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ORIGINAL PAPER

Alien species along the Italian coasts: an overview

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Abstract We present a contribution to the knowledge of marine and brackish water alien species (infraspecific taxa included) recorded along the Italian coasts. The Italian Peninsula, with over 7,000 km of coastline, is located in the center of the Mediterranean Sea, splitting the Western and the Eastern basins. Data were collected from published material, mostly authored by the experts of different marine taxa participating in the "Allochthonous Species Group" of the Italian Society of Marine Biology (SIBM). The data have been reviewed according to the taxonomic expertise of the authors and are organized in a referenced database containing information on each species about: distribution along Italian coasts, the native range, most probable vectors of introduction, population status and impact. The

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total number of marine alien species recorded along Italian coasts during the selected time period 1945–2009 is relatively high: 165 species, in many cases native from tropical regions of the world. Most of them were introduced in the 1980s and 1990s, whereas in the last few years the number of new records has decreased. The highest number of alien species has been observed in the northern Adriatic Sea, particularly in the Lagoon of Venice, which is the main hotspot of introduction. Of the total number of species, 46% was unable to establish resident populations in the Italian seas; 15% (24 species) rapidly increased their populations and extended their geographical range, consequently they may be considered invasive species.

Keywords Allochthonous species · Non-indigenous species · Italy · Mediterranean Sea · Vectors of introduction · Marine invertebrates · Fishes · Macrophytes

Problem

Introduction and spread of alien (allochthonous, non-indigenous) species are considered one of the main threats to biodiversity at different scales and extent (Hulme et al. 2009); this is also a concern in the marine context (Bax et al. 2003; Molnar et al. 2008). The new Millennium economical policy is responsible for species globalization (Leppäkoski and Olenin 2000; Carlton 2002; Occhipinti-Ambrogi and Savini 2003; Galil 2008; Galil et al. 2008).

Alien species inventories are increasingly being published in the scientific literature and considerable international effort is devoted to gather and process information about the current situation in several parts of the globe.

Also Public Administrations are interested in the description of baseline situations and in the analysis of temporal trends, in connection with projects aimed at controlling the impact of the introduction of non-indigenous species.

As far as the marine and brackish fauna is concerned, the efforts to establish a comprehensive and coherent framework of available information have been numerous and have promoted a surge of initiatives in this field of investigation. Since the eighties the ICES (International Council for the Exploration of the Sea), through its Working Group on Introduced and Transfer of Marine Organisms (WGITMO), has promoted the annual preparation of National Reports (Gollasch 2007), which has created a common framework for the exchange of information about new sightings in different parts of the world. Other regional initiatives such as those in the USA (Ruiz et al. 2000; Pedersen et al. 2003) or Australia and New Zealand (Hewitt and Martin 2001) have been promoted by Governments and have resulted in well-structured databases.

The situation in Europe, as described by the book edited by Leppäkoski et al. (2002), encompasses a lively, yet fragmented, spurt of investigations and has recently been reviewed by a number of research projects funded by the European Commission (DAISIE: Delivering Alien Invasive Species Inventories for Europe http://www.europe-aliens.org and IMPASSE: Environmental impacts of alien species in aquaculture http://www.hull.ac.uk/hifi/IMPASSE/). Aspects dealing with algae have been specially treated by the European Project ALIENS (Algal Introductions to European shores) (Guala et al. 2004).

Several inventories for the Mediterranean Sea have been published (Zibrowius 1992; Ribera Siguan 2002; Cormaci et al. 2004; Streftaris et al. 2005; Zenetos et al. 2005, 2008; Galil 2008, 2009); discrepancies might arise mainly from taxonomic inconsistency and from the inclusion of species which have arrived by natural pathways (e.g. Gibraltar). A valuable coordination initiative, through the publication of several Atlases on different taxonomic groups (Golani et al. 2002; Galil et al. 2002; Zenetos et al. 2002; Verlaque et al. 2010) and the organization of workshops and round tables, has been provided by the Commission for the Scientific Exploration of the Mediterranean (CIESM 2002; Zibrowius 2001; Galil 2004), encompassing also the southern and eastern shores of this sea, probably the areas most affected by alien species.

The burst of initiatives and the eagerness in compiling reports for the different needs of a variety of local, national, regional and international agencies must be backed by thorough and independent scientific scrutiny by experts with strong taxonomic and ecological backgrounds, in order to guarantee accurate data.

An updated inventory of alien species in Italian inland waters is provided by Gherardi et al. (2008); as far as we know, no similar publication is available for marine and transitional waters.

The present contribution by Italian scientists, who have undertaken this task on a voluntary basis, being part of the "Allochtonous Species Group" (ASG) within the Italian Society of Marine Biology (SIBM), aims to present the updated status of introduced specific and intraspecific taxa (hereafter referred to as "species" for convenience) in the coastal water bodies of the Italian Peninsula, deriving from a plethora of different research programs and published records in our country.

A first list of marine alien species in Italy was published by Occhipinti-Ambrogi (2002), with an updated version presented by the ASG in 2004, during the 39th European Marine Biology Symposium (EMBS) held in Genoa (Italy) (Gruppo Alloctoni SIBM coordinated by A. Occhipinti-Ambrogi 2004). The present contribution updates and improves that early list, which was not published *in extenso* in the EMBS proceedings, with the aim of contributing to accurate monitoring of the spread of alien species in the Mediterranean Sea and providing the correct basis for coordinated international action on a larger scale. At the same time we believe that such information has to be clearly and openly made available to the scientific community and should not constitute an indistinct and unsubstantial pool of 'expert opinions' upon which public interest decisions are taken.

The Italian Peninsula, with over 7,000 km of coastline, has a specially important position in the context of the Mediterranean Sea. It is placed at the crossroads between different Mediterranean basins and hydrographic conditions of the water masses going from the north-western Mediterranean, whose characteristics are reflected mainly in the Ligurian Sea (Astraldi et al. 1995), and the eastern part of the basin, influencing the Ionian and the southern Adriatic Seas (Pinardi and Masetti 2000). The northern Adriatic Sea has special hydrographic and morphological characteristics that make it an *unicum* with a peculiar role in the introduction of alien species, as discussed below. The Straits of Messina and Sicily are the passageway from south to north and from east to west, and are crucial in the analysis of the spread of alien species within the Mediterranean.

Methods

The current database of marine and brackish alien species of Italy originates from the work of the ASG, coordinated by Anna Occhipinti-Ambrogi, which has been working since 1999 to contribute with the Italian data to the ICES-WGITMO Annual Reports (e.g. Occhipinti-Ambrogi 2007, 2008, 2009). Such reports contain all the information gathered and analyzed by the ASG members on alien species along the Italian coasts: records of new introductions, changes in the population status of already known aliens, update of nomenclature, and other additional data. We decided to start the list of alien introduction from the year 1945, considering all previous records as historical ones and referring to somehow "naturalized" species.

Although the terms alien and non-native are often used as synonyms in the literature, we have distinguished between "true" alien species occurring outside their native distribution range and dispersion potential as a consequence of human action, and non-native species, which have extended their range as a result of changing environmental conditions (e.g. temperature, current regime) (Occhipinti-Ambrogi and Galil 2004). This distinction follows the recent definition of alien species by Pyšek et al. (2009): "the presence of these species in a given region is due to intentional or unintentional introduction or care by humans, or they have arrived there without the help of people from an area in which they are alien".

In the case of the Mediterranean Sea, species originating from the Red Sea through the Suez Canal fall in the definition of alien species; species that have autonomously entered through the Strait of Gibraltar from the eastern Atlantic, where they are considered alien, are classified as cases of secondary dispersal of alien species.

Conversely, species that have autonomously entered through the Strait of Gibraltar, and are not considered alien in the eastern Atlantic, in the absence of reliable proof of their human-mediated introduction, have to be regarded as cases of natural range expansion.

In this article, species belonging to the latter category are presented in a separate list. They are mainly fishes or other organisms able to actively swim and autonomously cross the Strait of Gibraltar, or to be passively transported as floating material. The above distinction significantly influences the number of alien species that have resulted in the list, accounting for the differences in the number of Mediterranean alien species reported in the literature (see Galil 2009; Zenetos 2010 and discussion therein).

