

## **Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD).**

### **Part I. Spatial distribution**

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## Abstract

The state-of-art on alien species in the Mediterranean Sea is presented, making distinctions among the four subregions defined in the EU Marine Strategy Framework Directive: (i) the Western Mediterranean Sea (WMED); (ii) the Central Mediterranean Sea (CMED); (iii) the Adriatic Sea (ADRIA); and (iv) the Eastern Mediterranean Sea (EMED). The updated checklist (December 2010) of marine alien species within each subregion, along with their acclimatization status and origin, is provided. A total of 955 alien species is known in the Mediterranean, the vast majority of them having being introduced in the EMED (718), less in the WMED (328) and CMED (267) and least in the Adriatic (171). Of these, 535 species (56%) are established in at least one area.

Despite the collective effort of experts who attempted in this work, the number of introduced species remains probably underestimated. Excluding microalgae, for which knowledge is still insufficient, aliens have increased the total species richness of the Mediterranean Sea by 5.9%. This figure should not be directly read as an indication of higher biodiversity, as spreading of so many aliens within the basin is possibly causing biotic homogenization. Thermophilic species, i.e. Indo-Pacific, Indian Ocean, Red Sea, Tropical Atlantic, Tropical Pacific, and circum(sub)tropical, account for 88.4% of the introduced species in the EMED, 72.8% in the CMED, 59.3% in the WMED and 56.1% in the Adriatic. Cold water species, i.e. circumboreal, N Atlantic, and N Pacific, make up a small percentage of the introduced species, ranging between 4.2% and 21.6% and being more numerous in the Adriatic and less so in the EMED.

Species that are classified as invasive or potentially invasive are 134 in the whole of the Mediterranean: 108 are present in the EMED, 75 in the CMED, 53 in the Adriatic and 64 in the WMED. The WMED hosts most invasive macrophytes, whereas the EMED has the lion's share in polychaetes, crustaceans, molluscs and fish.

**Keywords:** Biological invasions; Marine aliens; Biogeography; Biodiversity; Mediterranean Sea.

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## Introduction

The Mediterranean Sea is one of the seas of the world most affected by biological invasions in terms of how long the invaders have been present (OCCHIPINTI-AMBROGI, 2000; STREFTARIS *et al.*, 2005), in number of alien species detected (COSTELLO *et al.*, 2010) and in the unprecedented rate of introduction (ZENETOS, 2009; 2010). Triggered by warming waters and a newly improved route through the Suez Canal, tropical/subtropical marine species, some very invasive, have progressively moved into the Mediterranean, disrupting ecosystem stability of the basin.

In 1978, there were 128 proven Lessepsian immigrants and 76 doubtful cases (POR, 1978). Since the first review of alien species in the Mediterranean (ZIBROWIUS, 1992), there have been many papers and reviews dealing with this subject. More recently, CIESM has published four Atlases of Exotic Species in the Mediterranean (GALIL *et al.*, 2002; GOLANI *et al.*, 2002; ZENETOS *et al.*, 2004; VERLAQUE *et al.*, in press). The most recent lists show 116 species of fishes, 70 species of decapod and stomatopod crustaceans, 137 species of molluscs and 110 species of macrophytes. This increased number of records, particularly over the past few years, has been partly

attributed to intensification of research effort in this topic. ZENETOS & POLYCHRONIDIS (2010), based on data gathered, analysed for and adopted in the European Environment Agency (EEA) and UNEP MAP RAC/SPA reports, estimated that nearly 1000 species entered the Mediterranean during the past century.

A recent synthesis on Mediterranean marine biodiversity (COLL *et al.*, 2010) described the Mediterranean Sea as a biodiversity hot spot hosting approximately 17,000 marine species, of which more than 600 (3.3%) are alien. These most recent detailed biodiversity estimates for alien species show a discrepancy from the figures provided by ZENETOS *et al.* (2005; 2008). However, as COLL *et al.* (2010) have pointed out, the true numbers of alien species are certainly biased downwards. The data are presumably accurate for large and conspicuous species that are easily distinguished from the native biota and for species that occur along a frequently sampled (or fished) coast and for which taxonomic expertise is readily available, but are entirely absent for many of the small members of invertebrates. This underrepresentation is common in many works and efforts have been made to include less studied groups in recent reviews (see ZENETOS *et al.*, 2008).

An up-to-date inventory of the alien species in the Mediterranean, apart from its scientific merits, can fulfil the needs of the regulatory requirements and environmental management options. This is of particular importance since the current

emergence of the new generation of EU political actions covering major maritime strategic objectives, such as the Marine Strategy Framework Directive (MSFD) (2008/56/EC), the European Strategy for Marine and Maritime Research (COM (2008) 534) encompassing the Marine Spatial Planning and the Ecosystem Approach (ECAP) within the Barcelona Convention by UNEP/MAP<sup>1</sup>, as well as many initiatives of the UNEP RAC/SPA. Alien species regulations are of major importance in those policies. In the current MSFD the descriptor: "Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems" is actually one of the eleven qualitative descriptors for determining Good Environmental Status (GES). It is also closely related to six other GES descriptors because of the great variety of impacts that Invasive Alien Species (IAS) may exert on native biodiversity, ecosystem functioning, and seabed habitats as well as commercial marine resources (OLENIN *et al.*, 2010).

This territorial and institutional scenario raises the need for a multi-level governance system with a quite complex coordination system in which non-EU Member States can also participate. This is particularly important in the Mediterranean, where the southern and eastern coast belong to non-EU Member States or countries with accession status (e.g. Turkey and Israel). Furthermore, the Barcelona Convention of the UNEP/MAP supports the introduction of MSFD (2009) concepts that can be useful throughout the basin despite the handi-

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<sup>1</sup> The Barcelona Convention of the UNEP/MAP supports the introduction of MSFD in the Mediterranean. To that end, they are following the ecosystem approach (including the concept of policy steps), which is the priority of the recently adopted 5-year programme. Presently they are working on assessing the state of the environment, including economic and social aspects, in the four subregions.

cap that only seven of 21 Mediterranean countries are Member States of UNEP/MAP.

Considering a) the high introduction rate, b) recent publications and reviews on little studied taxa and c) the need to assess the extent of the phenomenon at subregional level and inform the EU, UNEP/MED and other stakeholders accordingly, this work aims to present the 2010 state-of-art on the presence and acclimatization status of alien species at each MSFD Mediterranean subregion, namely: (i) the Western Mediterranean Sea (WMED); (ii) the Central Mediterranean Sea (CMED); (iii) the Adriatic Sea (ADRIA); and (iv) the Eastern Mediterranean Sea (EMED). The latter is also commonly referred to as the Aegean-Levantine basin, but in this work the Marmara Sea, bearing more similarities to the Aegean than to the neighbouring Black Sea, is also included.

## Methodology

Biological invasions have become a hot issue at a broad geographical scale such as that of Large Marine Ecosystems (LME). Among European LMEs, biological invasions are most pronounced in the Mediterranean (EEA, 2007a; ZENETOS *et al.*, 2009).

On the European scale, over a dozen partitions can be found dividing up the waters of the NE Atlantic, the Mediterranean Sea and the Black Sea on oceanographic or purely geometric bases, or a combination of both, as well as divisions based on national jurisdictions<sup>2</sup> (Fig. 1). In this work the Mediterranean is being

studied along the four subregions as adopted and described under the MSFD. The coastal areas of the countries and the regions included in these subregions are listed in Table 1. This division imposes some restrictions/difficulties in the case of countries whose waters lie within the boundaries of these subregions as in the case of Albania, Tunisia and Italy.

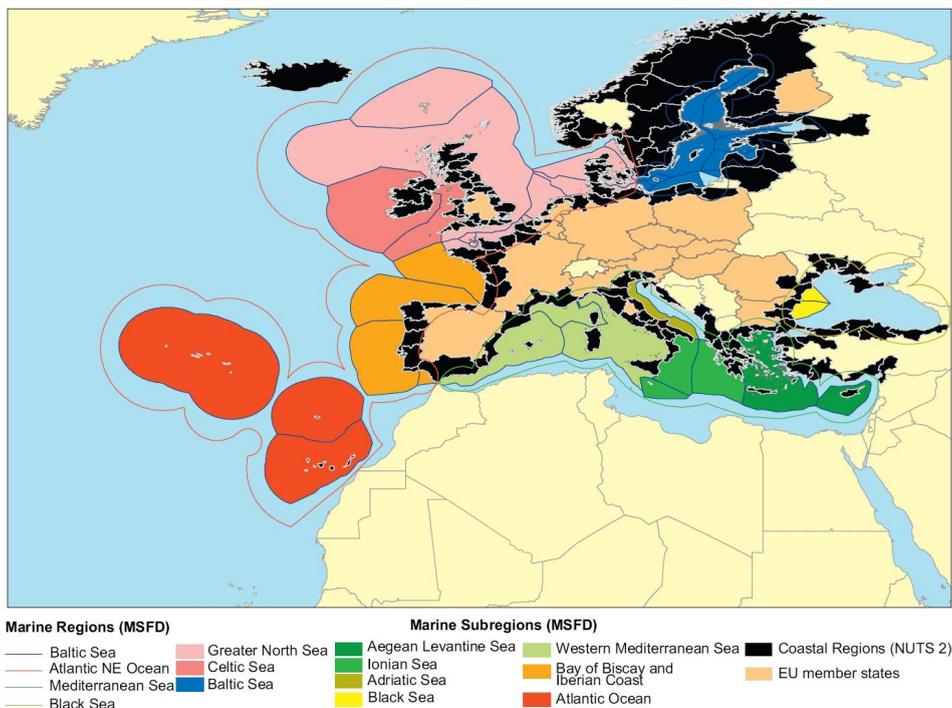
The borders of the CMED are hereby defined as the Kythira-Anti-Kythira Straits (Greece) and Libya-Egypt borders to the east, Otranto Strait (Italy, Albania) to the north, Cap Bon (Tunisia) and south-west Sicily to the west.

The list is updated based on valid species records up to December 2010. Alien species are investigated within all four regions in terms of their establishment success (casual, established, questionable, cryptogenic), as well as invasive success, their native range and geographical expansion. The species lists are presented for seven units which are systematic groups namely: 1) Protozoa (including Foraminifera), 2) Macrophytes, 3) Polychaeta, 4) Crustacea, 5) Mollusca, 6) Miscellaneous Invertebrata (Arthropoda Pycnogonida, Bryozoa, Chaetognatha, Chordata Ascidiacea, Cnidaria, Ctenophora, Echinodermata, Porifera, Sipuncula, Nematoda and Platyhelminthes), and 7) Fish, in each part.

The introduction of alien species in the Mediterranean Sea is hard to demonstrate for marine microalgae as for microorganisms in general (WYATT & CARLTON, 2002). Bearing in mind that it can rarely be excluded that a suspected microalgal invader was already present as part of the rare, hidden and unsampled phytoplankton, we refrain from citing a detailed list of plank-

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<sup>2</sup> EEZs, Marine Regions, and Subregions of the EU Directive on Marine Strategy (2008/56/CE).



