in the EMED, may have reached the Italian coasts of the CMED unaided (dispersal with currents and/or adult movements). The majority of the findings come from the Strait of Sicily, mostly from the area of the Pelagie Islands. This geographical sector includes most of the first records for Italian waters such as: *Elates ransonnettii* (Mastrototaro *et al*., 2007), *Chlorurus rhakoura* (Insacco & Zava, 2017), *H. far* (see ref. above), *Platycephalus indicus*, *Saurida lessepsianus* (Castriota *et al*., 2009 as *S. undosquamis*), *Pterois miles* (Azzurro *et al*., 2017), *Upeneus pori* (Deidun *et al*., 2018), *Etrumeus golanii* (Falautano *et al*., 2006), *S. luridus* (Azzurro & Andaloro, 2004), and *Siganus rivulatus* (Azzurro & Giardina in Stamouli *et al*., 2017). Other NIS recorded from the CMED are the red drum *Sciaenops ocellatus*, probably introduced through aquaculture activities (Langeneck *et al*., 2017), and *Cephalopholis taeniops*, detected for the first time in Italian waters (Lampedusa Island) in 2009 by Guidetti *et al*. (2010). Notwithstanding its Atlantic origin, the distance between the Strait of Gibraltar and the current Mediterranean records (all in the central-eastern parts of the basin) does not support the hypothesis of its arrival by natural range expansions, whilst shipping seems to be a more plausible vector. The recent record of *Ophioblennius atlanticus* can also be attributed to ship transport (Azzurro *et al*., 2018b).

3. MSFD WESTERN MEDITERRANEAN

Foraminifera

Detailed knowledge on the presence of alien foraminifera is currently limited to mostly larger symbiont-bearing taxa, which include *A. lessonii, A. lobifera, Coscinospira arietina, Parasorites* sp., and *Sorites variabilis* (Guastella, Mancin & Langer, unpubl. data; Mateu-Vicens *et al*., 2018). Non-symbiont-bearing species are only represented by *Spiroloculina antillarum*. The majority of them have established self-maintained populations, while *A. lessonii* and *A. lobifera* are invasive in the WMED. Foraminifera are indicative of warm tropical waters and the main vector driving their range expansion are rapidly rising global sea surface temperatures and isotherm shifts (Langer *et al*., 2012; Mouanga & Langer, 2014; Langer & Mouanga, 2016). Most species recorded here orginate from the Red Sea and Indo-Pacific Ocean areas and probably entered the Mediterranean Sea via the Suez Canal.

Macrophyta

Twenty-six alien macrophytes have been recorded in the area. The main introduction pathway is probably maritime traffic (fouling on vessel hulls). Twenty-one of them are established, four (*Bonnemaisonia hamifera, Chondria pygmaea, Lophocladia lallemandii, Melanothamnus harveyi*) are of unknown establishment success, whereas one, *Polysiphonia paniculata* (type locality Peru) is a casual record only recorded in Canale di San Pietro, Sardinia (Brambati *et al*., 1980). *Cutleria multifida,* also found in all the other MSFD subregions, has been included on the list of Kawai *et al*. (2016). Six species were ranked as invasive; three of them were collected in the Ligurian Sea, namely, the Indo-Pacific *A. preissii* [Cinelli & Sartoni, 1971 (1969)], *Caulerpa cylindracea,* first recorded in Livorno (Piazzi *et al*., 1994, as *C. racemosa),* and *W. setacea,* a first record for the Mediterranean (Benedetti Cecchi & Cinelli, 1989 as *Polysiphonia* sp.). *Caulerpa cylindracea* and *W. setacea* were also found in the Tyrrhenian Sea, from the Gulf of Salerno (Gambi & Terlizzi, 1998, as *C. racemosa*) and Arcipelago Toscano (Airoldi *et al*., 1995, as *Polysiphonia setacea*), respectively. The highest numbers of alien Macrophyta have been found in Livorno, including Gorgona Island (34.6%), and Sicily (Eolian Islands, Ustica, and Palermo) (23.1%). Sub-tropical and tropical species are sligthly more abundant than the cold/temperate species in this area. They mostly originate from the Indian Ocean, Indo-Pacific, or Red Sea, and have been reported mostly from the Ligurian Sea and Sicilian waters. Among species characterized by cold/temperate native distribution, the NE Atlantic taxa are the most numerous. Finally, examples of putative Lessepsian migrants include *Botryocladia madagascariensis*, *C. pygmaea, H. stipulacea*, *Hypnea spinella,* and *L. lallemandii,* although three of them may have arrived on vessels (fouling).

Polychaeta

Twenty-five alien polychaetes have been recorded, of which 21 established and four casual; this number also includes the putative Lessepsian species *Nereis jacksoni* (Somaschini, 1988), although not considered a true alien by Castelli *et al*. (2008). Four invasives were found in both the Tyrrhenian and Ligurian Sea, except for *B. boholense* and *B. luctuosum*, which apparently have not yet colonized the Ligurian Sea. Among them, the Lessepsian invader *F. enigmaticus* is a reef forming species that locally reaches very high densities. Most of the established species are native to the Pacific, Indo-Pacific, Indian Ocean, and/or Red Sea. The occurrence of the tropical Pacific serpulid *Pileolaria berkeleyana* in the Ligurian Sea before 1995 was obtained from the checklist of Castelli *et al*. (1995), which reports this species in "area 3" (i.e. Ligurian and Tyrrhenian Seas), although on a more recent checklist (Castelli *et al*., 2008) this species is reported only in the Ligurian and Ionian Seas. Nine species originate from the Atlantic, while six species may have arrived from the Pacific and/or the Atlantic. As an example, the latest polychaete recorded in the WMED (off Calafuria, Ligurian Sea), *Chaetozone corona*, may have originated from either the North East Pacific or the West Atlantic (Munari *et al*., 2017). The majority of the polychaetes recorded have probably reached the WMED through maritime traffic, especially in ballast water. *Neanthes agulhana* probably arrived unaided through the Strait of Gibraltar, after invading Spanish Atlantic waters. In five cases, the potential vector is still unknown (*Pista unibranchia*, *Podarkeopsis capensis*, *Prionospio pygmaeus*, *Pseudopolydora paucibranchiata*, and *Syllis pectinans*).

Crustacea

Overall, 31 alien crustaceans were recorded, specifically 27 in the Tyrrhenian and 17 in the Ligurian Sea. Twenty-two species are established, eight are casual records, while the establishment success of one species is unknown.