The following criteria have been applied to the preparation of the list. Only records of organisms found alive have been included. For example, literature reports of mollusc empty shells and stranded dead fishes have not been considered; species whose identification was affected by uncertainty have been excluded as well; similarly, records not accompanied by a published reference have not been taken into account. Single cases have been carefully discussed with a number of specialists in order to clearly identify real aliens from species of uncertain origin or from cryptogenic species (Carlton 1996).

The following groups have been taken into account: Macrophyta (Algae and higher plants), Porifera, Ctenophora, Cnidaria (Hydrozoa, Scyphozoa, Anthozoa), Annelida (Polychaeta), Mollusca (Bivalvia, Gastropoda, Cephalopoda), Crustacea (Copepoda, Peracarida, Decapoda), Picnogonida, Bryozoa, Tunicata and Vertebrata (Chondrichthyes, Osteichthyes). Each record has been carefully analyzed, with recourse to the published literature and, where necessary and possible, interviews with the authors. Some records have been harmonized with the CIESM Atlases of Exotic Species in the Mediterranean for each group treated in an Atlas, and have been discussed with specialists in the Mediterranean area. However, some differences still exist, especially in the case of fishes, because CIESM Atlases do not distinguish true alien species from those naturally expanding their range.

A specific database has been developed in a spreadsheet software, containing all collected data organized by single taxonomic groups. For each species, the following information has been recorded: first finding in Italy (year and location name, with latitude and longitude); distribution along Italian coasts (localities and seas); Italian location of mass growth; native distribution; population status as in Occhipinti-Ambrogi and Galil (2004): not established = only a few live individuals in a single location, established = durable population in time and space, invasive = mass population growth, rapidly extending its range. Information about the likely pathways of introduction (aquaculture, ship fouling, ballast waters, etc.) and the likely impacts (parasitism, habitat change, hybridization, competition with native species, etc.) has also been considered, whenever available. Furthermore, first records for the whole Mediterranean basin have been highlighted. All the relevant bibliographic references have been included.

The current database has been used to perform a detailed meta-analysis of the alien species along the Italian coasts, considering aspects such as taxonomic composition, invasiveness, geographic distribution and temporal evolution.

The geographic marine zones outlined in Fig. 1 reflect the main biogeographic divisions adopted in the checklist of the Italian marine fauna (Bianchi 2004; Relini 2008), as well as other sub-divisions that we considered useful to highlight the possible influence of the habitat and of the research efforts on the distribution of hot spots of aliens species diversity along the Italian coast (see "Discussion" below).

Results

A total number of 165 marine and brackish aliens was recorded along the 7,375 km of the Italian coasts (Table 1). This means that, on average, Italy has received at least 2.2 alien species for every 100 km of its coastline since 1945. The set of alien species includes 33 Macrophyta, 1 Porifera, 2 Ctenophora, 15 Cnidaria, 33 Annelida Polychaeta, 31 Mollusca, 26 Crustacea, 2 Picnogonida, 7 Bryozoa, 4 Tunicata and 11 Osteichthyes (Table 1, Fig. 2). Out of these, 55 species are indicated as first records for the whole Mediterranean, mainly represented by cnidarians (9 species), macrophytes (11 species) and crustaceans (16 species).

Amongst the most recent records we mention: the red king crab *Paralithoides camtschaticus* (a single adult specimen), collected in 2008 in the Ionian Sea (Faccia et al. 2009), which is a puzzling discovery since this is a boreal species surviving in a warm-temperate sea, and the Atlantic polychaete *Polydora colonia*, recorded in 2009 at Torre Guaceto (southern Adriatic) by one of the authors (A. Giangrande) of the present article, which represents the first record of this species for Italian coasts.

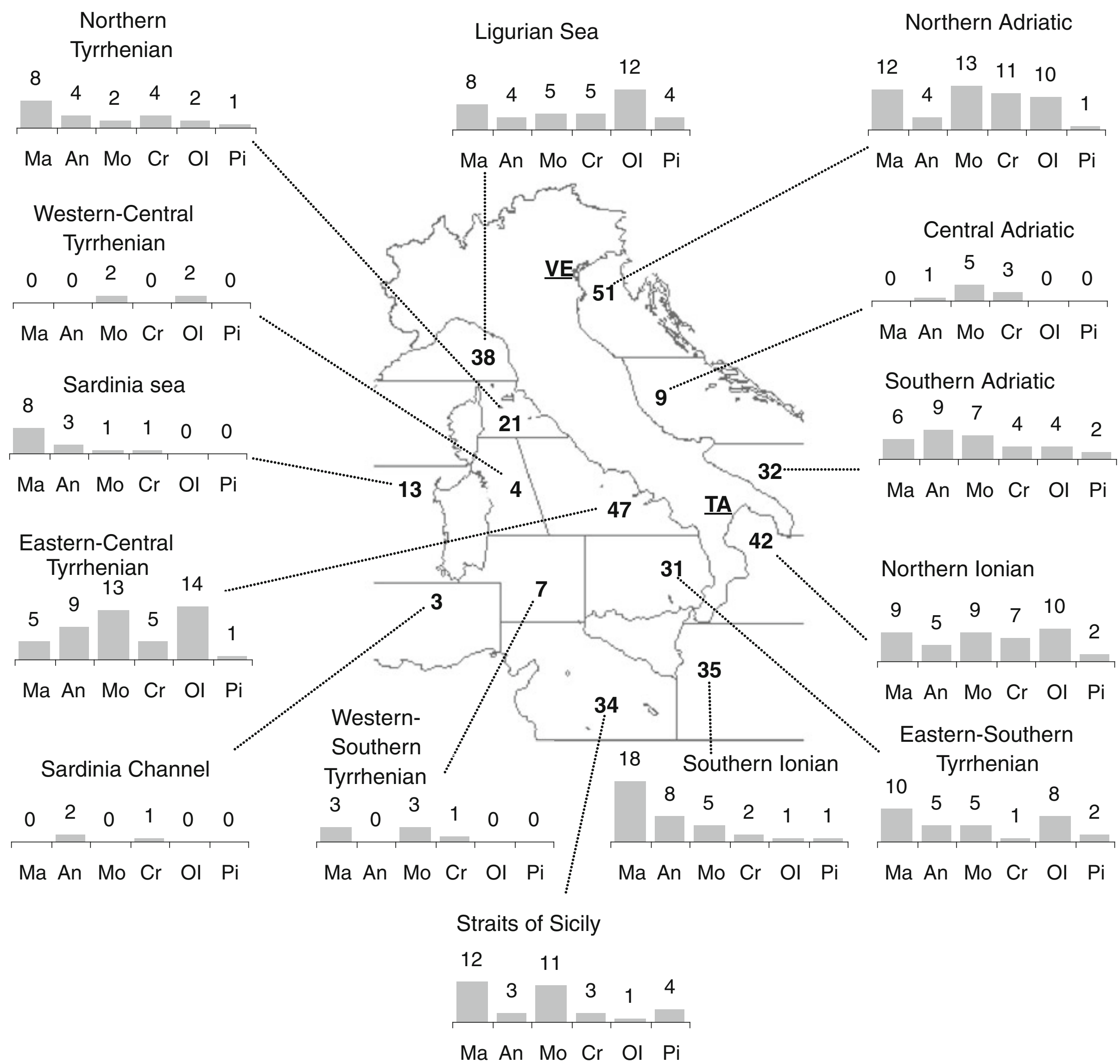


Fig. 1 Number (*in bold*) of alien species recorded in each Italian sea, lagoons included. Continuous lines indicate borders between seas. Number of alien species belonging to different taxa are indicated over the *bars*: *Ma* Macrophyta, *An* Annelida, *Mo* Mollusca, *Cr* Crustacea, *OI* other invertebrates, *Pi* Pisces. The two main hotspots of introduction are also indicated (*VE* Venice, *TA* Taranto)

Another 27 non-native species (4 Macrophyta, 2 Cephalopoda, 1 Decapoda, 4 Chondrichthyes and 16 Osteichthyes) that have naturally expanded their range through the Strait of Gibraltar, and/or are simply vagrant, are reported in Table 2. The term "vagrant" refers to the largest members of offshore nekton (mainly perciform fishes, sharks, large cephalopods and also marine mammals) recorded occasionally as isolated animals (Orsi-Relini 2009).