**Fig. 1:** European marine and coastal regions(source: SUREZ DE VERO *et al.*, 2009).

**Table 1**  
Subregions, areas and coast of the Mediterranean studied in this work.

Western Mediterranean	Central Mediterranean including the Ionian Sea	Adriatic Sea	Eastern Mediterranean (the Aegean-Levantine - Marmara Seas)
Tyrrhenian Sea	Greek Ionian Sea	Italian Adriatic Sea	Greek Aegean Sea
Ligurian Sea	Italian Ionian Sea	Slovenia	Turkish Aegean Sea
Sardinia	Albanian Ionian Sea	Croatia	Sea of Marmara
Corsica	Apulian Sea	Montenegro	South Turkey
France	South East Sicily	Albanian Adriatic Sea	Cyprus
Monaco	Malta		Syria
Spain	South Tunisia		Lebanon
Baleares	Libya		Palestine Authority
Gibraltar			Israel
Morocco			Egypt
Algeria			
North Tunisia			
West Sicily			

tonic and benthic microalgae as in ZENETOS *et al.* (2005, 2008).

The revised checklist has been as wide as possible. Contrary to the CIESM Atlas, we have taken into account alien species introduced from elsewhere within the Mediterranean when the introduction event was evident (e.g. the mollusc *Siphonaria pectinata* introduced from the WMED to Greece, or the algae *Cladosiphon zosterae*, *Desmarestia viridis*, *Ectocarpus siliculosus* var. *hiemalis* and *Pylaiella littoralis* from the Adriatic to the Thau Lagoon, WMED).

Freshwater species occurring in estuarine waters such as *Acipenser gueldenstaedtii*, *Acipenser baeri* and *Huso huso* in the North Aegean estuaries and *Micropterus salmoides* in Ionian Sea estuarine waters are not included in our list. Similarly, the freshwater crayfish *Procambarus clarkii*, though it can stand slightly brackish waters and has been reported in the inner part of the Varano Lagoon, Adriatic Sea (FLORIO *et al.*, 2008) and in the Palude di Torre Flavia, Tyrrhenian Sea (SCALICI *et al.*, 2010), is not included.

Alien [synonyms: Non-indigenous species (NIS), exotic, non-native, allochthonous] are species, subspecies or lower taxa, present in the wild, introduced outside of their natural range (past or present) and beyond their natural dispersal potential. This includes any part, gamete or propagule of such species that might survive and subsequently reproduce. Their presence in the given region is due to intentional or unintentional introduction resulting from human activities. Natural shifts in distribution ranges (e.g. due to climate change or dispersal by ocean currents) do not qualify a species as a NIS (OLENIN *et al.*, 2010). Specimens kept in captivity and specimens still attached to a ship's hull or other man-

made crafts are not considered.

The acclimatization status of each species was assessed, and is given here according to the following terminology.

**Established:** Introduced or feral population of species settled in the wild with free-living, self-maintaining and self-perpetuating populations unsupported by and independent of humans. Species with at least two records in the area spread over time and space (at least three records for fishes) are also classified as established, in the sense of the CIESM Atlas series.

**Casual:** Casual species are those having been recorded only once (no more than twice for fish) in the scientific and grey literature and are presumed to be non-established in the area. In this paper 'casual' is used in the same sense as 'alien' in the CIESM Atlas series.

**Questionable:** Species with insufficient information—'suspect'. This includes old casual records that have not been subsequently found despite appropriate investigation, and also new entries not verified by experts or species with taxonomic status unresolved.

**Cryptogenic:** Species with no definite evidence of their native or introduced status according to CARLTON (1996) and species whose probable introduction occurred in 'early times' and has not been witnessed (e.g. prior to 1800).

**Invasive:** Species defined as established aliens that have overcome biotic and abiotic barriers and are able to disseminate away from their area of initial introduction through the production of fertile offspring with noticeable impact, such as threat to the diversity or abundance of native species, the ecological stability of infested ecosystems, economic activities dependent on these ecosystems, and human health.

True aliens need to be separated from

species with seemingly isolated records, which have naturally spread to regions beyond their usual range. BOUCHET & TAVIANI (1992) illustrated this scenario with the case of deep-sea molluscs in the Mediterranean, brought into the basin as larvae carried by the inflowing surface waters, but unable to establish fertile populations. This is also the case of some Eastern Atlantic crustacean species seldom recorded in the West Mediterranean but occurring in the Alboran sea (*Penaeopsis serrata*, *Merhippolyte ancistrotata*, etc.), and of the big-eye thresher shark, *Alopias superciliosus*, which is distributed worldwide in tropical and temperate seas and was formerly classified as alien in the Mediterranean (ZENETOS *et al.*, 2008). Occurrences in this kind of context have been filtered out of alien species lists.

Regarding the native range, caution has been taken in establishing the origin of alien species. The true origin for many species is muddled after becoming widely dispersed over a long time. Precise localities will be known for some, but for others only a general region may be known. This is particularly important in the case of the Mediterranean where the true origin of populations of a species widely distributed in the Indo-Pacific Ocean may be its population in the Red Sea, or much further afield. The expression "Lessepsian migration" was coined by POR (1978) for those species that inched their way through the Suez Canal into the Mediterranean. However it is far from straightforward that all the Indo-Pacific species documented in the Mediterranean are Lessepsian immigrants, and at least two more pools of species can be individualized. One such pool would include tropical Indo-Pacific species that did not first show up on the Levantine or Egyptian coasts, but further away from the Suez Canal.

Finally, attention was paid to recent nomenclatural updates. These are the result of the latest taxonomic and/or molecular studies, such those of LAI *et al.* (2010) on the *Portunus pelagicus* species complex; of HUBER (2010) on *Anadara kagoshimensis*, formerly known as *Anadara inaequalis*; and of MALAQUIAS & REID (2008) on *Bulla arabica*, formerly known as *Bulla ampulla*. A list of all species catalogued under their currently valid names along with the old names is provided in the ANNEX.

Nomenclature adopted in this paper follows the World Register of Marine Species (WoRMS <[www.marinespecies.org](http://www.marinespecies.org)>) and contributing databases (AlgaeBase, CLEMMAM, FishBase...).

The time boundary is generally set from the date of the opening of the Suez Canal (1869): species established earlier are treated as cryptogenic (e.g. *Teredo navalis*).

## Results and Discussion

The core of this work is Table 2, which provides a full list of alien species within each Mediterranean sub-basin, along with their acclimatization status and origin. Furthermore, this part is built around eight sections. The first four deal in detail with the distribution of the seven systematic groups within each MSFD area. They are structured in a way so as to be autonomous and therefore understood by the independent taxonomist reader. The fifth section describes the state of art of phytoplankton within the Mediterranean LME. The last three sections are more general and attempt to discuss some trends from the elaboration of Table 2. A list of invasive or potentially invasive species for each basin is included. The possible role of warming in the observed trends is also addressed.

Table 2

List of species with origin and establishment success in all Mediterranean MSFD areas (WMED=Western Mediterranean, CMED=Central Mediterranean, ADRIA=Adriatic Sea, EMED=Eastern Mediterranean). Species in alphabetic order within each taxon. Establishment success abbreviated as est=established, cas=casual, cry=cryptogenic, que=questionable. One asterisk denotes planktonic form. Two asterisks denote recent name changes. P= Parasite.