Alien decapods (six casual and five established taxa) are mostly of Indian, Red Sea, Indo-Pacific, or Pacific origin. Four species originate from the Atlantic, the North/West mainly, while *P. gibbesi* has a wider native distribution, which includes the tropical parts of the Atlantic and East Pacific. The latest alien Decapoda recorded in the area, *Charybdis (Charybdis) feriata*, may have arrived in Livorno, Ligurian Sea (Tiralongo, 2016) via ship traffic (ballast water, hull-fouling or hitchhiking on other parts or cavities of vessels, e.g. the sea-chest); *P. aztecus* probably reached Castiglione della Pescaia (Tyrrhenian Sea) with ballast water or as a mariculture escapee (Cruscanti *et al*., 2015); *Rhithropanopeus harrisii* probably arrived via shipping or as a contaminant on shellfish in Livorno (Langeneck *et al*., 2015a). It was recorded one year later (in 2014) from Olbia, Sardinia, and the Tyrrhenian Sea (Ferrario *et al*., 2017). Furthermore, *C. sapidus* only recently spread to the Tyrrhenian Sea (recorded in Cabras, Sardinia[14]), although it was caught for the first time in 1964 in the harbour of Genoa (Tortonese, 1965); *P. gibbesi* was reported in 2000 from Isola Ustica, Capo Gallo, and San Vito (Sicily, Tyrrhenian Sea) where it formed self-perpetuating populations (Pipitone *et al.*, 2001), and later from Genoa in 2015 (Bianchi *et al.*, 2017).

All alien Copepoda, with the exception of *O. davisae*, were found in the Tyrrhenian Sea. The majority of them are established. The main pathway is probably shipping (ballast water), and the species are mostly of Red Sea and Indo-Pacific origin.

Three alien Amphipoda were found in the WMED, with the latest records pertaining to the West Atlantic *S. georgiana,* found in 2013 in Lerici (Ligurian Sea), which later showed a southward spreading pattern in the Tyrrhenian Sea; one year later it was recorded in Porto Torres (Sardinia) (Ferrario *et al.*, 2017), then in 2015 in Sorrento (Campania) and lastly in 2016 in Palermo. This taxon was detected in all the Italian seas except the Adriatic (Ferrario *et al.*, 2017; Ulman *et al.*, 2017).

The majority of alien Isopoda have been reported from the Tyrrhenian; their common vector of introduction is shipping, even though other pathways may be relevant, such as aquaculture. For example, two NW Pacific species *Ianiropsis serricaudis* and *P. japonica* may have been introduced as contaminants on bivalves or through fouling of vessel hulls. The Indian sphaeromatid *Sphaeroma walkeri* represents the first record in Italy, being recorded in La Spezia (Ligurian Sea) in 2010 (Lodola *et al.*, 2012), without apparently any record from the Tyrrhenian Sea.

With regards to Cirripedia, *Megabalanus tintinnabulum* constitutes the first alien cirriped recorded in Italy, spotted more than two centuries ago in the area, although the exact location of the finding is unknown (Poli, 1791 as *Lepas balanus*); it may have spread to the Tyrrhenian coasts via maritime traffic. In the harbour of Genoa, two more cirripeds have been recorded for the first time in the area: *B. trigonus* (Relini, 1969) and *A. improvisus* (Relini & Montanari, 1973).

Mollusca

With 22 alien molluscs, the WMED accounts for the highest number of findings. Of these, 15 have established self-sustaining populations, while six are just casual findings, i.e. *A. kagoshimensis, A. transversa, Chromodoris quadricolor, C. fornicata, M. mercenaria, Tremoctopus gracilis,* and *Crassostrea/Magallana* taxa are of unknown establishment success. Invasive behaviour in this MSFD subregion is manifested by *A. senhousia*, *B. pharaonis*, and *H. japonica.* Among established Bivalvia, just empty shells, with ligament, of *Fulvia fragilis* were initially recorded in Livorno (Ligurian Sea) in 2003 by Crocetta (2005); however, living specimens were subsequently reported from the same regional sea (Bartolini *et al.*, 2010). In the Tyrrhenian Sea, live samples were first collected in 2005 (Crocetta, 2005); this species is now established. In 1967, loose valves of *P. imbricata radiata* were collected at Isola Gallinara in the Ligurian Sea by Garavelli & Melone (1967); there are no other records of this species from that regional sea. In the Tyrrhenian, dead specimens were found initially (Bombace, 1967; Ricordi, 1993) and live ones later (Stasolla *et al.*, 2014). It now forms stable populations mostly along the coastline of Sicily. Among casual species, living specimens of *A. kagoshimensis* were collected from the Tyrrhenian by Di Natale (1982) in 1977 in Vibo Valentia, while in the Ligurian Sea only one record (samples of unknown vitality) was reported by De Longis (1987); two empty shells belonging to *A. transversa* were retrieved from the Tyrrhenian in 2005 in Bacoli and Torregaveta (Gulf of Naples) (Crocetta *et al.*, 2009b); subsequently, living specimens were reported (Stasolla *et al.*, 2014; Servello & Crocetta in Dailanis *et al.*, 2016). The Indo-Pacific gastropod *C. quadricolor* was collected for the first time in the Mediterranean in 1982 at Imperia (Ligurian Sea) (Cattaneo-Vietti, 1986). The alien Indo-Pacific cephalopod *T. gracilis* was seen alive off Isola di Ponza in 2002 by Belluscio *et al.* (2004), and constitutes the sole record of this species from Italy. The majority of the introductions seem to be related to shipping (ballast water), e.g. for the NW Pacific semelid *Theora lubrica*, and secondarily to currents (unaided pathway). *Cerithium scabridum*, *Haminoea cyanomarginata*, and *Melibe viridis* may have arrived via one of the two aforementioned pathways.

Miscellaneous Invertebrata

Alien Cnidaria amount to 11 species. In this subregion, the number of alien hydrozoans and scyphozoans is the highest in comparison to the other MSFD areas. Seven out of eight alien Hydrozoa reported from Italian waters have been found in the WMED, mostly of tropical or sub-tropical origin, e.g. the Indo-Pacific species *C. linearis* and *E. merulum. Eudendrium merulum* has been reported from each Italian sea except the Strait of Sicily, and was first recorded in 1984 at Promontorio di Portofino, Ligurian Sea. In the following year, it was reported from Panarea (Eolian Islands, Tyrrhenian Sea) (Bavestrello & Piraino, 1991). *Clytia linearis* has a circumtropical distribution and could have reached the WMED unaided, having been sighted in the Ligurian Sea in 1957 as *C. gravieri*, and subsequently in the Tyrrhenian in 1966 (Riedl, 1966). *Scolionema suvaense,* a species of Indo-Pacific distribution, represents a first record in Italy, having been reported from Ischia (Brinckmann-Voss, 1987, as *S. suvaensis*). Four alien Scyphozoa have been recorded in the Tyrrhenian: *A. coerulea, C. andromeda, P. punctata*, and *R. nomadica* (for more details see Boero *et al.*, 2009; Balistreri *et al.*, 2017; Scorrano *et al.*, 2017; Cillari *et al.*, 2018).