The north-western Tyrrhenian and the central Adriatic seas display the lowest number of alien species, whereas numbers are very high in the northern Adriatic Sea (51 species, 39 of which in the Lagoon of Venice), the Eastern-Central Tyrrhenian Sea (47), the Northern Ionian Sea (42), and the Ligurian Sea (38) (Fig. 1). Not all species have successfully established durable populations in the Italian seas (NE, non-established): for 76 species

Table 1 List of alien species recorded in the Italian Seas and brackish lagoons

Name	1st finding (year)	Population status	Likely vectors
Macrophyta			
**Acrothamnion preissii* (Sonder) E.M. Wollaston	1969	E	SF
Agardhiella subulata (C. Agardh) Kraft & M.J. Wynne	1987	E	A
**Aglaothamnion feldmanniae* Halos	1976	NE	SF, SB
Antithamnion amphigeneum A. Millar	1996	NE	SF
Antithamnion hubbsii E.Y. Dawson	1996	E	A
**Apoglossum gregarium* (E.Y. Dawson) M.J. Wynne	1992	E	U
Asparagopsis armata Harvey	1955	E	SF
Bonnemaisonia hamifera Hariot	1973	E	SF
**Botryocladia madagascariensis* Feldmann-Mazoyer	1991	E	SF, L + S
Caulerpa racemosa (Forsskål) J. Agardh var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque	1993	I	SF, SB, AQ(?)
Caulerpa taxifolia (Vahl) C. Agardh	1992	I	AQ
**Ceramium strobiliforme* G.W. Lawson & D.M. John	1991	E	SF
Chondria polyrhiza Collins & Hervey	1992	NE	SF
**Chondria pygmaea* Garbary & Vandermeulen	1991	E	L + S
Codium fragile (Suringar) Hariot ssp. *fragile*	1973	E	A
Grateloupia turuturu Yamada	1987	NE	A
Halophila stipulacea (Forsskål) Ascherson	1988	E	L + S
Hypnea cornuta (Kützing) J. Agardh	2002	NE	SF, L + S
Hypnea spinella (C. Agardh) Kützing	1985	E	SF
Hypnea valentiae (Turner) Montagne	2005	E	A
**Laurencia majuscula* (Harvey) A.H.S. Lucas	1983	E	U
Leathesia marina (Lyngbye) Decaisne	1996	NE	A
Lomentaria hakodatensis Yendo	2001	NE	A
Lophocladia lallemandii (Montagne) F. Schmitz	1969	E	L + S
Neosiphonia harveyi (J.W. Bailey) M.S. Kim, H.G. Choi, Guiry & G.W. Saunders	1969	E	A
Padina boergesenii Allender & Kraft	1963	NE	L + S
**Plocamium secundatum* (Kützing) Kützing	1991	NE	U, SF(?)
**Polysiphonia morrowii* Harvey	1999	E	A
Sargassum muticum (Yendo) Fensholt	1992	I	A
**Scytosiphon dotyi* M.J. Wynne	1978	E	A
**Symphyocladia marchantioides* (Harvey) Falkenberg	1984	NE	SF
Undaria pinnatifida (Harvey) Suringar	1992	I	A
Womersleyella setacea (Hollenberg) R.E. Norris	1986	I	SF
Porifera			
**Paraleucilla magna* Klatau et al., 2004	2001	I	SF, A
Ctenophora			
Beroe ovata sensu Mayer, 1912	2005	NE	SB
Mnemiopsis leidyi A. Agassiz, 1865	2005	E/I	SB
Hydrozoa			
**Amphogona pusilla* Hartlaub, 1909	1972	NE	L
**Clytia hummelincki* (Leloup, 1935)	1996	I	SF

Table 1 continued

Name	1st finding (year)	Population status	Likely vectors
Clytia linearis (Thornely, 1900)	1957	E	L
Clytia mccrady (Brooks, 1888)	1970	E	U
**Cirrholovenia tetranema* Kramp, 1959	1963	E	SB
Cordylophora caspia (Pallas, 1771)	1978	E	A, SB
Eudendrium carneum Clarke, 1882	1985	I	L + S
**Eudendrium merulum* Watson, 1985	1984	E	SB, SF
**Garveia franciscana* (Torrey, 1902)	1978	I	SF
Gonionemus vertens A. Agassiz, 1862	1959	E	SB, A
**Moerisia inkermanica* Paltschikowa-Ostroumova, 1925	1987	NE	U
Scolionema suvaense (A. Agassiz & Mayer, 1899)	1972	E	SB
Scyphozoa			
Phyllorhiza punctata von Lendenfeld, 1884	2009	NE	SB,L + S
Anthozoa			
**Diadumene cincta* Stephenson, 1925	1993	E	SF
**Oculina patagonica* De Angelis, 1908	1966	E	SF
Polychaeta			
Amphicorina pectinata (Banse, 1957)	1991	NE	SB
Branchiomma luctuosum (Grube, 1869)	1983	I	SB, SF
Desdemona ornata Banse, 1957	1986	I	SB
**Epidiopatra hupferiana hupferiana* Augener, 1918	1991	NE	SB
Epidiopatra hupferiana monroi Day, 1957	1982	NE	SB
Fabriciola qhardaqa Banse, 1959	1999	NE	U
Hyboscolex longiseta (Schmarda, 1861)	1980	NE	U
**Isolda pulchella* Müller, 1858	2001	NE	L + S
Leiochrides australis Augener, 1914	1990	NE	U
Linopherus canariensis Langerhans, 1881	2005	NE	S
Loimia medusa Savigny, 1818	1995	E	L + S
**Longibranchium atlanticum* (Day, 1973)	1997	NE	S
Lumbrinerides acutiformis (Gallardo, 1967)	1995	NE	SB
Lumbrinerides neogesae Miura, 1980	1991	NE	U
Lysidice collaris Grube, 1870	1961	E	L + S
Mediomastus capensis Day, 1961	1985	E	U
Megalomma claparedei Gravier, 1908	2008	NE	SF
Neanthes agulhana Day, 1963	2008	E	U
**Neopseudocapitella brasiliensis* Rullier & Amoureux, 1979	1983	E	U
Notomastus aberans Day, 1963	1980	E	U
Notopygos crinita Grube, 1855	1983	NE	U
Novafabricia infratorquata (Fithzugh, 1983)	2006	NE	SB, SF, A
**Ophryotrocha diadema* Åkesson, 1976	2006	E	S
Ophryotrocha japonica nomen nudum	2002	E	SB (?)
Pileolaria berkeleyana (Rioja, 1942)	1995	NE	U
Pista unibranchia Day, 1963	1981	E	SF
Platynereis australis (Schmarda, 1861)	1992	NE	U
Polydora colonia Moore, 1907	2009	NE	U