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<b>PROTOZOA</b>						
<b>Miscellaneous Protozoa</b>						
<i>Bonamia ostreae</i>	(Pichot <i>et al.</i> , 1979)	Circumboreal	cas		cas	
<i>Marteilia refringens</i>	Cavalier-Smith, 2002	unknown	cas		cas	
<i>Perkinsus olseni</i> **	Lester & Davis, 1981	Cosmopolitan	cry		cry	
<i>Photobacterium damsela</i>	-	NE Atlantic	est	?	?	?
<b>Foraminifera</b>						
<i>Agglutinella arenata</i>	(Said, 1949)	Indo-Pacific				cas
<i>Agglutinella compressa</i>	El-Nakhal, 1983	Indo-Pacific				cas
<i>Agglutinella robusta</i>	El-Nakhal, 1983	Indo-Pacific				cas
<i>Agglutinella soriformis</i>	El-Nakhal, 1983	Indo-Pacific/Atlantic				cas
<i>Amphisorus hemprichii</i>	Ehrenberg, 1840	Circumtropical				est
<i>Amphistegina lessonii</i>	d'Orbigny, 1826	Circumtropical		est?		est
<i>Amphistegina lobifera</i>	Larsen, 1976	Circumtropical		est?		est
<i>Amphistegina madagascariensis</i>	d'Orbigny, 1826	Indo-Pacific		est		est
<i>Archais angulatus</i>	(Fichtel & Moll, 1798)	W Atlantic			cry/cas	
<i>Articulina alicostata</i>	Cushman, 1922	Indo-Pacific				est
<i>Astacolus insolitus</i>	(Schwager, 1866)	Indo-Pacific				est
<i>Astacolus sublegumen</i>	(Parr, 1950)	Indo-Pacific				est
<i>Borelis</i> sp.		Circumtropical				est
<i>Brizalina simpsoni</i>	(Heron-Allen & Earland, 1915)	Indo-Pacific				cas
<i>Clavulina angularis</i>	d'Orbigny, 1826	Circumtropical			cry/cas	cry/est
<i>Clavulina</i> cf. <i>multicamerata</i>	Chapman, 1907	Indo-Pacific				est
<i>Coscinospira hemprichii</i>	Ehrenberg, 1839	Indo-Pacific			cry/cas	cry/est
<i>Cushmanina striatopunctata</i>	(Parker & Jones, 1865)	Circumtropical				cas
<i>Cycloforina</i> sp.		Indian/Red Sea				est
<i>Cyclorbiculina compressa</i>	(d'Orbigny, 1839)	Circumtropical				est
<i>Cymbaloporeta plana</i>	(Cushman, 1924)	Indo-Pacific	cry/est		cry/cas	cry/est
<i>Edentostomina cultrata</i>	(Brady, 1881)	Indo-Pacific				est
<i>Elphidium</i> cf. <i>charlottensis</i>	(Vella, 1957)	Indo-Pacific				est
<i>Elphidium striatopunctatum</i>	(Fichtel & Moll, 1798)	Indo-Pacific				est
<i>Euthymonacha polita</i>	(Chapman, 1904)	Indo-Pacific				cas
<i>Haddonina</i> sp.	Chapman, 1898	Indo-Pacific				est
<i>Hauerina diversa</i>	Cushman, 1946	Circumtropical				est
<i>Heterocyclus tuberculata</i>	(Moebius, 1880)	Indian				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Heterostegina depressa</i>	d'Orbigny, 1826	Circumtropical				est
<i>Miliolinella</i> cf. <i>hybrida</i>	(Terquem, 1878)	Indo-Pacific				est
<i>Nodophthalmidium antillarum</i>	(Cushman, 1922)	Circumtropical				est
<i>Operculina ammonoides</i>	(Gronovius, 1781)	Red Sea				cas
<i>Pegidia lacunata</i>	McCulloch, 1977	Indo-Pacific				est
<i>Peneroplis antillarum</i>	d'Orbigny, 1839	Caribbean or SW Atlantic				cas
<i>Planogypsina acervalis</i>	(Brady, 1884)	Circumtropical	cry	cry		cry
<i>Planogypsina squamiformis</i>	(Chapman, 1901)	Circumtropical				est
<i>Planorbulinella larvata</i>	(Parker & Jones, 1865)	Indo-Pacific				cas
<i>Pseudolachlanella slitella</i>	Langer, 1992	Indo-Pacific				est
<i>Pseudomassilina reticulata</i>	(Heron-Allen & Earland, 1915)	Indo-Pacific				est
<i>Pulleniatina obliquiloculata</i> *	(Parker & Jones, 1865)	Circumtropical				cas
<i>Pyramidulina catesbyi</i>	(d'Orbigny, 1839)	Indo-Pacific/Atlantic				est
<i>Pyrgo denticulata</i>	(Brady, 1844)	Indo-Pacific				est
<i>Quinqueloculina</i> cf. <i>mosharrafai</i>	Said, 1949	Indo-Pacific				est
<i>Schackoinella imperatoria</i>	d'Orbigny, 1846	Indo-Pacific	cry/cas		cry/cas	cry/cas
<i>Schlumbergerina alveoliniformis</i>	(Brady, 1879)	Circumtropical				est
<i>Sorites orbiculus</i>	Forskål, 1775	Circumtropical	cry/est		cry/cas	cry/est
<i>Sorites variabilis</i>	Lacroix, 1941	Indo-Pacific				est
<i>Spiroloculina antillarum</i>	d'Orbigny, 1839	Circumtropical				est
<i>Spiroloculina</i> cf. <i>angulata</i>	Cushman, 1917	Indo-Pacific				cas
<i>Triloculina fichteliana</i>	d'Orbigny, 1839	Circumtropical				est
MACROPHYTES						
Chlorophyta						
<i>Batophora</i> sp.		Atlantic		ques		
<i>Caulerpa distichophylla</i>	Sonder	Indo-Pacific		est		est
<i>Caulerpa mexicana</i>	Sonder ex Kützing	Indo-Pacific				est
<i>Caulerpa racemosa</i> var. <i>cylindracea</i>	(Sonder) Verlaque, Huisman & Boudouresque	Indo-Pacific	est	est	est	est
<i>Caulerpa racemosa</i> var. <i>lamourouxii</i> f. <i>requienii</i>	(Montagne) Weber-van Bosse	Indo-Pacific		est		est
<i>Caulerpa racemosa</i> var. <i>turbinata</i> / <i>uvifera</i>	(J. Agardh) Eubank/ (C. Agardh) J. Agardh	Indo-Pacific		cry/ques		cry/ques
<i>Caulerpa scalpelliformis</i>	(Brown ex Turner) C. Agardh	Indo-Pacific				est
<i>Caulerpa taxifolia</i>	(Vahl) C. Agardh	Indo-Pacific	est	est	est	
<i>Cladophora</i> cf. <i>patentiramea</i>	(Montagne) Kützing	Indo-Pacific				est
<i>Cladophora herpestica</i>	(Montagne) Kützing	Indo-Pacific				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Cladophora hutchinsioides</i>	Hoek & Womersley	Pacific	cas			
<i>Codium fragile</i> subsp. <i>fragile**</i>	(Suringar) Hariot	NW Pacific	est	est	est	est
<i>Codium parvulum</i>	(Bory ex Audouin) P.C. Silva	Indo-Pacific				est
<i>Codium taylorii</i>	P.C. Silva	Indo-Pacific		est		est
<i>Derbesia boergesenii</i>	(Lyengar & Ramanathan) Mayhoub	Indo West Pacific				cas
<i>Derbesia rhizophora</i>	Yamada	NW Pacific	est			
<i>Neomeris annulata</i>	Dickie	Indo-Pacific				est
<i>Ulva fasciata</i>	Delile	Cosmopolitan	est	cry/ques	cry/ques	cry/ques
<i>Ulva pertusa</i>	Kjellman	Indo-Pacific	est			
<i>Ulvaria obscura</i>	(Kützing) Gayral	NW Pacific	est	est	est	
<b>Fucophyceae</b>						
<i>Acrothrix gracilis</i>	Kylin	Circumboreal	est			
<i>Botryella cf. parva</i>	(Takamatsu) H.-S. Kim	Pacific			est	
<i>Chorda filum</i>	(Linnaeus) Stackhouse	N Atlantic/N Pacific	est			est
<i>Cladosiphon zosteræ</i>	(J. Agardh) Kylin	Atlantic	est	cry/ques	est	cry/ques
<i>Colpomenia peregrina</i>	Sauvageau	Indo-Pacific	est	est		est
<i>Desmarestia viridis</i>	(O.F. Müller) J.V. Lamouroux	Atlantic/Pacific	est		cry/ques	
<i>Ectocarpus siliculosus</i> var. <i>hiemalis</i>	(P.L. Crouan & H.M. Crouan) Foslie	Atlantic			est	cry/ques
<i>Fucus spiralis</i>	Linnaeus	Atlantic	cas			
<i>Halothrix lumbricalis</i>	(Kützing) Reinke	N Atlantic/N Pacific	est	cry/ques	cry/ques	cry/ques
<i>Leathesia marina</i>	(Lyngbye) Decaisne	Cosmopolitan	est	est	est	
<i>Microspongium tenuissimum</i>	(Hauck) A.F. Peters	Atlantic	est			
<i>Padina antillarum</i>	(Kützing) Piccone	Indo-Pacific				cas
<i>Padina boergesenii</i>	Allender & Kraft	Indo-Pacific	est	est		est
<i>Padina boryana</i>	Thivy in W.R. Taylor	Indo-Pacific		est		est
<i>Punctaria tenuissima</i>	(C. Agardh) Greville	NE Atlantic	est		est	
<i>Pylaiella littoralis</i>	(Linnaeus) Kjellman	N Atlantic/N Pacific	est	cry/ques	cry/ques	cry/ques
<i>Rugulopteryx okamuræ</i>	(Dawson) I.K. Hwang, W.J. Lee & H.S. Kim	Pacific	est			
<i>Saccharina japonica**</i>	(Areschoug) C.E. Lane, C. Mayes, Druehl & G.W. Saunders	NW Pacific	cas			
<i>Sargassum muticum</i>	(Yendo) Fensholt	NW Pacific	est		est	
<i>Scytosiphon dotyi</i>	Wynne	NE Pacific	est		est	
<i>Spatoglossum variabile</i>	Figari & De Notaris	Indo-Pacific				cas
<i>Sphaerotrichia firma</i>	(Gepp) A.D. Zinova	NW Pacific	est			est
<i>Styopodium schimperi</i>	(Kützing) Verlaque & Boudouresque	Indo West Pacific		est		est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Undaria pinnatifida</i>	(Harvey) Suringar	Pacific	est	cas	est	
<b>Magnoliophyta</b>						
<i>Halophila stipulacea</i>	(Forsskål) Ascherson	Red Sea	est	est	est	est
<b>Pelagophyceae</b>						
<i>Chrysonephos lewisii</i>	(W.R.Taylor) W.R.Taylor	W Atlantic	est			
<b>Rhodophyta</b>						
<i>Acanthophora nayadiformis</i>	(Delile) Papenfuss	Indo-Pacific	cry/ques	cry/ques	cry/ques	cry/ques
<i>Acrochaetium codicola</i>	Børgesen	Atlantic/Pacific	est	est	est	est
<i>Acrochaetium robustum</i>	Børgesen	Indo-Pacific				cas
<i>Acrochaetium spathoglossi</i>	Børgesen	Indo-Pacific				cas
<i>Acrochaetium subseriatum</i>	Børgesen	Indo-Pacific				cas
<i>Acrothamnion preissii</i>	(Sonder) E.M. Wollaston	Indo-Pacific	est	est	cas	
<i>Agardhiella subulata</i>	(C. Agardh) Kraft & M.J. Wynne	Atlantic/Pacific	est	est	est	
<i>Aglaothamnion feldmanniae</i>	Halos	N Atlantic	est		est	
<i>Ahnfeltiopsis flabelliformis</i>	(Harvey) Masuda	Pacific	est			
<i>Anotrichium okamurae</i>	Baldock	NW Pacific	cry/ques	cry/ques	cry/ques	cry/ques
<i>Antithamnion amphigeneum</i>	A. Millar	SW Pacific	est			
<i>Antithamnion hubbsii</i>	Dawson	Indo-Pacific	est		est	
<i>Antithamnionella boergesenii</i>	(Cormaci & G. Furnari) Athanasiadis	Indo-Pacific	cry/ques	cry/ques		
<i>Antithamnionella elegans</i>	(Berthold) J.H. Price & D.M. John	unknown	cry/ques	cry/ques	cry/ques	cry/ques
<i>Antithamnionella spirographidis</i>	(Schiffner) E.M. Wollaston	Indo-Pacific	est	est	est	Requires confirmation
<i>Antithamnionella sublittoralis</i>	(Setchell & Gardner) Athanasiadis	Pacific		est	est	
<i>Antithamnionella temifolia</i>	(J.D. Hooker & Harvey) Lyle	unknown	est			
<i>Apoglossum gregarium</i>	(E.Y. Dawson) M.J. Wynne	Pacific	est	est		
<i>Asparagopsis armata</i>	Harvey	SW Pacific	est	est	est	Requires confirmation
<i>Asparagopsis taxiformis</i>	Delile	Atlantic	cry/ques	cry/ques		cry/ques
<i>Asparagopsis taxiformis</i>	invasive strain	Indo-Pacific	est	est	est	est
<i>Bonnemaisonia hamifera</i>	Hariot	Indo-Pacific	est	est	est	est
<i>Botryocladia madagascariensis</i>	Feldmann-Mazoyer	Indian	est	est	est	est
<i>Caulacanthus okamurae**</i>	Yamada	NW Pacific	est			
<i>Ceramium bisporum</i>	D.L. Ballantine	W Atlantic	cry/ques			cry/ques
<i>Ceramium strobiliforme</i>	G.W. Lawson & D.M. John	N Atlantic		cry/ques	cry/ques	
<i>Chondria coerulescens</i>	(J. Agardh) Falkenberg	E Atlantic	est	cry/ques	cry/ques	cry/ques
<i>Chondria curvilineata</i>	F.S. Collins & Hervey	Atlantic	est			est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Chondria pygmaea</i>	Garbary & Vandermeulen	Indo-Pacific	est	est	est	
<i>Chondrus giganteus</i> f. <i>flabellatus</i>	Mikami	Pacific	est			
<i>Chrysomenia wrightii</i>	(Harvey) Yamada	Pacific	est			
<i>Dasya sessilis</i>	Yamada	Pacific	est			
<i>Dasyisiphonia</i> sp. (= <i>Heterosiphonia japonica</i> )	Yendo	NW Pacific	est		est	
<i>Galaxaura rugosa</i>	(J. Ellis & Solander) J.V. Lamouroux	Red Sea				est
<i>Ganonema farinosum</i>	(J.V. Lamouroux) K.C. Fan & Yung C. Wang	Indian	cry/ques	cry/ques		cry/ques
<i>Goniotrichopsis sublittoralis</i>	G.M. Smith	NW Pacific	est			
<i>Gracilaria arcuata</i>	Zanardini	Indo-Pacific/Red Sea		Requires confirmation		Requires confirmation
<i>Gracilaria vermiculophylla</i>	(Ohmi) Papenfuss	NW Pacific			est	
<i>Grateloupia asiatica</i>	Kawaguchi & Wang	NW Pacific	est			
<i>Grateloupia lanceolata</i>	(Okamura) Kawaguchi	Pacific	est	cas		
<i>Grateloupia minima</i>	P.L. Crouan & H.M. Crouan	Pacific	est			
<i>Grateloupia patens</i>	(Okamura) S. Kawaguchi & H.W. Wang	Pacific	cas			
<i>Grateloupia subpectinata</i>	Holmes	Pacific	est			
<i>Grateloupia turuturu</i>	Yamada	NW Pacific	est	est	est	
<i>Griffithsia corallinoides</i>	(Linnaeus) Batters	Atlantic/Pacific	est	est		est
<i>Herposiphonia parca</i>	Setchell	Indo-Pacific	est			
<i>Hypnea anastomosans</i> **	Papenfuss, Lipkin & Silva	Red Sea		cas		est
<i>Hypnea cornuta</i>	(Kützing) J. Agardh	Cosmopolitan		est		est
<i>Hypnea flagelliformis</i>	Greville ex J. Agardh	Indo-Pacific				Requires confirmation
<i>Hypnea flexicaulis</i>	Yamagishi & Masuda	Indo-Pacific			est	
<i>Hypnea spinella</i>	(C. Agardh) Kützing	Pantropical	est	est	est	est
<i>Hypnea valentiae</i>	(Turner) Montagne	Red Sea	est	est	cas	est
<i>Laurencia caduciramulosa</i>	Masuda & Kawaguchi	SW Pacific	est	est		
<i>Laurencia okamurae</i>	Yamada	Pacific	est			
<i>Lithophyllum yessoense</i>	Foslie	Pacific	est			
<i>Lomentaria flaccida</i>	Tanaka	Pacific	cas			
<i>Lomentaria hakodatensis</i>	Yendo	Pacific	est		est	
<i>Lophocladia lallemandii</i>	(Montagne) F. Schmitz	Indo-Pacific	est	est	est	est
<i>Nemalion vermiculare</i>	Suringar	NW Pacific	est			
<i>Neosiphonia harveyi</i>	(J. Bailey) M.-S. Kim, H.-G. Choi, Guiry & G.W. Saunders	NW Pacific	est	est	est	est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Nitophyllum stellato-corticatum</i>	Okamura	Pacific	est			
<i>Osmundea oederi</i>	(Gunnerus) G. Furnari	Atlantic	cry/ques	cry/ques		
<i>Plocamium secundatum</i>	(Kützing) Kützing	tropical/subtropical	est	est		
<i>Polysiphonia atlantica</i>	Kapraun & J.N. Norris	N Atlantic/N Pacific	cry/ques	cry/ques	cry/ques	cry/ques
<i>Polysiphonia fucoides</i>	(Hudson) Greville	N Atlantic	est	cry/ques	cry/ques	cry/ques
<i>Polysiphonia morrowii</i>	Harvey	NW Pacific	est		est	est
<i>Polysiphonia paniculata</i>	Montagne	E Pacific	est	cas	cas	
<i>Polysiphonia stricta</i>	(Dillwyn) Greville	NE Atlantic	est			
<i>Porphyra yezoensis</i>	Ueda	Pacific	est			
<i>Pterosiphonia tanakae</i>	Uwai & Masuda	Pacific	est			
<i>Rhodophysema georgei</i>	Batters	Atlantic/Pacific	cas			cas
<i>Rhodymenia erythraea</i>	Zanardini	Indo West Pacific				cas
<i>Sarconema filiforme</i>	(Sonder) Kylin	Indo West Pacific	cas			est
<i>Sarconema scinaoides</i>	Børgesen	Indian				est
<i>Solieria dura</i>	(Zanardini) F. Schmitz	Indo-Pacific				cas
<i>Solieria filiformis</i>	(Kützing) Gabrielson	N Atlantic	est	est	est	
<i>Spongoconium caribaenum**</i>	(Børgesen) M.J. Wynne	W Atlantic	est			
<i>Symphyclocladia marchantioides</i>	(Harvey) Falkenberg	Indo-Pacific	est			
<i>Womersleyella setacea</i>	(Hollenberg) R.E. Norris	Indo-Pacific	est	est	est	est
<b>POLYCHAETA</b>						
<i>Amphicorina pectinata</i>	(Banse, 1957)	Pacific	cas	cas		
<i>Apoprionospio pygmaea**</i>	(Hartman, 1955)	Pacific	cas			
<i>Branchiomma bairdi</i>	(McIntosh, 1885)	Atlantic/Pacific				est
<i>Branchiomma bohollensis</i>	(Grube, 1878)	Indo-Pacific	est	est		est
<i>Branchiomma luctuosum</i>	(Grube, 1869)	Indo-Pacific	est	est	est	est
<i>Capitellethus dispar</i>	(Ehlers, 1907)	Indo-Pacific/Red Sea				ques
<i>Ceratonereis mirabilis</i>	Kinberg, 1866	Indo-Pacific		cas		est
<i>Chaetozone corona</i>	Berkeley & Berkeley, 1941	unknown				cry
<i>Cirriformia semicincta</i>	(Ehlers, 1905)	Red Sea				ques
<i>Cossura coasta</i>	Litamori, 1960	unknown				cry/ques
<i>Dasybranchus carneus</i>	Grube, 1870	Red Sea				ques
<i>Desdemona ornata</i>	Banse, 1957	Indo-Pacific	est		est	est
<i>Dispia magnus</i>	(Day, 1955)	Indian		ques		
<i>Dispia uncinata</i>	Hartman, 1951	W Atlantic	cas	cas		
<i>Dodecaceria capensis</i>	Day, 1961	Indian		ques		ques
<i>Dorvillea similis</i>	(Crossland, 1924)	Indo-Pacific				est
<i>Eunice antennata</i>	(Savigny, 1820)	Indo-Pacific	est	est		est
<i>Eunice cf. cariboea</i>	Grube, 1856	W Atlantic	ques			
<i>Eunice floridana</i>	(Pourtalès, 1867)	W Atlantic		ques		