Alien Bryozoa comprise eight species. The invasive *A. verticillata* has been reported from all the MSFD

14 https://www.unionesarda.it/articolo/cronaca/2017/11/21/cabras_nelle_acque_della_laguna_compare_il_granchio_blu-68-668440.html .

subregions and the world oceans. Galil & Gevili (2014) considered it alien to the Mediterranean fauna and pseudonative, being described in the Gulf of Naples at the beginning of the XIX century (Delle Chiaje, 1822 as *Hydra verticillata*), whereas Floerl *et al*. (2009) considered it a cryptogenic species. Future comparison of molecular data from topotypic and West Atlantic material may answer the question but, for the time being, *A. verticillata* is listed herein as a NIS. *Crisularia serrata* was reported from Italy for the first time in 1986 in the Tyrrhenian Sea (Di Geronimo, 1990).

Alien ascidians in the WMED include five species (*C. oblonga, M. squamiger, P. zorritensis, S. plicata*, and *S. brakenhielmi*), all established. Some of these species were reported a long time ago, such as *Styela plicata*, while others were only recently reported, such as *Symplegma brakenhielmi* (Trainito, 2004 misidentified as *Distomus variolosus*; Trainito & Baldacconi, 2014 as *S. brakenhielmi*). Further findings of this last species in the Tyrrhenian Sea, confirmed its establishment in the WMED (Ulman, 2016).

The list of alien miscellaneous invertebrates includes the ctenophore *Mnemiopsis leidyi*, which has formed invasive self-sustaining populations in the area (Diciotti *et al*., 2016). *Anoplodactylus californicus,* a circumtropical species, is exclusively recorded in the WMED (Civitavecchia) (Chimenz *et al*., 1980 as *A. portus* Krapp & Sconfietti, 1983), where it is established. Although thriving throughout the Mediterranean basin (Guardiola *et al*., 2010), *P. magna,* has not shown invasive traits in Italian waters. It originates from the tropical Atlantic and it is the only alien sponge reported from Italy, where it was first detected in the Tyrrhenian, and precisely in Naples harbour (Longo *et al*., 2007). One alien Sipuncula, the Indo-Pacific *Phascolion (Isomya) convestitum,* was recorded in the Ligurian Sea (Murina, 1977) as a casual record. Another casual record is the Indo-Pacific parasite trematode *Allolepidapedon fistulariae* that was discovered on *F. commersonii* in Arbatax (Sardinia), and is the first record for the Mediterranean (Pais *et al*., 2007).

Fishes

Thirteen alien Fishes have been recorded in the WMED, mostly in the Tyrrhenian (ten were reported on the basis of one or two findings, while three might have established permanent populations). Ten species originate from the Indo-Pacific, Indian Ocean, or Red Sea, and three species from the Atlantic. Lessepsian fishes are represented by *Fistularia commersonii*, *Siganus luridus*, *Stephanolepis diaspros* and *Pomadasys stridens*; the latter being detected for the first time in the Mediterranean in 1968 from Nattarella di Savona (Gulf of Genoa), based on a single specimen (Torchio, 1969). These species, after entering the Mediterranean through the Suez Canal, have formed self-sustaining populations in the EMED and have likely expanded towards the Italian coasts by secondary spread. Casual occurrences are those related to aquarium trade (intentional release) such as *Acanthurus chirurgus*, *Chaetodon auriga*, and *Zebrasoma xanthurum*. Tyrrhenian records of these Fishes also represent first sightings for Italy. In particular, *A. chirurgus* was found in Isola d'Elba (Langeneck *et al*., 2015b), *C. auriga* in Cape Miseno (Tiralongo *et al*., 2018), while *Z. xanthurum* in Isola di Tavolara (Sardinia) (Guidetti *et al*., 2016). *Lutjanus sebae* was recorded in 2016 off Palermo and its potential pathway is still unknown (Deidun & Piraino, 2017). The Atlantic *Lutjanus jocu* (Vacchi *et al*., 2010) and the W Atlantic *Pinguipes brasilianus* (Orsi Relini, 2002) are casual records in the WMED (Ligurian Sea), being recorded in this marine subregion for the first time in Italy. The casual records of *Abudefduf vaigensis* can be attributed to independent introductions of this species by ship transport or aquarium release (Tardent, 1959; Vacchi & Chiantore, 2000).

4. OVERALL ASSESSMENTS

Overall, 265 NIS have been recorded in Italian waters (Figure 2). The most numerous group among them is Macrophyta, totalling 65 species (41 Rhodophyta, 13 Ochrophyta, 10 Chlorophyta, and one Tracheophyta), of which 55 are established in at least one MSFD subregion. Crustacea ranks second with 48 species, followed by Polychaeta with 43 species. Among Crustacea, Decapoda is the most species-rich order with 24 taxa, followed by Copepoda (9), Isopoda (6), Amphipoda (4), Cirripedia (3), and Stomatopoda and Anostraca, with one species each. Mollusca amount to 29 species. Among the miscellaneous Invertebrata, the dominant group, Cnidaria, includes 15 alien species (eight Hydrozoa, five Scyphozoa, and two Anthozoa), while other taxa, i.e. Bryozoa comprise 13 species, and Foraminifera and Ascidiacea nine species each; lastly, Pycnogonida include two species, while for Ctenophora, Porifera, Sipuncula and Platyhelminthes, only one species each was reported. The list of alien fishes recorded in Italy includes 28 species.

Establishment success categories per MSFD subregion and per taxonomic groups are depicted in Figure 3. A similar number of NIS was reported for the various MSFD subregions: the CMED hosts the highest number of aliens (154 species), followed by the WMED (151 species), while the ADRIA hosts 143 species. In total, 180 NIS have established self-sustaining populations in at least one MSFD subregion. In particular, 112 species are established in WMED, 105 in the ADRIA and 101 in CMED. Casual findings amount to 42 species in CMED, 33 in WMED and 34 in ADRIA. Species with unknown establishment success belong mainly to Macrophyta, Polychaeta, and to a lesser extent Crustacea and Mollusca.