Table 1 continued

Name	1st finding (year)	Population status	Likely vectors
Prionospio pygmaea Hartman, 1955	1991	NE	U
Protodorvillea egena (Ehlers, 1913)	2001	NE	SB (?)
Spirorbis marioni Caullery & Mesnil, 1897	1981	E	SF (?)
Streblosoma comatus (Grube, 1856)	1981	E	SB
Syllis hyllebergi Licher, 1999	2005	NE	U
Gastropoda			
Aeolidiella indica (Bergh, 1888)	1968	NE	U
Aplysia dactylomela Rang, 1828	2003	E	U
Aplysia parvula Guilding in Mørch, 1863	1978	E	U
Bursatella leachii De Blainville, 1817	1968	E	L
Cerithium scabridum Philippi, 1848	1976	E	L + S
**Chromodoris quadricolor* (Rueppell & Leuckart, 1828)	1982	NE	U
Crepidula fornicata (L., 1758)	1973	NE	U
**Cuthona perca* (Marcus, 1958)	1976	NE	U
Erosaria turdus (Lamarck, 1810)	2005	NE	U
Haminoea callidegenita Gibson & Chia, 1989	1992	NE	A
Haminoea cyanomarginata Heller & Thompson T., 1983	2007	NE	U
Melibe viridis (Kelaart, 1858)	1984	E	U
**Polycera hedgpethi* Marcus Er., 1964	1986	NE	U
Polycerella emertoni Verrill, 1881	1964	NE	U
Rapana venosa (Valenciennes, 1846)	1973	I	U
Syphonota geographica (Adams e Reeve, 1850)	2001	NE	U
Thais lacera (Born, 1778)	1983	NE	A
Bivalvia			
Anadara inaequivalvis (Bruguière, 1789)	1969	E	U
Anadara transversa (Say, 1822)	2000	I	U
Brachidontes pharaonis (Fisher, 1870)	1969	E	L + S
Crassostrea gigas (Thunberg, 1793)	1966	E	A
Fulvia fragilis (Forskål in Niebuhr, 1775)	2003	E	L + S
Mercenaria mercenaria L., 1758	1983	NE	A
Musculista senhousia (Bensor in Cantor, 1842)	1994	I	A
Mya arenaria L., 1758	1987	NE	U
Pinctada radiata (Leach, 1814)	1967	E	U
Saccostrea commercialis (Iredale & Roughley, 1933)	1984	NE	A
Ruditapes philippinarum (Adams & Reeve, 1850)	1983	I	A
Theora lubrica Gould, 1861	2001	NE	U
Xenostrobus securis (Lamarck, 1819)	1992	I	A
Cephalopoda			
Tremoctopus gracilis (Eydoux/Souleyet, 1852)	2002	NE	U
Copepoda			
Acartia grani Sars, 1904	1999	E	SB
Acartia tonsa Dana, 1849	1989	I	SB, A
**Metacalanus acutioperculum* Ohtsuka, 1984	1995	NE	U

Table 1 continued

Name	1st finding (year)	Population status	Likely vectors
Peracarida			
**Caprella scaura* Templeton, 1936	1994	I	A, SF
Elasmopus pectenicrus (Bate, 1862)	1981	E	L + S
Paracerceis sculpta (Holmes, 1904)	1980	E	A, SF
**Paradella dianae* (Menzies, 1962)	1985	NE	SF
Decapoda			
**Actumnus globulus* Heller, 1861	1978	NE	U
Calappa pelii Herklots, 1851	1993	NE	U
**Callinectes danae* Smith, 1869	1981	NE	U
**Callinectes sapidus* Rathbun, 1896	1949	E	SB
**Charybdis lucifera* (Fabricius, 1798)	2006	NE	S
**Dromia spinirostris* (Miers, 1881)	1970	NE	U
**Dyspanopeus sayi* (Smith, 1869)	1992	I	A
Eriocheir sinensis H. Milne Edwards, 1853	2005	NE	LI
**Herbstia nitida* Manning & Holthuis, 1981	2002	NE	U
Heteropanope laevis (Dana, 1852)	1956	NE	S
Marsupenaeus japonicus (Bate, 1888)	1986	NE	A
**Menaethius monoceros* (Latreille, 1825)	1978	NE	S
**Paralithoides camtschaticus* (Tilesius, 1815)	2008	NE	SB
**Percnon gibbesi* (H. Milne Edwards, 1853)	1999	I	SB
Portunus pelagicus (L., 1758)	1966	E	SB
Procambarus clarkii (Girard, 1852)	2006	NE	A
**Rhithropanopeus harrisii* (Gould, 1841)	1994	E	LI, S
**Scyllarus caparti* Holthuis, 1952	1977	NE	U
**Thalamita gloriensis* Crosnier, 1962	1977	NE	S
Picnogonida			
Ammothea hilgendorfi (Böhm, 1879)	1979	E	SF, L + S
Anoplodactylus californicus (Hall, 1912)	1965	E	SF
Bryozoa			
Arachnoidea protecta (Harmer, 1915)	1992	E	SF
Celleporella carolinensis (Ryland, 1979)	1993	E	SF
Crepidacantha poissonii (Audouin, 1826)	1982	NE	SF
Electra tenella (Hincks, 1880)	1990	NE	SB,SF
Pherusella brevituba Soule, 1951	1996	E	SF
**Tricellaria inopinata* d'Hondt et Occhipinti Ambrogi, 1985	1982	I	A, SF
Bugula serrata (Lamarck, 1816)	1992	E	SF
Tunicata			
**Botrylloides violaceus* Oka, 1927	1993	E	LI, S
**Distaplia bermudensis* Van Name, 1902	2000	I	LI, S
Microcosmus squamiger (reported as *M. exasperatus* by Monniot, 1981) Hartmeyer and Michaelsen, 1928	1971	E	LI, S
**Polyandrocarpa zorritensis* (Van Name, 1931)	1974	I	LI, S

Table 1 continued

Name	1st finding (year)	Population status	Likely vectors
Osteichthyes			
**Abudefduf vaigiensis* (Quoy & Gaimard, 1825)	1957	NE	S
**Elates ransonnettii* (Steindachner, 1876)	2005	NE	L + S
Epinephelus coioides (Hamilton, 1822)	1998	NE	S
Etrumeus teres (Dekay, 1842)	2005	NE	L
Fistularia commersonii Rüppel, 1838	2002	I	L
**Oreochromis niloticus niloticus* L., 1758	1999	E	A
**Pinguipes brasilianus* Cuvier & Valenciennes, 1829	1990	NE	S
**Pomadasys stridens* (Forsskål, 1875)	1968	NE	S
Siganus luridus (Rüppel, 1829)	2003	E	L
Stephanolepis diaspros Fraser-Brunner, 1940	1967	E	L
**Synagrops japonicus* (Doderlein, 1883)	1987	NE	S

E established, *NE* non established, *I* invasive, *A* aquaculture, *AQ* aquarium trade, *L* lessepsian, *L + S* lessepsian arrived by shipping, *LI* live imports, *S* shipping, *SB* shipping ballast, *SF* shipping fouling, *U* unknown

Differently from Zoological nomenclatural rules, the art. 46 of the International Code of Botanical Nomenclature (McNeill et al. 2006) does not require any date indications after the author(s) of names of taxa

* First Mediterranean record

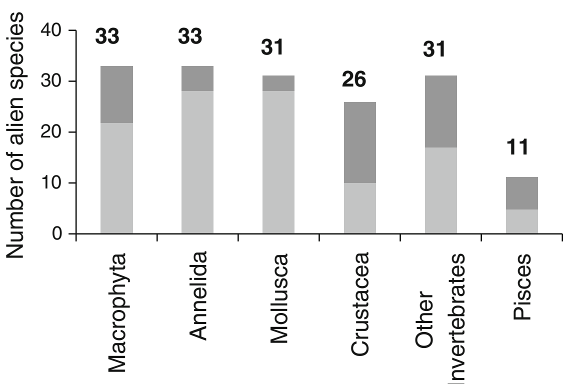


Fig. 2 Number of alien species belonging to different taxa. The *dark-grey* part of each column represents species recorded for the first time in the Mediterranean sea

(46% of the total) it has only been possible to observe a few live individuals/colonies in a single location. This is especially the case of fish species, which may have occasionally been recorded with one or a few individuals. Conversely, 66 species (40%) have established (E) in Italian seas and other 24 species (15%) have developed mass population growth, becoming invasive (I) and affecting several marine habitats at different levels. Well-documented cases of invasions in the Italian seas and lagoons are: the seaweeds *Caulerpa taxifolia* (Ligurian Sea, Tyrrhenian, Sicily, Sardinia) and *Caulerpa racemosa* var. *cylindracea* (Ligurian Sea, Tyrrhenian, Sicily, Sardinia, south-Adriatic), *Sargassum muticum* (northern Adriatic) and *Undaria pinnatifida* (northern Adriatic, northern Ionian), the molluscs *Anadara transversa*, mentioned as *A. demiri* in Morello et al. (2004) (central and northern Adriatic, Ionian, southern Tyrrhenian), *Musculista senhousia* (northern Adriatic, Ionian), *Ruditapes philippinarum* (northern Adriatic) and *Rapana venosa* (northern Adriatic), the crustacean *Dyspanopeus sayi* (northern Adriatic), the bryozoan *Tricellaria inopinata* (northern Adriatic) and, most recently, as reported by Boero et al. (2009), also the ctenophore *Mnemiopsis leidyi* (northern Adriatic, Ligurian Sea, Tyrrhenian, Ionian).