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Epidiopatra hupferiana hupferiana</i>	Augener, 1918	Tropical Atlantic		cas		
<i>Epidiopatra hupferiana monroi</i>	Day, 1957	Indian		cas		
<i>Eunice indica</i>	Kinberg, 1865	Indo-Pacific				ques
<i>Erinaceusyllis serratosetosa</i>	(Hartmann-Schroder, 1982)	Pacific	est			
<i>Euniphysa tubifex</i>	(Crossland, 1904)	Indian				ques
<i>Eurythoe complanata</i>	(Pallas, 1766)	Atlantic/Pacific	ques			ques
<i>Eusyllis kupfferi</i>	Langerhans, 1879	Atlantic				est
<i>Exogone africana</i>	Hartmann-Schröder, 1974	Indo-Pacific				cas
<i>Exogone brevi antennata</i>	Hartmann-Schröder, 1959	Circumtropical				est
<i>Fabriciolla qhardaqa</i>	Banse, 1959	Red Sea			cas	
<i>Ficopomatus enigmaticus</i>	(Fauvel, 1923)	Subtropical	est	est	est	est
<i>Glycinde bonhourei</i>	Gravier, 1904	Indo-Pacific				est
<i>Haploscoloplos kerguelensis</i>	Mc Intosh, 1885	Antarctic	ques			
<i>Hesionura serrata</i>	(Hartmann-Schroder, 1960)	Red Sea	cas			
<i>Hyboscolex longiseta</i>	Schmarda, 1861	Cosmopolitan	ques	ques		ques
<i>Hydroides albiceps</i>	Grube, 1870	Indo Pacific/Red Sea	cas			
<i>Hydroides branchyacanthus</i>	Rioja, 1941	Indo-Pacific				est
<i>Hydroides dianthus</i>	(Verrill, 1873)	NW Atlantic	est	est	est	est
<i>Hydroides diramphus</i>	Mörch, 1863	Circumtropical	est	est		est
<i>Hydroides elegans</i>	(Haswell, 1883)	Circumtropical	est	est	est	est
<i>Hydroides heterocerus</i>	(Grube, 1868)	Indian/Red Sea				est
<i>Hydroides homocerus</i>	Pixell, 1913	Indian				est
<i>Hydroides minax</i>	(Grube, 1878)	Indo-Pacific/Red Sea				est
<i>Hydroides operculatus</i>	(Treadwell, 1929)	Indian				est
<i>Hydroides steinitzi</i>	Ben-Eliahu, 1972	Red Sea	cas			cas
<i>Janua (Dexiospira) steueri</i>	(Sterzinger, 1909)	Indo-Pacific				cas
<i>Isolda pulchella</i>	Muller, 1858	Circumtropical		cas		
<i>Laonome elegans</i>	Gravier, 1906	Red Sea				cas
<i>Laonome triangularis</i>	Hutchings & Murray, 1984	SW Pacific				est
<i>Leiochrides australis</i>	Augener, 1914	Pacific	cas	cas	cas	
<i>Leocrates chinensis</i>	Kinberg, 1866	Pacific	ques	ques	ques	ques
<i>Leonnates decipiens</i>	Fauvel, 1929	Indo-Pacific				est
<i>Leonnates indicus</i>	Kinberg, 1966	Indo-Pacific				est
<i>Leonnates persicus</i>	Wesenberg-Lund, 1949	Indo-Pacific				est
<i>Lepidonotus carimulatus</i>	(Grube, 1870)	Indo-Pacific/Red Sea				ques
<i>Lepidonotus tenuisetosus</i>	(Gravier, 1902)	Indo-Pacific/Red Sea				cas
<i>Linopherus canariensis**</i>	Langerhans, 1881	Atlantic		est		est
<i>Longibranchium atlanticum</i>	(Day, 1973)	Atlantic	cas	cas		
<i>Loimia medusa</i>	(Savigny, 1818)	Cosmopolitan		ques		ques