The vast majority of introduced species are native to the Indian/Indo-Pacific/Red Sea, followed by those of North Pacific and Tropical Atlantic origin. This pattern is similar to that documented for the Ionian, Adriatic, and Western Mediterranean by Tsiamis *et al.* (2018). Warm water species, such as those of Indo-Pacific, Indian, Red Sea, tropical (Atlantic and Pacific), and circum(sub)tropical origin, represent approximately 61% in the WMED,

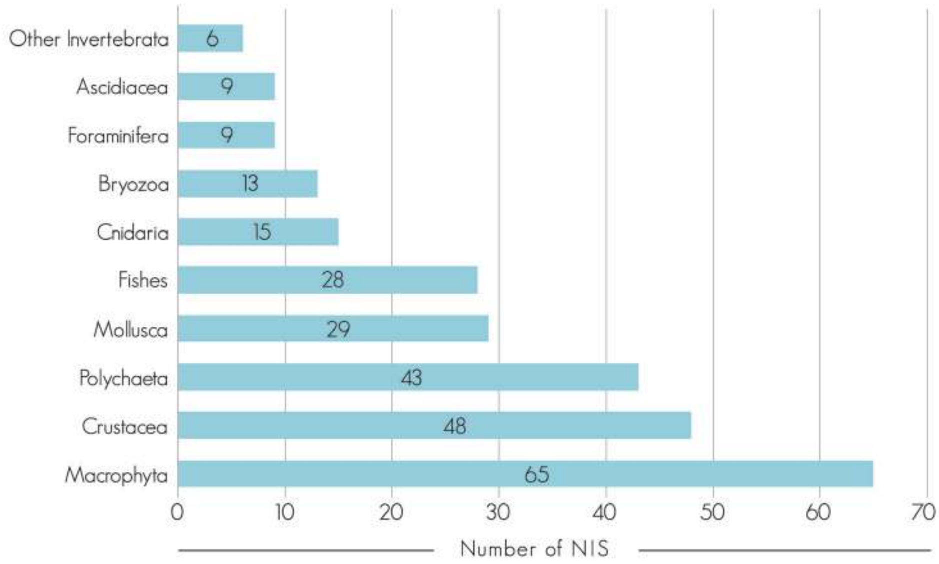

Fig. 2: Number of NIS per taxonomic group in Italy.

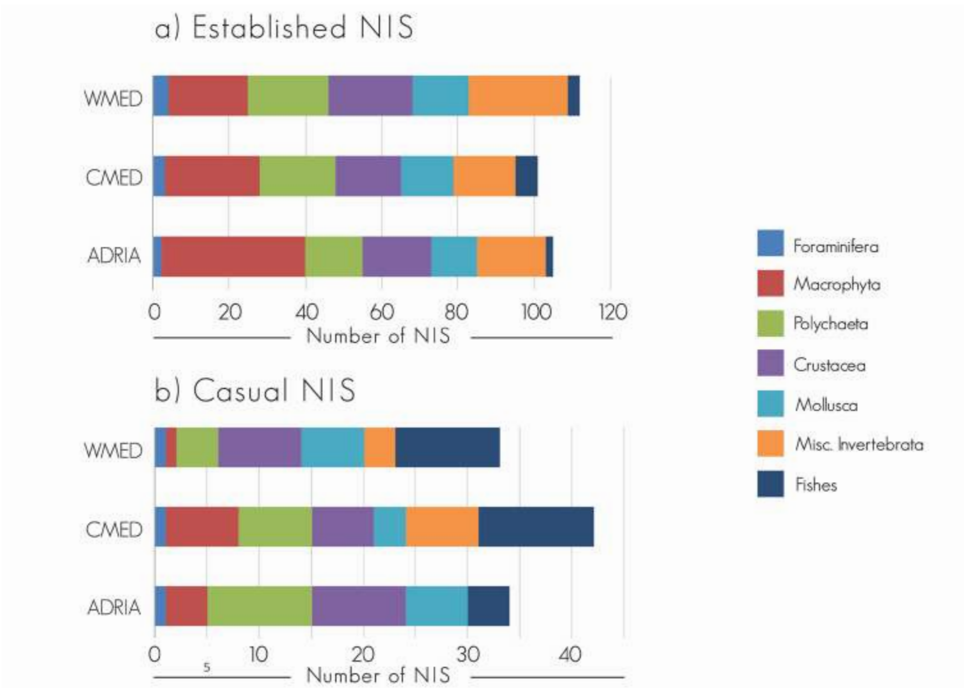

Fig. 3: Establishment success per taxonomic group in each MSFD subregion.

59% in the CMED, and 44% in the ADRIA. Cold water species such as those originating from the northern and southern regions of the Atlantic, and Pacific Oceans, and circumboreal species represent approximately 45% in the ADRIA, 28% in the CMED and 30% in the WMED subregion. The native distribution range of NIS per MSFD subregion are illustrated in Figure 4.

5. RATE OF NEW INTRODUCTIONS

All NIS reported in 2018 refer to species collected until December 2017. The rate of introduction, expressed as the number of new NIS findings per six-year intervals for the period 1970-2017, is presented in Figure 5. From 2012 to 2017, the introductions generally showed the highest increase, although characterised by variability among taxa. Noticeably, alien Macrophyta exhibited the highest number of sightings during the late 1980s - early 1990s and during the 2006-2011 period, when a relevant number of findings occurred among Polychaeta also, while fish entries peaked in the last six years (2012-2017). On average, from 1970 to 2017, alien Macrophyta have increased by seven new species every six years, Polychaeta and Crustacea by five new species, Mollusca and fishes by three new species every six years. Overall, 45 new alien species were recorded in 2012-2017, i.e. approximately one new alien species every seven weeks. The rate of introduction for the last assessment period is higher than that noticed in the previous periods (ranging from one new entry every 19.5 weeks in the 1970-75 period to one species every 9 weeks in 2006-2011). Since 2012, NIS have been reported for the first time mostly from the CMED. Moreover, earlier records of already reported species have been found, while self-sustaining NIS have spread between the Italian subregions. As a consequence, in the 2012-2017 period, 34 new findings have been reported from the CMED, 22 from the ADRIA and 21 from the WMED.

The highest increase in introductions of alien Macrophyta occurred during 1988-93 when for both the CMED and WMED introduction peaks were noticed. In the ADRIA, the highest number of new entries was documented between 1994 and 1999 when 12 alien macrophytes were reported (Table 1). During the last six years, alien macrophytes along the Italian coasts showed a general increase of 10.7%. During this period, the NIS increased in the ADRIA and CMED subregions by four new records each, while only one new species was collected in WMED subregion.

In general, alien Polychaeta showed the highest increase in introductions from 1976 to 1987. The highest number (9 new species) was seen in the CMED from 2006 to 2011 (graph not shown here). From 2012 to 2017, the number of alien polychaetes in Italian waters moderately increased by five new taxa.