The composition of the alien flora and fauna differs greatly among areas (Fig. 3). The Lagoon of Venice in the northern Adriatic Sea, with its crowded recreational and commercial harbours, as well as a flourishing mariculture activity, is the Italian locality with the highest number of marine aliens: 39 species, including 12 algae, 9 molluscs, and 9 crustaceans. Out of them there have been cases of biological invasions, such as the seaweeds *Undaria pinnatifida* and *Sargassum muticum*, as well as by invertebrates of smaller dimensions showing a high invasion potential

Table 2 List of non-native species having displayed natural range expansion through the Strait of Gibraltar (G), and vagrant species (V) recorded in the Italian Seas

Name	1st finding (year)	Population status	Likely vectors
Macrophyta			
Colpomenia peregrina Sauvageau	1969	E	G
Halothrix lumbricalis (Kützing) Reinke	1978	NE	G
Laurencia chondrioides Børgesen	1994	E	G
Osmundea oederi (Gunnerus) G. Furnari	1987	E	G
Cephalopoda			
Cycloteuthis sirventi Joubin, 1919	1992	NE	G
Stoloteuthis leucoptera (Verrill, 1878)	1990	NE	G
Decapoda			
Panaeopsis serrata Bate, 1881	2003	NE	G
Chondrichthyes			
Carcharhinus falciformis (Müller & Henle, 1839)	2001	NE	V
Galeocerdo cuvier (Peron & Le Sueur, 1822)	1998	NE	V
Rhizoprionodon acutus (Rüppel, 1837)	1984	NE	V
Sphyrna mokarran (Rüppel, 1837)	1969	NE	V
Osteichthyes			
Beryx splendens Lowe, 1934	1993	E	G
Cephalopholis taeniops (Valenciennes, 1828)	2009	NE	G
Chaunax suttkusi Caruso, 1989	1997	NE	G
Diodon hystrix L., 1758	1953	NE	V
Halosaurus ovenii Johnson, 1864	1980	NE	G
Kyphosus incisor (Cuvier, 1831)	2009	NE	G
Lutjanus jocu (Bloch & Schneider, 1801)	2005	NE	G
Makaira indica (Cuvier,1832)	1986	NE	V
Microchirus hexophthalmus (Bennett, 1831)	1987	NE	G
Pisodonophis semicinctus (Richardson, 1848)	1997	NE	G
Psenes pellucidus Lutken, 1880	1995	E?	G
Seriola carpenteri Mather, 1971	1996	E	G
Seriola fasciata (Bloch, 1793)	1997	E	G
Seriola rivoliana Cuvier, 1833	2000	NE	V, G?
Sphoeroides marmoratus (Lowe, 1838)	1977	NE	G
Sphoeroides pachygaster (Müller & Troschel, 1848)	1984	E	G?

E established, *NE* non established

in the hard-bottom communites, such as the bryozoan *Tricellaria inopinata* (Occhipinti-Ambrogi 2000).

The Taranto seas (Mar Piccolo and Mar Grande), transitional basins in the northern Ionian Sea that include Taranto harbour, also display a large number of aliens, 24 species. In the Tyrrhenian sea, the Gulf of Naples and the harbour of Leghorn host 16 and 14 species respectively. Small islands also present high numbers of aliens: 14 species were recorded in the Tuscan Archipelago (Tyrrhenian Sea) and in the islands north of Sicily (the Aeolian Archipelago and Ustica in the eastern-southern Tyrrhenian), and 19 species in the small islands south of Sicily (the Pelagian Archipelago and Pantelleria in the Strait of Sicily).

To investigate the geographical origin of the marine aliens registered along Italian seas, their native distribution has been assessed. The total number of species indicated as native from each single ocean/sea has been calculated and plotted (Fig. 4). Non-established species have been excluded

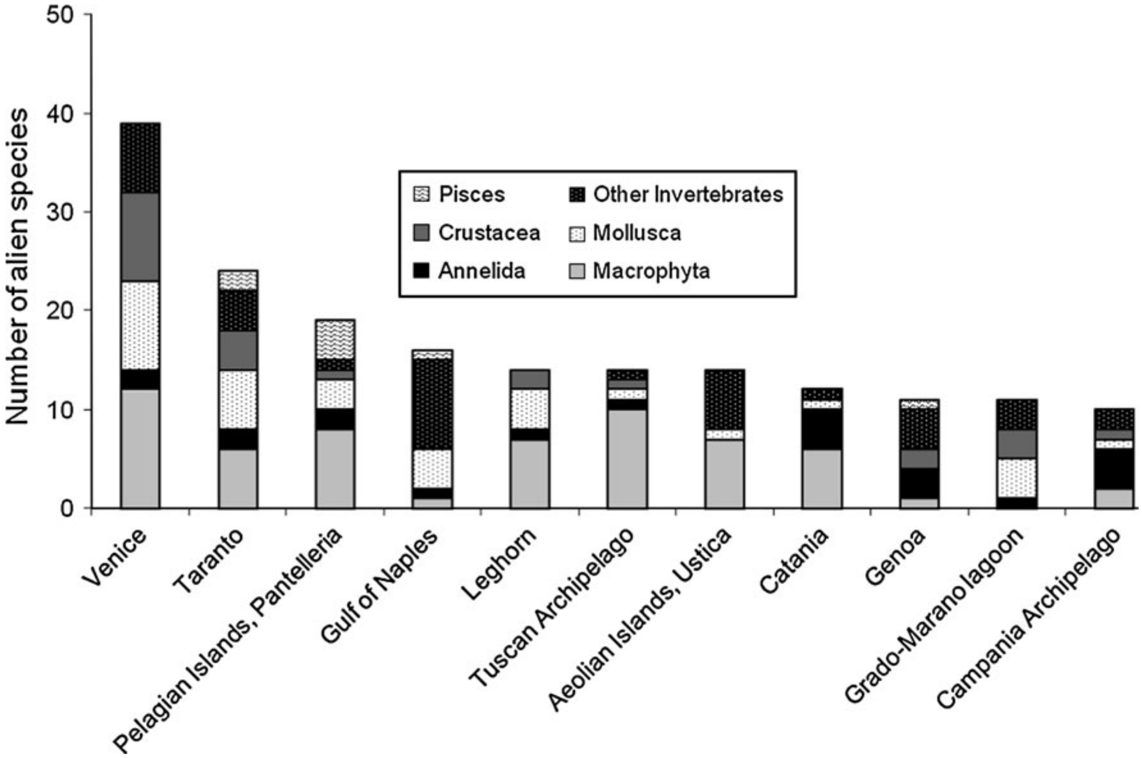
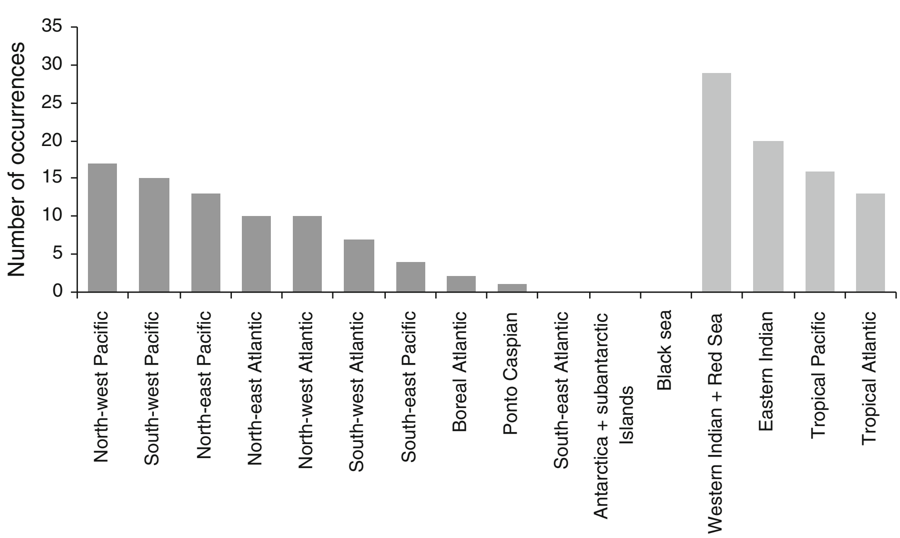


Fig. 3 Number of alien species recorded in the hotspots of introduction along the Italian coast

from this analysis. The majority of marine and brackish water alien established species in Italy (up to 42% of algae and 38% of fishes) are native to the western Indian Ocean and Red Sea: in several cases these species have entered the Mediterranean through the Suez Canal (Lessepsian introductions). The Italian seas thus host a majority of species showing warm-water affinities, but fewer cases exist of cold water species, such as the sub-antarctic seaweed *Plocamium secundatum* and the polychaete worm

Fig. 4 Native distribution of established marine alien species recorded in Italy. The total number of species resulting from this graph is higher than the total recorded in Italy, because species with a wide native range account for several oceans/seas



Protodorvillea egena, or the aforementioned boreal crab *Paralithoides camtschaticus.* These three species were recorded in the warm Ionian Sea, but were not proven able yet to establish durable populations there.