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Lumbrineris acutifrons</i>	(Gallardo, 1967)	Pacific	ques	cas		
<i>Lumbrineris neogesae</i>	Miura, 1980	S Africa	cas		cas	
<i>Lumbrineris perkinsi</i> **	Carrera-Parra, 2001	Indo-Pacific	est	est		est
<i>Lysidice collaris</i>	Grube, 1870	Pacific/Red Sea	est	est	est	est
<i>Lysidice natalensis</i>	(Kinberg, 1865)	Indo-Pacific				ques
<i>Marphysa disjuncta</i>	Hartman, 1961	Pacific				cas
<i>Mediomastus capensis</i>	Day, 1961	Indian	ques	ques	ques	
<i>Megalomma claparedei</i>	Gravier, 1908	Red Sea			cas	
<i>Metasychis gotoi</i>	(Izuka, 1902)	Indo-Pacific	est	est	est	est
<i>Naineris quadraticeps</i>	Day, 1965	Red Sea				ques
<i>Neopseudocapitella brasiliensis</i>	Rullier & Amoureux, 1979	W Atlantic/ Red Sea	est	est	est	est
<i>Neanthes agulhana</i>	(Day, 1963)	S Africa	est	est		
<i>Neanthes willeyi</i>	(Day, 1934)	Indo-Pacific				cas
<i>Nereis gilchristi</i>	Day, 1960	Red Sea				cas
<i>Nereis jacksoni</i>	Kinberg, 1866	Indo-Pacific	est			est
<i>Nereis persica</i>	Fauvel, 1911	Indo-Pacific			ques	est
<i>Notomastus aberans</i>	Day, 1957	Indian/Red Sea	est	est	est	est
<i>Notomastus mossambicus</i>	(Thomassin, 1970)	Indian	est			est
<i>Notopygos crinita</i>	Grube, 1855	W Atlantic		ques		
<i>Novafabricia infratorquata</i>	Fitzhugh, 1983	W Atlantic	est		est	
<i>Ophryotrocha diadema</i>	Åkesson, 1976	Pacific	est			
<i>Ophryotrocha japonica</i>	Claparède & Meczniow, 1968	Pacific	est	est	est	
<i>Oenone cf. fulgida</i>	(Savigny, 1818)	Indo-Pacific/Red Sea	ques			ques
<i>Onuphis eremita oculata</i>	Hartman, 1951	W Atlantic				est
<i>Palola valida</i>	(Gravier, 1900)	Red Sea				est
<i>Paradyte cf. crinoidicola</i>	(Potts, 1910)	Indo-Pacific				ques
<i>Paraehlersia weissmaniodes</i>	(Augener, 1913)	Indo-Pacific				cas
<i>Paraprionospio coora</i>	Wilson, 1990	Pacific	cry			cry
<i>Perinereis nuntia</i>	(Savigny, 1818)	Indian				cas
<i>Pherusa parmata</i>	(Grube, 1878)	Indo-Pacific				cas
<i>Pherusa saldanha</i>	Day, 1961	Indian				cas
<i>Pileolaria berkeleyana</i>	(Rioja, 1942)	E Pacific	est			
<i>Pisione guanche</i>	San Martín, López & Núñez, 1999	Tropical Atlantic				cas
<i>Pista unibranchia</i>	Day, 1963	Indo-Pacific	est			est
<i>Platynereis australis</i>	(Schmarda, 1861)	Pacific			ques	
<i>Podarkeopsis capensis</i>	(Day, 1963)	Indo-Pacific	cas			ques
<i>Polycirrus twisti</i>	Potts, 1928	Suez Canal				est
<i>Polydora colonia</i>	Moore 1907	W Atlantic	cas		cas	
<i>Polydora cornuta</i>	Bosc, 1802	Cosmopolitan	est			est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Polydora spongicola</i>	Berkeley & Berkeley, 1950	Pacific				ques
<i>Pomatoleios kraussii</i>	(Baird, 1865)	Indo-Pacific/Red Sea				est
<i>Prionospio (Aquilaspio) krusadensis</i>	Fauvel, 1929	Indo West Pacific				est
<i>Prionospio (Aquilaspio) sexoculata</i>	Augener, 1918	Atlantic/Pacific				est
<i>Prionospio (Prionospio) depauperata</i>	Imajima, 1990	NE Pacific				est
<i>Prionospio (Prionospio) saccifera</i>	Mackie & Hartley, 1990	Indo-Pacific				est
<i>Prionospio (Prionospio) paucipinnulata</i>	Blake & Kudenov, 1978	Pacific				est
<i>Prionospio (Minuspio) pulchra</i>	Imajima, 1990	Atlantic/Pacific				cas
<i>Protodorvillea egena</i>	(Ehlers, 1913)	Indian/Red Sea		ques		
<i>Protodorvillea biarticulata</i>	Day, 1963	Indian		ques		ques
<i>Prosphaerosyllis longipapillata**</i>	(Hartmann-Schröder, 1979)	SW Pacific				cas
<i>Pseudonereis anomala</i>	(Gravier, 1900)	Indo-Pacific		est		est
<i>Pseudopolydora paucibranchiata</i>	Okuda, 1937	Pacific				est
<i>Scoletoma debilis</i>	(Grube, 1878)	Indo-Pacific				ques
<i>Sigambra constricta</i>	(Southern, 1921)	Indo-Pacific/Red Sea				ques
<i>Sigambra parva</i>	(Day, 1963)	Indian	cas			
<i>Spirobranchus tetraceros</i>	(Schmarda, 1861)	Circumtropical				est
<i>Spirorbis marioni</i>	Caullery & Mesnil, 1897	Atlantic/Pacific	est			est
<i>Streblosoma comatus**</i>	(Grube, 1856)	Indo-Pacific	est		cas	est
<i>Streblospio gynobranchiata</i>	Rice & Levin, 1998	W Atlantic				est
<i>Syllis alosae</i>	San Martín, 1992	W Atlantic			ques	
<i>Syllis bella</i>	(Chamberlin, 1919)	Pacific				est
<i>Syllis hyllebergi</i>	(Licher, 1999)	Red Sea		est		
<i>Syllis cf. mayeri</i>	Musco & Giangrande, 2005	W Atlantic				ques
<i>Syllis pectinans</i>	Haswell, 1920	Pacific	est			est
<i>Synelmis rigida</i>	(Fauvel, 1919)	Indo-Pacific				ques
<i>Syllis schulzi</i>	(Hartmann-Schröder, 1962)	Indian/Red Sea	ques			ques
<i>Terebella ehrenbergi</i>	Grube, 1870	Indo-Pacific/Red Sea	ques			ques
<i>Timarete anchylochaeta</i>	(Schmarda, 1861)	Pacific				ques
<i>Timarete caribous</i>	(Grube, 1859)	W Atlantic				cas
<i>Timarete dasylophius</i>	(Marenzeller, 1879)	Indo-Pacific				ques
<i>Timarete punctata</i>	(Grube, 1859)	Indo-Pacific				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<b>CRUSTACEA</b>						
<b>Amphipoda</b>						
<i>Bemlos leptochirus</i>	(Walker, 1909)	Indian				cas
<i>Caprella scaura</i>	Templeton, 1836	Indian	est	est	est	
<i>Cymadusa filosa</i>	(Savigny, 1816)	Indo-Pacific		cry		cry
<i>Elasmopus pecteniscrus</i>	(Bate, 1862)	Circumtropical	cas?	est	est	est
<i>Gammaropsis togoensis</i>	(Schellenberg, 1925)	Cosmopolitan				cry/est
<i>Linguimaera caesaris</i> **	Krapp-Schickel, 2003	Indo-Pacific		est		est
<i>Monocorophium sextonae</i>	(Crawford, 1937)	unknown	cry		cry	cry
<i>Parhyale explorator</i>	Arresti, 1989	NE Atlantic				cas
<i>Photis lamellifera</i>	Schellenberg, 1928	Indian				cas
<i>Rhabdosoma whitei</i>	Bate, 1862	Red Sea				cas
<i>Stenothoe gallensis</i>	Walker, 1904	Circumtropical	ques	est		est
<b>Cirripedia</b>						
<i>Amphibalanus eburneus</i> **	(Gould, 1841)	W Atlantic	est	est	est	est
<i>Austrominius modestus</i> **	Darwin, 1854	Tropical Pacific	est		est	
<i>Balanus reticulatus</i>	Utinomi, 1967	Circumtropical	ques			est
<i>Balanus trigonus</i>	Darwin, 1854	Circumtropical	est	est	est	est
<i>Heterosaccus dollfusi</i> <sup>p</sup>	Boschma, 1960	Red Sea				est
<i>Megabalanus tintinnabulum</i>	(Linnaeus, 1758)	Circumtropical	ques	ques		est
<i>Tetraclita squamosa rufotinta</i>	Pilsbry, 1916	Indo-Pacific		cas		
<b>Copepoda</b>						
<i>Acartia centrura</i>	Giesbrecht, 1889	Indian				cas
<i>Acartia fossae</i>	Gurney, 1927	Indo-Pacific				est
<i>Acartia tonsa</i>	Dana, 1849	W Atlantic / Indo-Pacific	est	est	est	est
<i>Arietellus pavoninus</i>	(G. O. Sars, 1905)	Tropical-subtropical			cas	est
<i>Calanopia biloba</i>	Bowman, 1957	W subtropical Atlantic				cas
<i>Calanopia elliptica</i>	(Dana, 1846)	Indo-Pacific	ques			est
<i>Calanopia media</i>	Gurney, 1927	Indo-Pacific				est
<i>Calanopia minor</i>	A. Scott, 1902	Indo-Pacific				cas
<i>Canuellina insignis</i>	Gurney, 1927	Indo-Pacific				ques
<i>Centropages furcatus</i>	(Dana, 1852)	Indo-Pacific/Atlantic				est
<i>Clavellisa ilishae</i> <sup>p</sup>	Pillai, 1962	Indian				est
<i>Enhydrosoma vicinum</i>	Por, 1967	Indo-Pacific				ques
<i>Euchaeta concinna</i>	Dana, 1849	Indo-Pacific		cas		cas
<i>Labidocera agilis</i>	(Dana, 1849)	Indo-Pacific				cas
<i>Labidocera detruncata</i>	(Dana, 1849)	Indo-Pacific	ques			cas
<i>Labidocera madurae</i>	(A. Scott, 1909)	Indo-Pacific				est
<i>Labidocera orsinii</i>	Giesbrecht, 1889	Red Sea				cas