Although during the first half of the 1970s no alien crustaceans were detected, from 1976 to 2017 a total of 39 new species were registered. Both the ADRIA and WMED display peaks in introductions from 2000 to 2005, when increases of 75% and 78% occurred, respectively. Finally, in 2012-2017, seven new crustacean entries were documented in the CMED.

From 1970 to 2012, 21 alien molluscs were report-

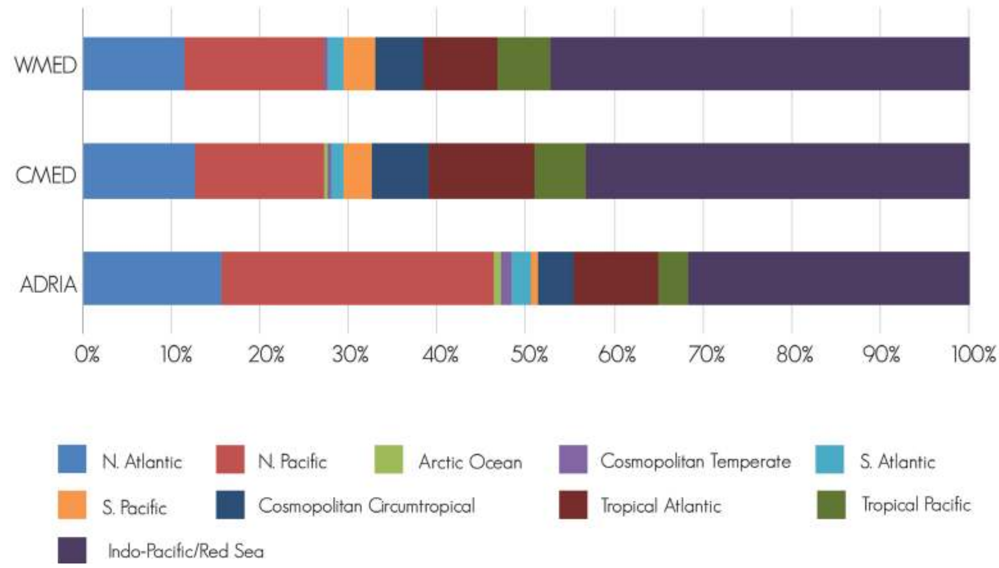

Fig. 4: Native distribution per MSFD subregion.

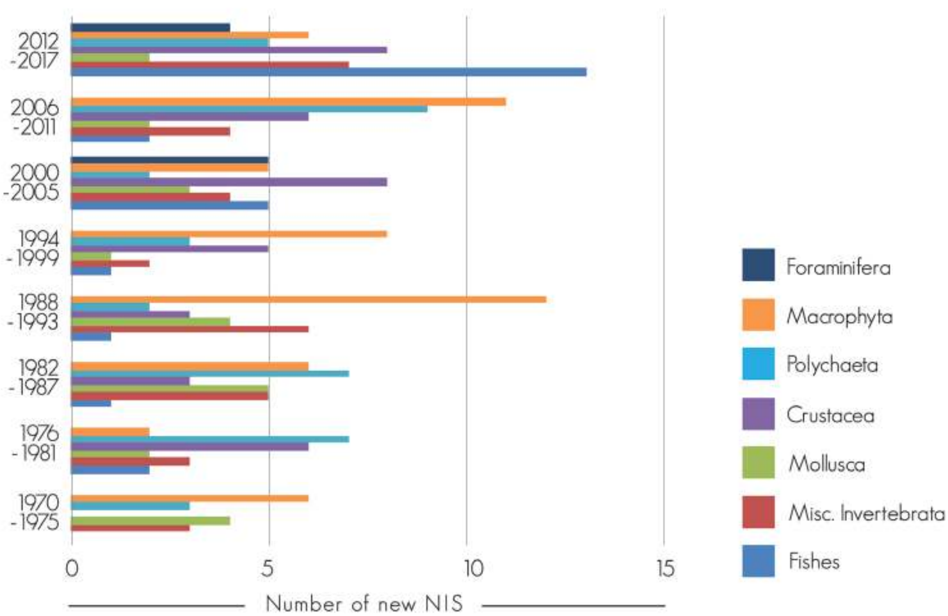

Fig. 5: Number of new NIS in Italian waters per six-year periods from 1970 to 2017.

ed, while after 2012 only two new species were added, namely, *B. fulvipunctata* and *Lottia* sp. that have already established stable populations in the CMED. From 2000 to 2005, a peak in introductions was seen in the WMED, with six new molluscs (Table 1) while four new introductions in this area were recorded after 2005. In the CMED, in 2012-2017, four new taxa were reported, while in the ADRIA, during the same period, only one new alien bivalve (*Pinctada imbricata radiata*) was detected.

Among introduced miscellaneous Invertebrata, Cnidaria displayed their highest increase in the 2012-2017 period when a peak in introductions was seen among alien scyphozoans (three new species were recorded), while a clear decrease in introductions was seen among the alien Hydrozoa; after a peak in introductions in the 1980s, not a single new species was sighted from year 2000 to 2017. Among alien Bryozoa, during the 2012-2017 period, an increase of ~33% was reported, the majority of which were found in the CMED and WMED. Among the other invertebrates (Ctenophora, Porifera, Sipuncula, Platyhelminthes, and Pycnogonida), a peak of introductions was noticed during the 2000-2005 period with no new introductions after 2012.

During 2012-2017, alien fish sightings increased significantly; thirteen new species were reported, while between 1970 and 2011, i.e. within the previous 41 years, only 12 species had been detected. After 1975, introductions and affected areas continuously increased with a marked surge during the period 2000-2017. In the last six years, the CMED, which hosts the majority of alien fishes (17 species), displayed an increase of 100%, with eight new alien species. During the same period, the number of alien Fishes increased by two in the ADRIA and five in the WMED.

6. PATHWAYS OF INTRODUCTION

6a. Contribution of pathways

Trend in pathways has been proposed as an indicator for the measurement of the effectiveness of management measures, especially in high risk areas such as harbours, marinas, and mariculture facilities.

Around half of the NIS (~52%) recorded in Italy have probably arrived as transport-stowaways (attributed to maritime traffic). Transport as contaminants on animals (mainly farmed shellfish) and unaided spread of species are equally important pathways of introduction of new aliens in Italy. The relative contribution of each pathway responsible for NIS in each MSFD subregion and overall in Italian Seas is presented in Figure 6.