Shipping (S) and aquaculture (A) are the main vectors of introduction (Table 1). In particular: 91 species have been introduced by vessels (S), 38 of which probably as ship fouling (SF) and 27 in ballast waters (SB). Introductions of species for aquaculture purposes have brought 32 aliens along Italian coastal waters, including both target and non-target organisms. Amongst the target organisms, we account for the unusual findings of the Louisiana crayfish *Procambarus clarkii* and the Nile tilapia, *Oreochromis niloticus niloticus*. Although being freshwater species, they have been repeatedly recorded in brackish lagoons, where they have arrived through freshwater streams (Florio et al. 2008; Scalici et al. 2010). *O. niloticus* has probably escaped from local fish farms (Scordella et al. 2003; Florio et al. 2008).

A pool of 25 species is likely to have been introduced through the Suez Canal: it is well known that Erythrean or Lessepsian species entering by ways of the man-made canal of Suez form a large proportion of the species introduced into the Mediterranean. In Italy, 18 of them are likely to have been transported by vessels (L + S), whereas only 8 other species, mainly bony fishes, could have reached the Italian coasts by secondary range expansion within the Mediterranean (L). These Erythrean species have been mainly recorded in the southern Adriatic and Ionian seas, or in the Straits of Sicily and Messina, which are areas most affected by Lessepsian introductions. Other vectors (e.g. aquarium trade, AQ, and live imports, LI, related to fish market) are responsible for a lower number of introduction events. The results of the analysis on introduction vectors are affected by the high number of unknown cases: for 42 species it was not possible to make any hypothesis about the likely vector (U) and for some species there may have been multiple vectors of introduction.

Also, the studies on biological interactions between alien and native species and the ecological consequences of their introduction on populations, communities, and ecosystems are yet to be completed.

A good deal of research has been devoted to investigating the interactions of invasive *Caulerpa* spp. with the native vegetation (Ceccherelli et al. 2002; Piazzi et al. 2003, 2007; Balata et al. 2004), including long term effects after removal (Piazzi and Ceccherelli 2006). Factors involved in the colonization success of *Caulerpa* spp. were studied, including tolerance to sedimentation (Piazzi et al. 2005), photo- (Raniello et al. 2006) and thermal (Flagella et al. 2008) acclimation, and allelopathy (Raniello et al. 2007).

For the invertebrates, the most clear-cut examples are two bivalves introduced intentionally for farming purposes, and disseminated by fishermen associations into the wild, having developed large natural populations: the Pacific oyster, *Crassostrea gigas*, and the Manila clam, *Ruditapes philippinarum*, which have prevailed over native oysters (*Ostrea edulis*) and clams (the grooved carpet shells *Tapes decussatus*) in the lagoons of the northern Adriatic sea. They are also known as powerful vectors for unintentional introductions of other non-target species, concealed in the packaging material and among imported seed clumps, or dwelling as epibionts on the shells. Another example is the sabellid polychaete *Branchiomma luctuosum*, out-competing the Mediterranean native tubeworm *Sabella spallanzanii* (M.C. Gambi and A. Giangrande, unpublished data).

Some species are known as habitat modifiers, such as: the seaweeds *Womersleyella setacea* and *Caulerpa racemosa* var. *cylindracea* causing a decrease of diversity and large differences in the structure and species composition related to non-invaded assemblages (Piazzi and Balata 2009) and *Sargassum muticum*, a canopy-forming species that reduces the PAR (Photosynthetically Active Radiation) with repercussions on the underlying layers, leading to a decrease in species number and surface cover (Curiel et al. 1998); the sponge *Paraleucilla magna*, a bioengineering species (Longo et al. 2007); the bivalve *Musculista senhousia*, responsible for alterations of sandy bottoms (Mistri 2003); the crab *Eriocheir sinensis*, an active burrower causing sediment erosion (Dittel and Epifanio 2009). Obviously, the most significant habitat modification ever in Italian coastal waters has been brought about by the two *Caulerpa* species, which have invaded large portions of the already degraded *Posidonia oceanica* meadows in many Mediterranean sectors (Montefalcone et al. 2007, 2010).

There are only a few examples of other types of impacts. An indopacific gastropod, the veined welk *Rapana venosa*, has been investigated in order to assess its potential to cause changes in the local pattern of benthic/pelagic interactions (Savini and

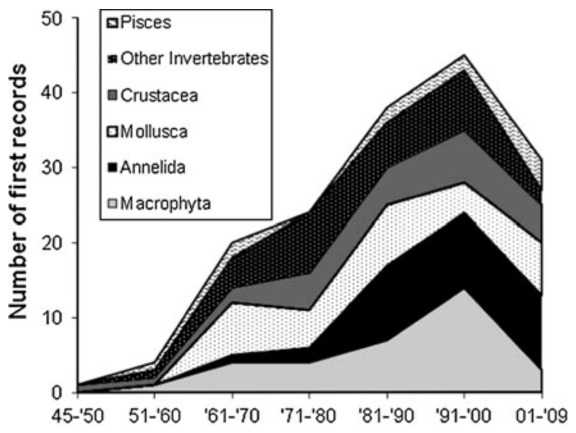


Fig. 5 Number of species recorded in the recent decades (the year of first record has been considered)

Occhipinti-Ambrogi 2006). Being a selective and voracious predator of bivalves, *R. venosa* was thought responsible for altering local community structure, influencing competition amongst filter feeder/suspension feeder bivalves and causing a long-term ecological impact in the Black Sea (Zolotarev 1996) and has been the object of thorough screening and eradication campaigns in Chesapeake Bay, since its introduction (Mann and Harding 2000). So far, no records of actual consequences have been reported from the northern Adriatic Sea, where it was introduced in the 1970s.

The temporal evolution of sightings of new introduced species in Italian seas is illustrated in Fig. 5, where data are organised in separate decades, taking into account the year each species was first recorded. The highest number of new records, mainly algae and annelids, was discovered in the 1980s and 1990s (38 and 45 species, respectively). In the last decade (2001–2009) the number of new records has only slightly decreased: 31 new species have been reported, most of them in 2001 and 2005, whereas in the last few years new records have been less frequent.

Discussion

History of marine and brackish alien species in Italy

It is well known that many species could have been transported by human activities in historical times (Bianchi and Morri 2000), and yet evidence is lacking of their status as introduced or native in a particular area. This situation is referred to in the literature with the term of cryptogenic species (Carlton 1996), and is not taken into account in this paper.

Tracing of first alien species in Italian waters dates back to a century ago, e.g. the fish *Lactophrys triqueter*, native in western central Atlantic, was observed in the Genoa harbour (Parona 1909); the ascidian *Aplidium pallidum* was recorded in Italy in 1913 (Brément 1913); other species, such as *Balanus amphitrite* and *Ficopomatus enigmaticus*, have been common representatives in fouling communities since the first decades of 1900, but general awareness of human-mediated introduction of alien species has increased mostly in the last three decades. Some pioneer papers about the occurrence of alien species in the Lagoon of Venice date back to the 1980s (Sacchi et al. 1983, 1990) drawing attention to the ecological implications of faunal additions to a very well-studied environment. The obvious increase in the so-called propagule-pressure (Verling et al. 2005), that is the increase of supply of adult or developing individuals, due to the growing traffic between distant areas of the world oceans, has been backed by the novel interest of the scientific community towards the occurrence of non-indigenous species. This was probably due to the dramatic evidence of severe ecological and economic impacts of species introduction, as paradigmatically demonstrated by the voracious ctenophore *Mnemiopsis leidyi*, leading in a few years to the collapse of the Black Sea anchovy fishery (reviewed by Shiganova et al. 2001). The bulk of new findings in the 1980–1990 period could also be an outcome of new targeted field collections and re-examination of old collections.