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Labidocera pavo</i>	Giesbrecht, 1889	Indo-Pacific				est
<i>Metacalanus acutioperculum</i>	Ohtsuka, 1984	Pacific	est	est		
<i>Mitrapus oblongus</i> <sup>p</sup>	(Pillai, 1964)	Indian				est
<i>Mycicola ostreae</i> <sup>p</sup>	Hoshina & Sigiura, 1953	Pacific	est			
<i>Mytilicola orientalis</i> <sup>p</sup>	Mori, 1935	Pacific	est			
<i>Nothobomolochus fradei</i> <sup>p</sup>	Marques, 1965	Atlantic/Indian				est
<i>Paracalanus indicus</i>	Wolfenden, 1905	Subtropical Atlantic, Red Sea	cry/ques			
<i>Paracartia grani</i>	G. O. Sars, 1904	Atlantic	est	est	est	est
<i>Parvocalanus crassirostris</i> **	Dahl, 1894	Indo-Pacific/Atlantic	cas			est
<i>Parvocalanus elegans</i>	Andronov, 1972	Indo-Pacific				cas
<i>Parvocalanus latus</i>	Andronov, 1972	Indian				cas
<i>Pseudocyclops xiphophorus</i> <sup>p</sup>	Wells, 1967	Indian		cry		
<i>Pseudocalanus elongatus</i>	(Boeck, 1865)	E Atlantic	cry		cry	cry
<i>Robertsonia salsa</i>	Gurney, 1927	Indo-Pacific				ques
<i>Scaphocalanus amplius</i>	Park, 1970	Subtropical Atlantic	cas			
<i>Scaphocalanus brevirostris</i>	Park, 1970	Subtropical Atlantic/ Indian		cas		
<i>Scolecithrix valens</i>	Farran, 1926	Subtropical Atlantic	cas			
<i>Scottolana longipes</i>	(Thompson & Scott, 1903)	Indo-Pacific				ques
<i>Spinocalanus terranovae</i>	Damkaer, 1975	Antarctic		ques		ques
<i>Stenhelia inopinata</i>	(A. Scott, 1902)	Indo-Pacific				ques
<i>Stenhelia minuta</i>	(A. Scott, 1902)	Indo-Pacific				ques
<i>Subeucalanus subcrassus</i> **	Giesbrecht, 1888	Atlantic/Pacific	ques	ques		ques
<i>Triconia hawii</i>	(Böttger-Schnack & Boxshall, 1990)	Red Sea	est			
<i>Triconia rufa</i>	(Boxshall & Böttger, 1987)	Indian/Red Sea	est			ques
<i>Triconia umerus</i>	(Böttger-Schnack & Boxshall, 1990)	Red Sea	est	cas		cas
<b>Cumacea</b>						
<i>Eocuma rosae</i>	Corbera & Galil, 2007	Indo-Pacific/Red Sea				cas
<i>Eocuma sarsii</i>	(Kossmann, 1880)	Indo-Pacific	est			est
<i>Scherocumella gurneyi</i>	(Calman, 1927)	Red Sea				cas
<b>Decapoda</b>						
<i>Actumnus globulus</i>	Heller, 1861	Red Sea	cas			
<i>Alpheus audouini</i>	Coutiere, 1905	Indo West Pacific				est
<i>Alpheus inopinatus</i>	Holthuis & Gottlieb, 1958	Indian/Red Sea		cas		est
<i>Alpheus migrans</i>	Lewinsohn & Holthuis, 1978	Red Sea				est
<i>Alpheus rapacida</i>	de Man, 1908	Indo West Pacific				est
<i>Ashtoret lunaris</i>	(Forsskål, 1775)	Indo West Pacific				cas
<i>Atergatis roseus</i>	(Rüppell, 1830)	Indo-Pacific				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Calappa hepatica</i>	(Linnaeus, 1758)	Indo-Pacific				cas
<i>Calappa pelii</i>	Herklots, 1851	E Atlantic	cas	cas		cas
<i>Callinectes danae</i>	Smith, 1869	W Atlantic			cas	
<i>Callinectes sapidus</i>	Rathbun, 1896	W Atlantic	cas	cas	est	est
<i>Carupa tenuipes</i>	Dana, 1851	Indo-Pacific				est
<i>Charybdis feriata</i>	(Linnaeus, 1758)	Indo-Pacific	cas			
<i>Charybdis japonica</i>	(A. Milne-Edwards, 1861)	Indo-Pacific			cas	
<i>Charybdis helleri</i>	(A. Milne-Edwards, 1867)	Indo West Pacific				est
<i>Charybdis longicollis</i>	Leene, 1938	Indian/Red Sea				est
<i>Charybdis lucifera</i>	(Fabricius, 1798)	Indo-Pacific			cas	
<i>Coleusia signata</i>	(Paulson, 1875)	Indo West Pacific				est
<i>Cryptosoma cristatum</i>	Brulle, 1837	Tropical East Atlantic	cas			
<i>Daira perlata</i>	(Herbst, 1790)	Indo West Pacific				cas
<i>Dorippe quadridens</i>	(Fabricius, 1793)	Indo West Pacific				est
<i>Dyspanopeus sayi</i>	(Smith, 1869)	N East Atlantic			est	
<i>Eriocheir sinensis</i>	H. Milne Edwards, 1853	Pacific	cas		cas	
<i>Eucrate crenata</i>	de Haan, 1835	Indo-Pacific		est		est
<i>Eurycarcinus integrifrons</i>	de Man, 1879	Indian/Red Sea				cas
<i>Farfantepenaeus aztecus</i>	(Ives, 1891)	W Atlantic				est
<i>Fenneropenaeus merguensis</i>	(De Man, 1888)	Indo West Pacific				cas
<i>Glabropilumnus laevis**</i>	(Dana, 1852)	Indian	cas			cas
<i>Gonioinfradens paucidentata</i>	(A. Milne Edwards, 1861)	Indo-Pacific				est?
<i>Grapsus granulosus</i>	H. Milne-Edwards, 1853	Red Sea		cas		
<i>Halimede tyche</i>	(Herbst, 1801)	Indo West Pacific				cas
<i>Hemigrapsus sanguineus</i>	(de Haan, 1835)	Pacific	cas		cas	
<i>Herbstia nitida</i>	Manning & Holthuis, 1981	Tropical East Atlantic			cas	
<i>Hyastenus hilgendorfi</i>	de Man, 1887	Indo West Pacific				est
<i>Ixa monodi</i>	Holthuis & Gottlieb, 1956	Red Sea				est
<i>Leptochela aculeocaudata</i>	Paulson, 1875	Indo West Pacific				est
<i>Leptochela pugnax</i>	de Man, 1916	Indo West Pacific				est
<i>Libinia dubia</i>	H. Milne Edwards, 1834	W Atlantic		est		
<i>Lucifer hanseni</i>	Nobili, 1905	Indo West Pacific				ques
<i>Macrophthalmus graeffei</i>	A. Milne Edwards, 1873	Indo West Pacific				est
<i>Marsupenaeus japonicus</i>	(Bate, 1888)	Indo-Pacific	cas	cas	cas	est
<i>Melicertus hathor</i>	(Burkenroad, 1959)	Indian				est
<i>Menaethius monoceros</i>	(Latreille, 1825)	Indo-Pacific	cas			
<i>Metapenaeopsis aegyptia</i>	Galil & Golani, 1990	Indo-Pacific				est
<i>Metapenaeopsis mogiensis consobrina</i>	(Nobili, 1904)	Indo West Pacific				est
<i>Metapenaeus affinis</i>	(H. Milne Edwards, 1837)	Indo West Pacific				est
<i>Metapenaeus monoceros</i>	(Fabricius, 1798)	Indo West Pacific		est		est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Metapenaeus stebbingi</i>	(Nobili, 1904)	Indian		est		est
<i>Micippa thalia</i>	(Herbst, 1803)	Indo West Pacific				est
<i>Myra subgranulata</i>	Kossmann, 1877	Indian/Red Sea				est
<i>Necora puber</i>	(Linnaeus, 1767)	NW Atlantic	est	est		cas
<i>Notopus dorsipes</i>	(Linnaeus, 1758)	Indo West Pacific				cas
<i>Ogyrides mjoebergi</i>	(Bals, 1921)	Indo West Pacific				est
<i>Palaemonella rotumana</i>	(Borradaile, 1898)	Indo West Pacific				est
<i>Palinurus ornatus</i>	(Fabricius, 1798)	Indo West Pacific				cas
<i>Paralithodes camtschaticus</i>	(Tilesius, 1815)	NE Pacific		cas		
<i>Penaeus semisulcatus</i>	de Haan, 1844	Indo West Pacific				est
<i>Percnon gibbesi</i>	(H. Milne Edwards, 1853)	W Atlantic	est	est	cas	est
<i>Periclimenes calmani</i>	Tattersall, 1921	Indo-Pacific				cas
<i>Pilumnopus vauquelini</i>	(Audouin, 1826)	Indian/Red Sea	cas	est		est
<i>Pilumnus minutus**</i>	de Haan, 1835	Indo-Pacific		cas		est
<i>Plagusia squamosa</i>	(Herbst, 1790)	Indo West Pacific	ques	est	cas	cas
<i>Portunus segnis**</i>	(Forsskål, 1775)	Indian	cas	est		est
<i>Processa macrodactyla</i>	Holthuis, 1952	Tropical East Atlantic	est?			cas
<i>Rhithropanopeus harrisi</i>	(Gould, 1841)	Noth Atlantic	cas?	est	est	
<i>Rimapenaeus similis</i>	(Smith, 1885)	W Atlantic		est		
<i>Scyllarus caparti</i>	Holthuis, 1952	Tropical East Atlantic			cas	
<i>Scyllarus posteli</i>	Forest, 1963	Temperate-tropical East Atlantic	cas			
<i>Sirpus monodi</i>	Gordon, 1953	Tropical East Atlantic		cas		cas
<i>Solenocera crassicomis</i>	(H.Milne Edwards, 1837)	Indo West Pacific				cas
<i>Sphaerozius nitidus</i>	Stimpson, 1858	Indo West Pacific				cas
<i>Stenodromia spinirostris**</i>	(Miers, 1881)	Tropical East Atlantic		cas		
<i>Synalpheus tumidomanus africanus**</i>	Crosnier & Forest, 1966	Tropical East Atlantic	cry			cry
<i>Thalamita gloriensis</i>	Crosnier, 1962	Indo West Pacific	cas			
<i>Thalamita indistincta</i>	Apel & Spiridonov, 1998	Indian				cas
<i>Thalamita poissonii</i>	(Audouin, 1826)	Indo West Pacific		cry		cry
<i>Trachysalambria palaestinensis</i>	(Steinitz, 1932)	Red Sea		est		est
<i>Urocardella pulchella</i>	Yokes & Galil, 2006	Indo-Pacific				est
<b>Isopoda</b>						
<i>Anilocra pilchardi<sup>p</sup></i>	Bariche & Trilles, 2006	Indo-Pacific				cas
<i>Apanthura sandalensis</i>	Stebbing, 1900	S Africa		est		est
<i>Cymothoa indica<sup>p</sup></i>	Schioedte & Meinert, 1884	Indo-Pacific				cas
<i>Mesanthura</i> spp.		Tropical/subtropical	ques	ques		ques
<i>Paracerceis sculpta</i>	(Holmes, 1904)	Subtropical	est	est	est	est
<i>Paradella dianae</i>	(Menzies, 1962)	NE Pacific	est	est?		est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Sphaeroma venustissimum</i>	Monod, 1931	Tropical/subtropical E Atlantic	est			
<i>Sphaeroma walkeri</i>	Stebbing, 1905	Indian	est	est		est
<b>Stomatopoda</b>						
<i>Clorida albolitura</i>	Ahyong & Naiyanetr, 2000	Indo West Pacific				est
<i>Erygosquilla massavensis</i>	(Kossmann, 1880)	Indian/Red Sea		est		est
<i>Erythroquilla</i> sp. (postlarvae)		Indo-Pacific	cas			
<b>Tanaidacea</b>						
<i>Zeuxo (Parazeuxo) coralensis</i>	Sieg, 1980	Circumtropical				est
<b>MOLLUSCA</b>						
<b>Bivalvia</b>						
<i>Acar plicata</i>	(Dillwyn, 1817)	Indo-Pacific/Red Sea				cas
<i>Afrocardium richardi</i>	(Audouin, 1826)	Red Sea				est
<i>Alectryonella crenulifera</i>	(Sowerby, 1871)	Pacific/Red Sea				ques
<i>Anadara granosa</i>	(Linnaeus, 1758)	Indo West Pacific				cas
<i>Anadara inflata</i>	(L. A. Reeve, 1844)	NW Pacific				cas
<i>Anadara kagoshimensis</i> **	(Tokunaga, 1906)	Temperate North Pacific	est		est	est
<i>Anadara natalensis</i>	(Krauss, 1848)	W Pacific/Red Sea				est
<i>Anadara transversa</i> **	(Say, 1822)	W Atlantic	est	est	est	est
<i>Angulus flacca</i>	(Roemer, 1871)	Indo Pacific/Red Sea				cas
<i>Antigona lamellaris</i>	Schumacher, 1817	Indo-Pacific/Red Sea				cas
<i>Atactodea glabrata</i>	(Gmelin, 1791)	Indo Pacific/Red Sea		cas		cas
<i>Brachidontes pharaonis</i>	(Fischer, 1870)	Indian/Red Sea	est	est	est	est
<i>Callista florida</i>	(Lamarck, 1818)	Indian/Red Sea	cas			cas
<i>Cardites akabana</i>	(Sturany, 1899)	Red Sea				cas
<i>Chama asperella</i>	Lamarck, 1819	Indo-Pacific/Red Sea				cas
<i>Chama aspersa</i>	Reeve, 1846	Indo-Pacific				est
<i>Chama pacifica</i>	Broderip, 1834	Indo-Pacific				est
<i>Circe scripta</i>	(Linnaeus, 1758)	Indo West Pacific				cas
<i>Circenita callipyga</i>	(von Born, 1778)	Red Sea				cas
<i>Clementia papyracea</i>	(Gray, 1825)	Indo-Pacific/Red Sea				est
<i>Crassostrea gigas</i>	(Thunberg, 1793)	NW Pacific	est	est	est	est
<i>Dendrostrea frons</i>	(Linnaeus, 1758)	Indo Pacific/Red Sea				est
<i>Diplodonta bogii</i> **	Van Aartsen, 2004	Red Sea				est
<i>Divalinga arabica</i>	Dekker & Gould, 1994	Persian Gulf/Red Sea				cas
<i>Dosinia erythraea</i>	Römer, 1860	W Pacific/Red Sea				est
<i>Electroma vexillum</i>	(Reeve, 1857)	Indian/Red Sea				est
<i>Ensiculus cultellus</i>	(Linnaeus, 1758)	Indo West Pacific				cas
<i>Fulvia australis</i>	(Sowerby G.B., 1834)	Indo-Pacific/Red Sea				cas
<i>Fulvia fragilis</i>	(Forsskål, 1775)	Indian	est	est		est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Gafrarium pectinatum</i>	(Linnaeus, 1758)	Indo-Pacific/Red Sea				est
<i>Glycymeris arabicus</i>	(Adams H., 1871)	W Pacific/Red Sea				cas
<i>Hiatula ruppelliana</i>	(Reeve, 1857)	Red Sea				cas
<i>Laternula anatina</i>	(Linnaeus, 1758)	Indo-Pacific/Red Sea				est
<i>Limopsis multistriata</i>	(Forsskål, 1775)	Indo-Pacific/Red Sea				cas
<i>Maetra lilacea</i>	Lamarck, 1818	Indo-Pacific/Red Sea				est
<i>Maetra olorina</i>	Philippi, 1846	Red Sea				est
<i>Malvufundus regula</i>	(Forsskål, 1775)	Indo-Pacific/Red Sea		est		est
<i>Mercenaria mercenaria</i>	(Linnaeus, 1758)	W Atlantic	est		est	
<i>Modiolus auriculatus</i>	(Krauss, 1848)	Indian/Red Sea				est
<i>Musculista perfragilis</i>	(Dunker, 1857)	Indo-Pacific/Red Sea				est
<i>Musculista senhousia</i>	(Benson in Cantor, 1842)	Temperate North Pacific	est	est	est	est
<i>Mya arenaria</i>	Linnaeus, 1758	N Atlantic	est		est	est
<i>Mytilopsis sallei</i>	(Recluz, 1849)	W Atlantic				est
<i>Nanostrea exigua</i>	Harry, 1985	Indo-Pacific				est
<i>Paphia textile</i>	(Gmelin, 1791)	Indo-Pacific/Red Sea				est
<i>Pedicirca sulcata</i>	(Gray, 1838)	Red Sea				ques
<i>Petricola hemprichi</i>	(Issel, 1869)	Indo-Pacific				est
<i>Petricola pholadiformis</i>	Lamarck, 1818	W Atlantic				est
<i>Pinctada margaritifera</i>	(Linnaeus, 1758)	Indo-Pacific/Red Sea				ques
<i>Pinctada radiata</i>	(Leach, 1814)	Indo-Pacific/Red Sea	est	est	cas	est
<i>Psammotreta praerupta</i>	(Salisbury, 1934)	Indo-Pacific/Red Sea				cas
<i>Pseudochama corbieri</i>	(Jonas, 1846)	Red Sea				est
<i>Ruditapes philippinarum</i>	(Adams & Reeve, 1850)	Temperate North Pacific	est	est	est	est
<i>Saccostrea commercialis</i>	(Iredale & Roughley, 1933)	Australia			cas	
<i>Saccostrea cucullata</i>	(Born, 1778)	Indo-Pacific	ques			est
<i>Septifer bilocularis</i>	(Linnaeus, 1758)	Indo-Pacific				cas
<i>Septifer forskali</i>	Dunker, 1855	Red Sea				est
<i>Sphenia rueppelli</i>	A. Adams, 1850	Indian				est
<i>Spondylus groschi</i>	Lamprell & Kilburn, 1995	Indian/Red Sea				ques
<i>Spondylus cf. multisetosus</i>	Reeve, 1856	Indo-Pacific				ques
<i>Spondylus nicobaricus</i>	Schreibers, 1793	Indo-Pacific				cas
<i>Spondylus spinosus</i>	Schreibers, 1793	Indo-Pacific/Red Sea				est
<i>Tellina valtonis</i>	Hanley, 1844	Indian/Red Sea				est
<i>Teredo navalis</i>	Linnaeus, 1758	Circumtropical			cry	cry
<i>Theora lubrica</i>	Gould, 1861	Indo-Pacific	est			est
<i>Timoclea marica</i>	(Linnaeus, 1758)	Red Sea				cas
<i>Trapezium oblongum</i>	(Linnaeus, 1758)	Indo-Pacific/Red Sea				ques
<i>Xenostrobus securis</i>	(Lamarck, 1819)	Tropical Atlantic	est		est	