As regards the Transport-Stowaway/Shipping related pathway, ~28% of the aliens appear to have arrived as biofoulers on ship hulls as opposed to 22% introduced with ballast waters, while ~2% (mostly alien Decapoda introductions) probably arrived as hitchhikers. Two alien macroalgae, namely, *Ascophyllum nodosum* and *Undaria pinnatifida* were probably introduced as stowaways on "organic packing material". Approximately one third of the species whose introduction is attributed to transport on vessels were casual occurrences, while the majority are now established in Italy. Unintentional transportation by ship/boat represents the main pathway of introduction for alien Crustacea (70%), miscellaneous Invertebrata (66%), Mollusca (59%), and Polychaeta (53%) to the Italian waters.

The Unaided pathway is linked to the introduction of 18.5% of NIS, corresponding almost exclusively to the spread of Lessepsian immigrants (~16% of the Italian NIS). Approximately 45% of the Lessepsian species have been reported merely on the basis of few records, while ~54% have established durable populations in at least one

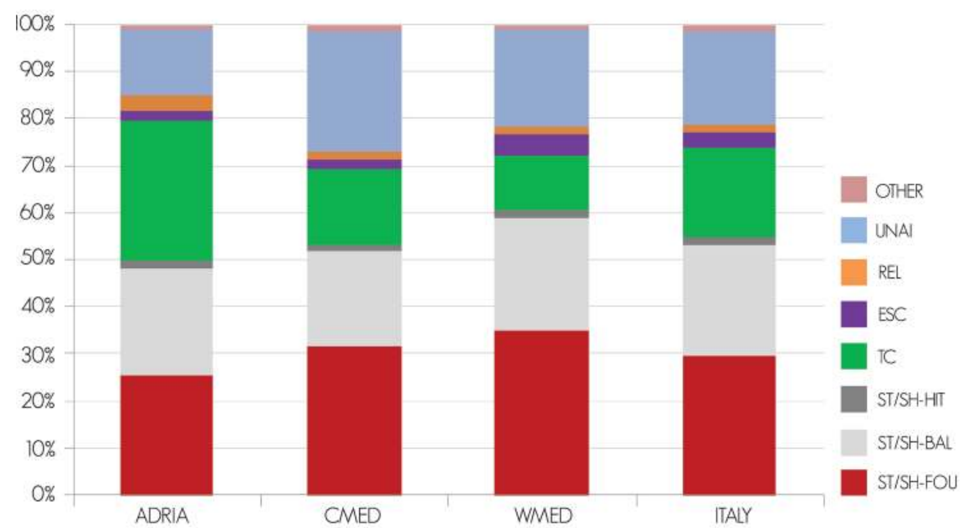

Fig. 6: Potential pathways of introduction to each MSFD subregion and to Italy. **ST/SH-FOU**=TRANSPORT-STOWAWAY: Ship/boat hull fouling; **ST/SH-BAL**=TRANSPORT- STOWAWAY: Ship/boat ballast water; **ST/SH-HIT**=TRANSPORT-STOWAWAY: Hitchhikers on ship/boat; **TC**=TRANSPORT-CONTAMINANT; **ESC**=ESCAPES FROM AQUACULTURE/MARICULTURE+ESCAPES FROM CONFINEMENT: Aquaria (domestic +public including live food for such species), **REL**=RELEASE IN NATURE, **UNAI**=UNAIDED: Natural dispersal across borders.

MSFD subregion. Unaided is the most common pathway for alien fish (50% of the introductions), especially in the CMED, where 11 Lessepsian alien fish are present. Nevertheless, none of the alien fishes has developed invasive populations in Italian waters to-date.

Transport as contaminants on animals (previously assigned to *accidental introductions with aquaculture imports/movements*) (Harrower *et al*., 2018) is estimated to be responsible for the introduction of 17.6% of the species in Italian waters. Typically, it refers to epibionts or species adhering to commercial bivalve seeds (spat) attributed to the aquaculture trade and related activities. This pathway constitutes the main mode of introduction for alien phytobenthos, probably accounting for 43% of the introductions of alien Macrophyta. Moreover, multiple introductions may have occurred on various occasions by different means. ADRIA has the highest share (60%) of alien Macrophyta introduced as contaminants on animals.

Escapes are responsible for the introduction to Italian waters of 3.3% of NIS in Italian waters, with the highest percentage of escapes from domestic aquaria (1.7%), followed by those from aquaculture facilities and public aquaria. Escapes of live food represent 0.2% of the introductions. This pathway essentially concerns species involuntarily released in the wild due to possible connections of facilities where specimens are kept, to the natural environment or failure to apply sound practices in order to prevent unintentional movements.

Release in nature is likely related to the introduction in the wild of 1.7% of NIS. This pathway category comprises release after intentional transportation and introduction of live alien organisms for the purpose of human use in the (semi)natural environment (Harrower *et al*., 2018). Two more alien crustaceans, *Penaeus japonicus* and *Artemia franciscana*, appear to be intentionally released. The edible seaweed, *Pyropia yezoensis* (Armeli-Minicante, 2013), which is used in Japanese cuisine for the preparation of sushi and onigiri as "nori", could have been released into Venice Lagoon but could also be a putative contaminant on shellfish.

Finally, the pathway category "parasites on animals" accounts for only one case, namely, the Indo-Pacific trematode *Allolepidapedon fistulariae*, an endoparasite in *Fistularia commersonii* collected from the WMED.

6b. Trends per pathway (main categories)

Patterns of introduction, considering the potential vectors, are plotted for the period 1970-2017 (Figure 7); they display a stable increase in introductions via the Unaided pathway and especially, in more recent years, via ship-boat hull fouling. Since the 1980s, a growing number of records have been registered throughout all the MSFD subregions, and most noticeably in the CMED.