In the last decade, the records of new species in Italian waters have slightly decreased, although prohibitive measures regarding veterinary controls and ballast waters transportations have not changed significantly.

It must also be pointed out that, according to what is known in the other areas, the majority of alien species recorded so far are relatively large and conspicuous species, whereas limited knowledge is available on less evident taxa, especially of smaller body size (e.g. meiofaunal organisms, parasites).

The observed 'invasion' of the Mediterranean sea by thermophilic species, as recently pointed out by many authors and for a variety of organisms, including macroalgae, plankton, invertebrates and fishes (Francour et al. 1994; Dulčić et al. 2004; Bianchi 2007;

CIESM 2008; Orsi-Relini 2009; Puce et al. 2009; Tunin-Ley et al. 2009), is actually occurring in Italy as well. The phenomenon involves not only established alien species, such as those plotted in the graph of native distributions (Fig. 4), but also other species that are naturally extending their range northwards to the Italian coasts. These cases of natural displacements are an ecological indicator of the ongoing environmental changes in the Mediterranean Sea and together with species transported by human vectors contribute to the rapid change in the structure of its biocenoses. The record of the African hind *Cephalopholis taeniops* (Table 2) in the Strait of Sicily is the most recent example of natural expansion of a thermophilic organism: it represents the northernmost record of a species whose native range is the eastern Atlantic coast of Africa, from Angola to Morocco (Guidetti et al. 2010).

Problematic species

The creation of a reliable list of alien species for the Italian coasts has involved the process of checking a number of uncertain records and the deletion of several 'fake' records, in order to avoid the proliferation of mistakes that are almost impossible to control once disseminated. Literature accounts for findings of dead specimens of alien species that cannot be considered as new species introduction and have not been included in our database. For example, the Pacific molluscs *Pyramidella dolabrata* (L., 1758) and *Dentalium octangulatum* Donovan, 1804 were found by shell collectors in the Adriatic coast: they probably originate from dead packaging material of fishing baits imported from Taiwan (Tisselli et al. 2005). Similarly, empty shells of an indo-pacific gastropod, *Strombus persicus* Swainson 1821, reported as *S. decorus* in De Min and Vio (1998), were found in the nets of fishing boats. Other species have been excluded since they display Tethyan affinity (*sensu* Taviani 2002): for example, the red alga *Acantophora nayadiformis* (Delile) Papenfuss (Cormaci et al. 2004), the mollusc *Eastonia rugosa* (Helbling, 1779) (Cavallo and Repetto 1992), and the copepod crustacean *Pseudocyclops xiphophorus* Wells, 1967 (Zagami et al. 2005). Some older records have been deleted, since over the years the identity of the species themselves has become questionable, as have their native origin and alien status. This is the case of a polychaete, *Lumbrineris inflata* (Moore, 1911) (Giangrande et al. 1981; Cinar 2009; see also Carrera-Parra 2006 for a revision of the genus *Lumbrineris*) and of two amphipods, *Stenothoe gallensis* Walker, 1904 (Krapp-Schickel 1976) and *Cymadusa filosa* Savigny, 1816 (Krapp-Schickel 1982; see also Peart 2004 for a revision of the *Cymadusa filosa* complex).

A number of species, occasionally appearing in other lists of Mediterranean aliens, have been moved to the set of non-native species having naturally expanded their range (Table 2). A relevant example is given by the sole *Microchirus hexophthalmus*, found in the Venice Lagoon in the 1980s (Li Greci et al. 1987). This species, distributed from Africa to the North Sea, entered the Mediterranean (Spanish and French coasts), where its reproducing populations were observed (Quignard and Tomasini 2000). Therefore, this species has displayed a natural range expansion, and its presence in the Lagoon of Venice, although possibly favoured by human transport (shipping), represents an outlier of a population in expansion. For this reason, *Microchirus hexophthalmus*, as well as other Atlantic fishes, has not been listed as alien. Other pelagic organisms, like the squids *Stoloteuthis leucoptera* and *Cycloteuthis sirventi* (Bello 2008) and the penaeid crustacean *Panaeopsis serrata* (Froglia 2010), have been included in the set of non-native species whose presence in the Mediterranean is more likely to represent a natural range expansion than a human-mediated introduction, considering the possible presence of paralarvae and larvae at Gibraltar. The same applies to some macrophytes, which can cover large distances by passive transport as floating material.

The hypothesis of natural range expansion through Gibraltar has not been considered appropriate in the case of some Atlantic benthic invertebrates, because of their null or moderate movement capability. In particular, the scattered distribution of some species has suggested their introduction by shipping rather than a slow eastwards and northwards colonisation process from the Western Mediterranean. Examples are the sea slug *Aplysia parvula*, common in the Atlantic, reported in Apulia near ports (Perrone 1983; Terlizzi et al. 2003), and the crab *Percnon gibbesi*. This crab, known on tropical shores of eastern Pacific, western and eastern Atlantic, and Macaronesian Islands, was first observed in the Mediterranean Sea in 1999–2000: Linosa (Pelagian Islands, Italy) and Spain (Balearic Islands). In both cases an introduction by shipping is more likely than long-distance range expansion, and the 'alien' status of these species has been considered consistent. The very quick expansion of *P. gibbesi* in the eastern Mediterranean (Greece, Turkey and Libya), only a few years after it was first found, has been linked to both a long larval life and a ship mediated introduction (Yokes and Galil 2006; Cannicci et al. 2008).

A particular case of fish-ship relationship regards species that in a juvenile phase, generally in tropical waters, tend to shelter under ships (Chetodontidae, Pomacentridae, Kyphosidae etc.). When the ships set sailing, it was verified that animals followed the ship for 1 month (Quoy and Gaimard 1824). Such behaviour allows us to classify as alien fish (human mediated introduction) individuals that appeared in Italian waters more than one century ago, e.g. *Kyphosus sectator* at Trieste, Palermo and Genoa (Orsi Relini et al. 2010) and possibly to recognize the recently appeared *Kyphosus incisor* (distributed in eastern Atlantic, from Madeira to Angola) as a true alien species. Also the recent finding of a single specimen of the dog snapper *Lutjanus jocu,* common in the tropical western Atlantic and reported in the tropical eastern Atlantic as well (Vacchi et al. 2010) might fall in this category. Since this particular kind of human mediated transport is anecdotal for these two fishes, at present they are listed in Table 2.

Existing gaps of knowledge: vectors and impacts

The list of Italian non-indigenous species is in itself a valuable tool, covering a large extent of our coastal environments with a relatively small spatial resolution and often with repeated observations, in order to assess the current situation and to compare the temporal development of past and foreseen evolution of the occurrence of alien species. The critical examination of literature data and some analysis on the occurrence of species in space and time have provided new insight into the context of the Mediterranean biota evolution. Nevertheless, additional information that has been incorporated in the database shows gaps of knowledge that are particularly critical and need to be addressed in a more direct and conscious way, along with the necessity for a stronger commitment by the financing agencies involved.

The database of marine and brackish waters alien species occurring in Italy shows limited evidence of pathways of introduction. This is in general a common feature for many published sources: information on vectors are mostly derived from the authors' speculations, since specific research projects aimed at identifying vectors and occurrences are complicated and demanding large resources. Attempts to do this have been rare in Italian locations, with only a few studies on the content of ballast water tanks (Flagella et al. 2006, 2007), in contrast with the wealth of published reports issued on maritime traffic worldwide (BWM 2005). To the best of our knowledge, specific analysis of the packaging material of imported species for aquaculture, such as those performed by Verlaque et al. (2007), have never been performed in Italy. Genetic analyses aimed at investigating the origins of Italian alien populations have only been carried out for the macroalga *Caulerpa racemosa* var. *cylindracea* (Verlaque et al. 2003), the bivalve *Brachidontes pharaonis* (Terranova et al. 2006), the rabbitfish *Siganus luridus* (Azzurro et al. 2006) and the cornetfish *Fistularia commersonii* (Golani et al. 2007). In a large number of cases, likely pathways are merely inferred, for example taking into account the most common activity occurring in a specific location (shipping, aquaculture), but no scientific evidence is provided. In the absence of other clues, the pathway is classified as 'unknown': this is the case of 42 species in the database (25% of the total).