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Zygochlamys patagonica</i> **	(King & Broderip, 1832)	W Atlantic	cas	cas		
<b>Cephalopoda</b>						
<i>Octopus aegina</i>	Gray, 1849	Indo-Pacific/Red Sea				est
<i>Octopus cyanea</i>	Gray, 1849	Indo-Pacific				cas
<i>Sepia gibba</i>	Ehrenberg, 1831	Red Sea				cas
<i>Sepia pharaonis</i>	Ehrenberg, 1831	Pacific/Red Sea				ques
<i>Sepioeuthis lessoniana</i>	Lesson, 1830	Indo-Pacific				est
<i>Tremoctopus gracilis</i>	(Eydoux & Souleyet, 1852)	Indo-Pacific	cas		cas	
<b>Gastropoda</b>						
<i>Acteocina crithodes</i>	Melville & Standen, 1907	Indo-Pacific/W Indian				cas
<i>Acteocina mucronata</i>	(Philippi, 1849)	Red Sea		ques		est
<i>Alvania dorbignyi</i>	(Audouin, 1826)	Cosmopolitan	cry	cry		cry
<i>Amathina tricarinata</i>	(Linnaeus, 1767)	Red Sea				est
<i>Angiola punctostriata</i>	(Smith E.A., 1872)	Red Sea				ques
<i>Anteaeolidiella foulisi</i> **	(Angas, 1864)	Circumtropical	cas	cas		
<i>Aplysia dactylomela</i>	Rang, 1828	Circumtropical		est	est	est
<i>Aplysia parvula</i>	Guilding in Mörch, 1863	Circumtropical		cry	cry	cry
<i>Ays angustatus</i>	Smith, 1872	Red Sea				cry
<i>Ays cylindricus</i>	(Helbling, 1779)	Indo-Pacific/Red Sea				cas
<i>Bostrycapulus odites</i> **	Collin, 2005	Tropical Atlantic	est			
<i>Bulla arabica</i> **	Malaquias & Reid, 2008	Indo-Pacific				est
<i>Bursatella leachii</i>	De Blainville, 1817	Circumtropical	est	est	est	est
<i>Calonia indica</i>	(Bergh, 1896)	Indo-Pacific				cas
<i>Canarium mutabile</i> **	(Swainson, 1821)	Indo-Pacific/Red Sea				ques
<i>Cantharus tranquebaricus</i>	(Gmelin, 1791)	Indian				cas
<i>Cellana rota</i>	(Gmelin, 1791)	Indian/Red Sea		cas	cas	est
<i>Cerithidium diplax</i> **	(Watson, 1886)	Persian Gulf				est
<i>Cerithidium perparvulum</i> **	(Watson, 1886)	Pacific				est
<i>Cerithiopsis pulvis</i>	(Issel, 1869)	Red Sea				est
<i>Cerithiopsis tenthrenois</i>	(Melville, 1896)	Indian				est
<i>Cerithium columna</i>	Sowerby 1834	Indo West Pacific				ques
<i>Cerithium egenum</i>	Gould, 1849	Indo-Pacific/Red Sea				est
<i>Cerithium litteratum</i>	(Born, 1778)	W Atlantic				cas
<i>Cerithium nesioticum</i>	Pilsbry & Vannata, 1906	Indian/Red Sea				est
<i>Cerithium nodulosum</i>	Bruguère, 1792	Indo West Pacific				ques
<i>Cerithium scabridum</i>	Philippi, 1848	Indian/Red Sea	est	est		est
<i>Chelidonura fulvipunctata</i>	Baba, 1938	Indo-Pacific		est		est
<i>Chromodoris annulata</i>	(Eliot, 1904)	Indian				est
<i>Chromodoris quadricolor</i>	(Rüppell & Leuckart, 1828)	Red Sea	cas	cas		est
<i>Chrysallida fischeri</i>	Hornung & Mermod, 1925)	Red Sea			est	est
<i>Chrysallida maiae</i>	(Hornung & Mermod, 1924)	Red Sea				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Chrysallida micronana</i>	Öztürk & van Aartsen, 2006	Red Sea				cas
<i>Chrysallida pirintella</i>	(Melvill, 1910)	Red Sea				est
<i>Cingulina isseli</i>	(Tryon, 1886)	Subtropical				est
<i>Clypeomorus bifasciatus</i>	(Sowerby G.B. II, 1855)	Indo-Pacific/Red Sea		cas		est
<i>Conomurex persicus**</i>	(Swainson, 1821)	Persian Gulf		est	cas	est
<i>Conus arenatus</i>	Hwass, 1792	Indo-Pacific/Red Sea				cas
<i>Conus fumigatus</i>	Hwass, 1792	Red Sea		cas		
<i>Conus inscriptus</i>	Reeve, 1843	Indian				cas
<i>Conus rattus</i>	Hwass, 1792	Indo-Pacific				cas
<i>Coralliobia madreporarum</i>	(Sowerby, 1832)	Pantropical			cas	cas
<i>Crepidula fornicata</i>	(Linnaeus, 1758)	NW Atlantic	est	cas		est
<i>Cuthona perca</i>	(Marcus, 1958)	Tropical Atlantic			cas	
<i>Cycloscala hyalina</i>	(Sowerby, 1844)	Indo-Pacific/Red Sea				est
<i>Cylichnina girardi</i>	(Audouin, 1826)	Indo-Pacific				est
<i>Dendrodoris fumata</i>	(Rüppell & Leuckart, 1830)	Indo Pacific/Red Sea				cas
<i>Diala semistriata</i>	(Philippi, 1849)	Indo-Pacific/Red Sea				est
<i>Diodora funiculata</i>	(Reeve, 1850)	Indo-Pacific				est
<i>Diodora ruppellii</i>	(Sowerby, 1834)	Indo-Pacific/Red Sea		cas		est
<i>Discodoris lilacina</i>	(Gould, 1852)	Indo-Pacific/Red Sea	cry			cry
<i>Doxander vittatus**</i>	(Linnaeus, 1758)	Indo-Pacific				cas
<i>Echinolittorina punctata</i>	(Gmelin, 1791)	Tropical Atlantic	Native	est		Native
<i>Elysia grandifolia</i>	Kelaart, 1858	Indian				est
<i>Elysia tomentosa</i>	Jensen, 1997	Indo West Pacific				est
<i>Engina mendicaria</i>	(Linnaeus, 1758)	Indo West Pacific				cas
<i>Ergalatax contracta</i>	(Reeve, 1846)	Red Sea				cas
<i>Ergalatax junionae**</i>	Houart, 2008	Persian Gulf/Red Sea				est
<i>Erosaria turdus</i>	(Lamarck, 1810)	Indian/Red Sea		est		est
<i>Ethminolia hemprichi</i>	(Issel, 1869)	Red Sea				cas
<i>Favorinus ghanensis</i>	Edmunds, 1968	Tropical Atlantic	est			
<i>Finella pupoides</i>	A. Adams, 1860	Indo-Pacific				est
<i>Flabellina rubrolineata</i>	(O'Donoghue, 1929)	Indo-Pacific/Red Sea				est
<i>Fusinus verrucosus</i>	(Gmelin, 1791)	Indian				est
<i>Gastrochaena cymbium</i>	(Spengler, 1783)	Indo-Pacific/Red Sea				est
<i>Gibborissoa virgata</i>	(Philippi, 1849)	Indo-Pacific				est
<i>Gibbula albida</i>	(Gmelin, 1791)	Adriatic Sea	est		Native	
<i>Godiva quadricolor</i>	(Barnard, 1927)	Eastern Pacific	cas			
<i>Halgerda willeyi</i>	Elliot 1904	Indo West Pacific			cas	
<i>Haliotis pustulata cruenta</i>	Reeve, 1846	Indian/Red Sea		cas		cas
<i>Haminoea cyanomarginata</i>	Heller & Thompson, 1983	Red Sea		est		est
<i>Haminoea japonica**</i>	(Pilsbry, 1895)	Pacific			est	
<i>Hinemoa cylindrica</i>	(de Folin, 1879)	Indo-Pacific				cas