6c. Trends per activity

Shipping. Growing economic activities, such as tourism and commercial shipping, as well as recreational boating, provide favourable routes for the spreading of alien species via maritime traffic (Zenetos *et al*., 2012). From 1970 to 2017, approximately 51.8% of the species were introduced to Italy through shipping related pathways. An increase of introduced species that arrived on vessels occurred during the past six years (2012-2017) (19 new species vs 14 in the 2006-2011 period). In the ADRIA, maritime traffic was responsible for 46.5% of the introductions between 1970 and 2017. In this MSFD subregion, ship-stowaways showed the highest peak in introductions from 2000 to 2011. In the period from 1970 to 2017, inputs through vessel movements account for

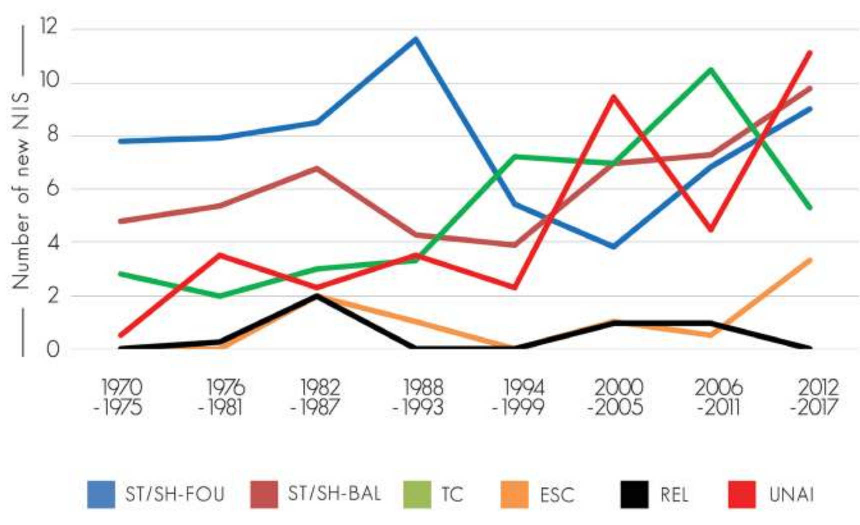

Fig. 7: Trends in the introductions of NIS in Italy according to the main potential pathway of first introduction events from 1970 to 2017. **ST/SH-FOU**=TRANSPORT- STOWAWAY: Ship/boat hull fouling; **ST/SH-BAL**=TRANSPORT- STOWAWAY: Ship/boat ballast water; **TC**=TRANSPORT-CONTAMINANT; **ESC**=ESCAPE FROM CONFINEMENT; **REL**=RELEASE IN NATURE; **UNAI**=UNAIDED.

39.8% and 56.3% of the introductions in the CMED and the WMED, respectively (Fig. 8a).

Aquaculture. This activity encompasses three pathways: release in nature for fishery purposes, escapes from aquaculture/mariculture confinements, and transport as contaminants on animals**.** In Italy, dismissed and released alien species into the wild, represent 2.5% of the introductions that occurred from 1970 to 2017. After a peak in 1982-87, in the last six years introductions dropped to zero. In ADRIA, release in nature represents 3.1% of the new entries and showed a peak in the period 1982-87. In the CMED, two commercial species, *Crassostrea/Magallana* sp. and *R. philippinarum*, were released in the 1960s and 1980s, respectively. Release in nature accounts for 0.7% of introductions in the CMED, and for 0.8% in the WMED (Fig. 8b). Although the transport as contaminants on animals (i.e. shellfish) in 2006-2011 increased by 44%, it has dropped considerably since 2012. In the ADRIA, alien species accidentally transported as contaminants on living bivalves represent 28.8% of the introductions; after an increase in 1994-1999, their number declined during the past six years. In the 1970-2017 period, NIS transported as contaminants on living molluscs account for 15.5% of the introductions in the CMED and 11.1% in the WMED.

Aquarium trade. In Italy, this mode of introduction represents 2.3% of the introductions over the past 47 years. Nevertheless, in 2012-2017, escapees and irresponsible releases from confinement (domestic and public aquaria; live food) have exhibited a marked increase. In ADRIA, all the escapes from confinement, representing 1.2% of the introductions, occurred from 1994 to 2011. In CMED, aquarium trade related introductions account for 2.2% of the introductions, which occurred between 1988 and 2011, displaying a peak in the 1988-93 period. Escaped/released NIS from aquaria, which correspond to 4.4% of the introductions in the WMED, occurred from 1982 to 2017, with an extraordinary increase since 2012 (Fig. 8c).

Unaided introductions. The Unaided pathway represents about 18.5% of the introductions from 1970 to 2017. This vector has displayed a particularly steep upward trend since year 2000, with two peaks: the first one in 2000-2005 and the second in 2012-2017. In the ADRIA, the unaided species (38.6% of all introductions) exhibited the highest peak in introductions in the last six years. In the CMED, unaided species represent 23.3% of the introductions. Similarly to the ADRIA, the highest number was observed in 2012-2017. In the WMED, unaided species (19.3% of the NIS detected in this area from 1970 to 2017) displayed a peak in 2000-2005, with seven new alien species (Fig. 8d).

7. HOTSPOTS

It is argued that healthy native communities can positively outcompete non-indigenous newcomers. For this reason, the identification and delimitation of the hotspots of introduction are fundamental in controlling biologic pollution (Occhipinti-Ambrogi & Savini, 2003). Figure 9 illustrates the hotspots of first NIS detections in Italy. Some species, such as gelatinous plankton (*Aurelia coerulea, A. solida*, *Mnemiopsis leidyi,* and *Rhopilema nomadica*) were collected for the first time during the same year in more than one location; in this case, all the localities have been taken into account. The distribution of alien species recorded along the Italian coasts varies noticeably among localities; differences in alien taxa distribution and numbers may also reflect the presence/absence of taxonomic experts and of past studies along the various Italian coasts (Occhipinti-Ambrogi *et al*., 2011).

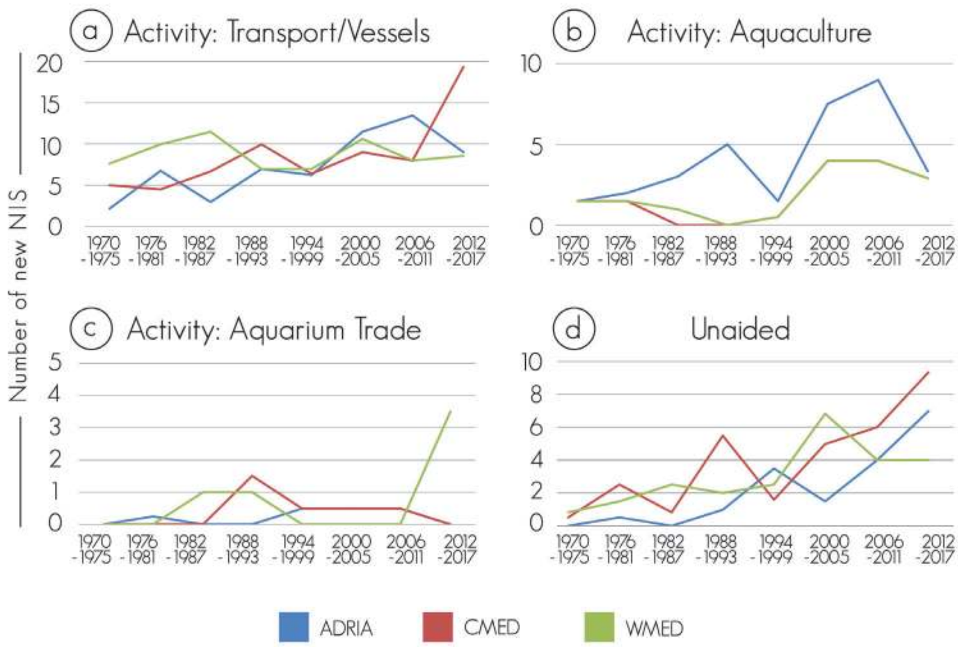

Fig 8: Trends in introduction according to main anthropogenic activities in the 3 MSFD subregions*:* **a)** transported by vessel; **b**) aquaculture related activities; **c)** aquarium trade; and **d**) unaided introductions.