The available data allow us to assess vessels (54%) and aquaculture (19%) as the main causes for alien species occurrence in Italian seas. This result differs from what has been observed in the Mediterranean basin overall. But while the majority of aliens (81%) in the eastern Mediterranean entered through the Suez Canal, in the western Mediterranean mariculture (42%), vessels (34%), or both (9%) are the main means of introduction (Galil 2009). It is evident that a detailed knowledge of vectors of introduction (and secondary spread as well, the importance of which has been demonstrated by Minchin et al. 2006) is necessary for a correct management of the biological invasion problem. Therefore, more effort in understanding this crucial stage is required.

Another important aspect that has unfortunately received little attention in the literature—as a consequence of insufficient development of *ad hoc* research projects—is the impact of alien species on natural ecosystems. Our database of Italian marine aliens contains information about impacts of only 32 species (19% of the total). The majority of these known impacts have been identified as competitive interactions with native species (27 cases) and habitat change (6 cases), whereas there are only single known cases of parasitism, or benthic/pelagic interactions. But the lack of investigation does not justify the assumption that these species have no impacts. Alien species are known to threaten marine ecosystems (Ruiz et al. 1997; Leppäkoski et al. 2002). Any new species introduced to an ecosystem has an impact, by affecting in some way various levels of biological organization—genetic, organism, population, community, habitat/ecosystem (Reise et al. 2006), although in many cases the effects may go unnoticed (Carlton 2002). The precautionary approach suggests the need to consider each alien species 'guilty until proven innocent', and to make more efforts to analyse its possible impacts. Unfortunately, up to now populations of alien species have raised the interest of local scientists only after they have markedly affected native communities. Whereas in Australia and North-America the problem of impacts has been repeatedly afforded the experimental investigation it deserves, in Italy and Europe in general a similar attitude has not yet been adopted. Such gaps in knowledge have also been highlighted by Savini et al. (2010), who have surveyed the scientific literature concerning the top 27 alien animal species intentionally introduced in European aquatic ecosystems (either marine or freshwater).

The advancement of the studies on the economical and ecological impact of introduced species is a prerequisite for the actual development of specific tools of risk assessment, such as those proposed by Copp et al. (2009) in the framework of the IMPASSE project for new species that are of potential interest to aquaculture.

Hotspots of introduction

Our study reveals that along the Italian coasts there are localities displaying a very high number of recorded aliens, compared to the average: the Lagoon of Venice in the North Adriatic Sea, the Gulf of Taranto in the Ionian Sea and the small islands surrounding Sicily.

In general, coastal lagoons and harbours present the highest numbers of alien species, and this can be justified by favourable conditions for the establishment of new species. The natural and anthropogenic disturbance that characterise such environments produces a depauperate, low-competition biota that can easily be occupied by opportunistic species, including new invaders brought by shipping and/or aquaculture (Occhipinti-Ambrogi and Savini 2003). For this reason, coastal lagoons and harbours have witnessed spectacular examples of biological invasions, such as those in the San Francisco Bay in the United States (Cohen and Carlton 1998) and the Thau lagoon in France (Verlaque 2001). As regards Italian lagoons, a recent study suggests that their benthic communities are not saturated, thus they are particularly susceptible to biological invasions (Munari and Mistri 2008).

In Italy, the Venice Lagoon is the main hotspot of introduction. Its relevant role in the phenomenon of biological invasions had already been acknowledged in the literature (Mizzan 1999; Occhipinti-Ambrogi 2000; Occhipinti-Ambrogi and Savini 2003; Sfriso and Curiel 2007). This fact has been explained by the existence of commercial and tourist ports, recreational marinas, aquaculture facilities (fish and shellfish farms), all structures that facilitate the introduction and secondary dispersal of non-native organisms. Furthermore, the rapid environmental changes that Venice has experienced over the past decades have made this lagoon a very favourable site for the establishment of alien species as well as for the increase in real invasions, as in the case of the brown seaweed *Sargassum muticum*, the bivalve *Ruditapes philippinarum*, the crab *Dyspanopeus sayi* and the bryozoan *Tricellaria inopinata* (Occhipinti-Ambrogi 2000).

The fauna and flora of this lagoon has been the object of investigations for the past two centuries (Pellizzato and Scattolin 1982) which have been carried out by academic teams (e.g. Sacchi et al. 1983, 1990, 1998; Bendoricchio et al. 1994; Sfriso et al. 1993, 2003; Sconfietti et al. 2003; Corriero et al. 2007; Sfriso and Curiel 2007), with periodic biological monitoring, so that the arrival of new species is promptly recorded.

The situation is similar for the second most important introduction hotspot. In the Taranto seas (Mar Piccolo and Mar Grande) there is a large extent of intercontinental naval traffic, due to both the presence of the most important Italian Navy base and to the merchant harbour, and numerous mussel farms. The concurrent presence of the above mentioned activities, together with the industrial emissions and sewage disposal, favoured not only the decay of the local benthic communities but also the introduction of several alien species (Mastrototaro et al. 2004a). Moreover, the continuous and extended monitoring of the flora and fauna of the basin carried out by the CNR Institute "Talassografico di Taranto" and the University of Bari (i.e. Tortorici and Panetta 1977; Cecere et al. 2000; Cecere and Petrocelli 2004, 2008; Longo et al. 2007; Brunetti and Mastrototaro 2004; Mastrototaro and Brunetti 2006; Mastrototaro et al. 2003, 2004a, b, 2008a, b), allowed us to record the occurrence of new alien species. Such figures on biological invasions appear to be lower in other important Italian ports, probably due to the fact that while researchers in Taranto and Venice concentrate their research activities within the lagoon areas, where also port activity and aquaculture facilities are located, researchers from Genoa (Ligurian Sea) or Naples (Eastern-Central Tyrrhenian) carry out their research mostly in locations outside port areas, and therefore subjected to a lower propagule pressure.

In Sicily and smaller surrounding islands the number of alien species has increased throughout the investigation period. While aquaculture industry is less developed there than in other parts of Italy, the geographic location explains the abundance of aliens in this area. Located at the crossroads between the eastern and western sectors of the Mediterranean, Sicily is characterised by intense maritime traffic, including fisheries and recreational fleets. The sudden spread of alien species previously established in the Levantine basin coincided with significant hydrographic changes concomitant with the warming of the Mediterranean waters (Occhipinti-Ambrogi and Galil 2010): the climatic conditions and geographical position of Sicily favour the settlement of Erythrean species that have crossed the Suez Canal, such as the bony fish *Siganus luridus* (Azzurro and Andaloro 2004). The presence of active marine biology centres based in Sicily is an obvious counterpart.

Conversely, the central Adriatic and western Tyrrhenian display low numbers of alien species. Factors that may explain the presence of only 7 aliens in the central Adriatic are: (1) dominance of soft-bottom substrates, with consequent low habitat diversification; (2) oceanographic conditions that prevent both the colonisation by thermophilic species from the South and the range expansion of cold-affinity species settled in the northern Adriatic; (3) minor concentration of research centres and taxonomic expertise in this area, compared to other Italian seas.

The known distribution of the different taxa may reflect the availability of taxonomic expertise within research centres along the coast. For example, records of macroalgae are principally reported from the northern Adriatic, the Ionian and the central and southern Tyrrhenian, since the taxonomic expertise of this group is mainly located in Venice, Florence and Pisa (Tuscany), Taranto (Apulia) and Catania (Sicily). Therefore, taxonomic expertise and research funds have a great importance in the process of alien species monitoring, and they should be improved for a more effective control of such an important biological phenomenon. Unfortunately, in Italy both are experiencing a constant decline! Most records of new species have originated from accidental 'encounters' while carrying out other research, whereas *ad hoc* studies on the alien fauna and flora have received inadequate financial support. The present work itself has been carried out on volunteer basis, in the hope that the relevance of the problem will soon be fully comprehended by institutional authorities.

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