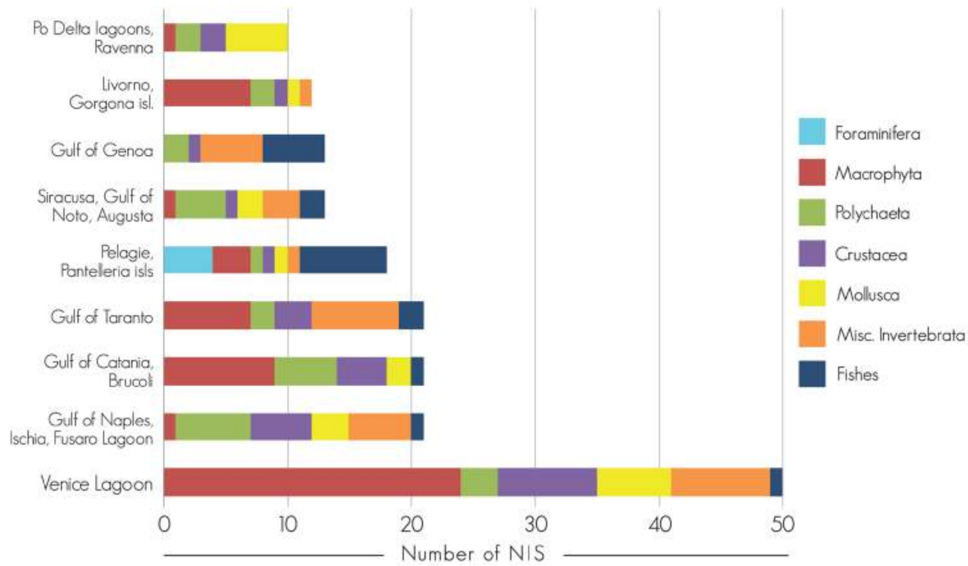

Fig. 9: Hotspots of first introduction to Italy.

Italian coastal lagoons, which are not saturated by benthic populations (Munari & Mistri, 2008), and harbours tend to host the highest number of alien species due to the degraded environmental conditions and to few competitors that facilitate occupation by opportunistic species but more importantly, due to the numerous anthropogenic activities and potential vectors of introduction that they host (Occhipinti-Ambrogi & Savini, 2003). Venice Lagoon is the most important hub of NIS introduction to Italy (Occhipinti-Ambrogi *et al*., 2011). Commercial and tourism ports, marinas, thriving shellfish aquaculture and live seafood trade are activities that have led to the characterization of the lagoon as a "sink but also a source" for further NIS dispersal (Marchini *et al*., 2015). Fifty new alien species, among those reported as first records in Italy, were first detected in Venice Lagoon: 24 Macrophyta, three Polychaeta, eight Crustacea, six Mollusca, eight other invertebrates, and one fish. Four of these, namely, the worm *H. elegans*, and the molluscs *X. securis*, *H. japonica* and *R. venosa* display invasive behaviour.

The Italian CMED is an exceptionally sensitive area for monitoring the spread of the NIS coming from the eastern Mediterranean. In particular, Sicily hosts two hotspots of introduction, the Gulf of Catania (including Brucoli, which is situated just south of the gulf) in the Ionian, and the Pelagian Islands and Pantelleria in the Strait of Sicily where newly recorded NIS amount to 39 (21 and 18 new species each). Taranto Gulf (including the transitional waters of Mar Piccolo and, with a lower number of records, Mar Grande and Taranto harbour) hosts a further 21 new findings. Although the Sicilian aquaculture industry is relatively small, this island receives large numbers of aliens due to its geographic location that makes it a crossroad between the Atlantic and Indo-Pacific fauna (Guidetti *et al*., 2010). Its coastal waters are characterized by important shipping, fishing and numerous leisure boats (Occhipinti-Ambrogi *et al*., 2011). In Taranto Gulf, the continuous growth of maritime traffic, and increased mariculture activities (shellfish import and trade), represent the main risk factors that are exacerbated by the lack of awareness among stakeholders (Cecere *et al*., 2016b).

In the WMED subregion, the hotspots of introduction comprise the Gulf of Naples (including Ischia and the Fusaro Lagoon), and the Gulf of Genoa (excluding the Gulf of La Spezia) and Livorno (the harbour in particular) in the Ligurian Sea, with 13 and 12 new species, respectively. Nowadays, in the Gulf of Naples, where 21 new alien species were recorded, an increasing number of native and allochthonous thermophilic species have been recorded due to rising sea temperatures. For example, the Phlaegrean islands (Ischia, Procida and Vivara) that in the past represented a biogeographic limit for many Mediterranean warm-affinity species now host a substantial number of alien species. In this area, most of the NIS are Lessepsian species that have spread unaided. Various NIS have also been reported from acidified areas and near the port of Ischia in impacted ecosystems due to the absence of competitors (Gambi *et al*., 2016). On the contrary, the Ligurian Sea is one of the northern-most and coldest areas of the western basin, and is characterized by less warm-temperate species, and more cold-temperate species than those of the southern Mediterranean (Bianchi & Morri, 1993, 1994).

The list of localities where the first Italian records of alien species were found encompasses a number of less affected areas. Nevertheless, Siracusa (including the Gulfs of Noto and Augusta) hosts 13 new species belonging to various groups. Ten newly recorded species, especially alien Mollusca, were found in the Po Delta lagoons (including Ravenna); nine in Messina (especially from Lake Faro); eight new species (none of which are Macrophyta) along the Latium coasts (including Sabaudia Lagoon), etc.

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The following supplementary information is available for the article:
S1 Table: "Classification of Pathways according to CBD, 2014".
(Excel)
S2 File. The file contains ''References for the first records of marine alien species in Italian Seas reported in Table 1''.
(PDF) https://ejournals.epublishing.ekt.gr/index.php/hcmr-med-mar-sc/article/view/18711/17283