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Hypselodoris infucata</i>	(Rüppell & Leuckart, 1828)	Indo-Pacific/Red Sea				est
<i>Iolaea neofelixoides</i>	(Nomura, 1936)	Pacific				cas
<i>Leucotina</i> cfr <i>eva</i>	Thiele, 1935	Indo-Pacific				cas
<i>Leucotina natalensis</i> **	Smith, 1910	Indo-Pacific/Red Sea				est
<i>Lienardia mighelsi</i>	Iredale & Tomlin, 1917	Pacific				cas
<i>Littorina saxatilis</i>	(Olivi, 1792)	Atlantic			cry	
<i>Melibe viridis</i> **	(Kelaart, 1858)	Indo-Pacific	est	est	est	est
<i>Metaxia bacillum</i>	(Issel, 1869)	Red Sea				est
<i>Mitrella psilla</i>	(Duclos, 1846)	Tropical Atlantic	est			
<i>Monetaria annulus</i>	(Linnaeus, 1758)	Indo-Pacific		ques		
<i>Monotigma lauta</i> **	(A. Adams, 1853)	Indo-Pacific/Red Sea				est
<i>Murchisonella columna</i>	(Hedley, 1907)	Indo-Pacific				cas
<i>Murex forskoehlii</i>	Roeding, 1798	Persian Gulf/Red Sea				est
<i>Nassa situla</i>	(Reeve, 1846)	Indo-Pacific				cas
<i>Nassarius arcularia plicatus</i>	(Roeding, 1798)	Indian/Red Sea				cas
<i>Nassarius concinnus</i>	(Powys, 1835)	unknown				cas
<i>Nassarius stolatus</i>	(Gmelin, 1791)	Indo-Pacific				cas
<i>Nerita sanguinolenta</i>	Menke, 1829	Red Sea		cas		est
<i>Notocochlis gualteriana</i> **	(Recluz, 1844)	Indo-Pacific/Red Sea		cas		est
<i>Odostomia lorioli</i>	(Hornung & Mermod, 1924)	Red Sea				cas
<i>Oscilla jocosa</i>	Melville, 1904	Persian Gulf				cas
<i>Oxynoe viridis</i>	(Pease, 1861)	Indo West Pacific				est
<i>Palmadusta lentiginosa</i>	(Gray, 1825)	Indian				cas
<i>Parviturbo dibellai</i>	Buzzurro & Celalupo, 2006	unknown				cry
<i>Patelloida saccharina</i>	(Linnaeus, 1758)	Pacific				cas
<i>Philinopsis cyanea</i>	(Martens, 1879)	Indian/Red Sea				cas
<i>Planaxis griseus</i>	(Brocchi, 1821)	Red Sea				cas
<i>Pleurobranchus forskalii</i>	Rüppell & Leuckart, 1828	Red Sea				cas
<i>Plocamopherus ocellatus</i>	Rüppell & Leuckart, 1830	Red Sea				est
<i>Polycera hedgpethi</i>	Marcus Er., 1964	NE Pacific	cas		cas	
<i>Polycerella emertoni</i>	Verrill, 1881	Pantropical	est	est		
<i>Pseudominolia nedyma</i>	Melville, 1897	Persian Gulf/Red Sea				est
<i>Purpuradusta gracilis notata</i>	(Gill, 1858)	Indian/Red Sea				est
<i>Pyrumculus fourierii</i>	(Audouin, 1826)	Indo-Pacific/Red Sea				est
<i>Rapana rapiformis</i>	(Von Born, 1778)	Indo-Pacific/Red Sea				ques
<i>Rapana venosa</i>	(Valenciennes, 1846)	Temperate North Pacific	est		est	est
<i>Retusa desgenettii</i>	(Audouin, 1826)	Red Sea				cas
<i>Rhinoclavis kochi</i>	(Philippi, 1848)	Indo-Pacific/Red Sea				est
<i>Rhinoclavis sinensis</i>	(Gmelin, 1791)	Indo West Pacific				cas

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Rissoina ambigua</i>	(Gould, 1849)	Indo-Pacific				cas
<i>Rissoina bertholleti</i>	Issel, 1869	Indian/Red Sea				est
<i>Rissoina spirata</i>	Sowerby, 1825	Indo-Pacific	cas			cas
<i>Sabia conica</i>	(Schumacher, 1817)	Indo-Pacific/Red Sea		ques		ques
<i>Siphonaria crenata</i>	de Blainville, 1827	Persian Gulf/ Arabian Sea				est
<i>Siphonaria pectinata</i>	(Linnaeus, 1758)	Atlanto-Mediterranean	Native			est
<i>Smaragdia souverbiana</i>	(Montrouzier, 1863)	Indo-Pacific/Red Sea				est
<i>Sticteulima cf. lentiginosa</i>	(A. Adams, 1861)	Indo-Pacific				cas
<i>Stomatella impertusa</i>	(Burrow, 1815)	Indo-Pacific/Red Sea				cas
<i>Syphonota geographica</i>	(Adams & Reeve, 1850)	Circumtropical		est		est
<i>Symola cinctella</i>	A. Adams, 1860	Indo-Pacific/Red Sea				cas
<i>Symola fasciata</i>	(Jickeli, 1882)	Indo-Pacific				est
<i>Symola lendix**</i>	(A. Adams, 1863)	Red Sea				est
<i>Thais lacera</i>	(von Born, 1778)	Indian	cas			est
<i>Thais sacellum</i>	(Gmelin, 1791)	Indian/Red Sea				est
<i>Tornus jullieni</i>	Adam & Knudsen 1969	W Africa		ques		
<i>Trivirostra triticum</i>	Schilder, 1932	Indo-Pacific				cas
<i>Trochus erithreus</i>	Brocchi, 1821	Persian Gulf				est
<i>Turbonilla edgarii</i>	(Melvill, 1896)	Indo-Pacific				est
<i>Vexillum depexum</i>	(Deshayes in Laborde, 1834)	Indian/Red Sea				ques
<i>Voorwindia tiberiana</i>	(Issel, 1869)	Red Sea				cas
<i>Zafra savignyi</i>	(Moazzo, 1939)	Red Sea				est
<i>Zafra selasphora</i>	(Melvill & Standen, 1901)	Indian/Red Sea				est
<b>Polyplacophora</b>						
<i>Acanthopleura gemmata</i>	(de Blainville, 1825)	Indo-Pacific/Red Sea		cas		
<i>Chiton hululensis</i>	(Smith E.E. in Gardiner, 1903)	Indo-Pacific/Red Sea				ques
<b>MISCELLANEA INVERTEBRATA</b>						
<b>Arthropoda/Pycnogonida</b>						
<i>Ammothea hilgendorfi</i>	(Böhm, 1879)	Circumboreal			est	
<i>Anoplodactylus californicus</i>	Hall, 1912	Circum(sub)tropical	est			est
<i>Anoplodactylus digitatus</i>	(Böhm, 1879)	Circum(sub)tropical				est
<i>Pigrogromitus timsanus</i>	Calman, 1927	Circum(sub)tropical				ques
<b>Bryozoa</b>						
<i>Aeverillia setigera</i>	(Hincks, 1887)	Circumtropical				cas
<i>Arachnoidea protecta</i>	(Harmer, 1915)	Indo-Pacific	ques			
<i>Bowerbankia gracillima</i>	(Hincks, 1877)	E Atlantic	cas	cas		
<i>Bugula fulva</i>	Ryland, 1960	NW Atlantic	est	cas	cas	cas
<i>Bugula serrata</i>	(Lamarck, 1816)	Indo-Pacific	est			
<i>Celleporaria aperta</i>	(Hincks, 1882)	Circumtropical		ques		est
<i>Celleporaria brunnea</i>	(Hincks, 1884)	NE Pacific				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Celleporaria pilaefera</i>	(Canu & Bassler, 1929)	Indo-W Pacific		ques		
<i>Celleporella carolinensis</i>	Ryland, 1979	W Atlantic			est	
<i>Crepidacantha poissoni</i>	(Audouin, 1826)	Circumtropical		ques		
<i>Electra tenella</i>	(Hincks, 1880)	Circumtropical		cas		
<i>Hippaliosina acutirostris</i>	Canu & Bassler, 1929	Indo-Pacific				ques
<i>Hippopodina feejeensis</i>	(Busk, 1884)	Indo-Pacific				cas
<i>Parasmittina egyptiaca</i>	(Waters, 1909)	Indian				est
<i>Parasmittina serruloides</i>	Harmelin, Bitar & Zibrowius, 2009	Indo-Pacific				est
<i>Parasmittina spondylicola</i>	Harmelin, Bitar & Zibrowius, 2009	Indo-Pacific				cas
<i>Pherusella brevituba</i>	Soule, 1951	NE Pacific	cas	cas		
<i>Reteporella jermanensis</i>	(Waters, 1909)	Red Sea				cas
<i>Rhynchozoon lareyi</i>	(Audouin, 1826)	Indo-Pacific				est
<i>Schizoretepora hassi</i>	Harmelin, Bitar & Zibrowius, 2007	Red Sea?				ques
<i>Scrupocellaria jolloisii</i>	(Audouin, 1826)	Indo-Pacific				est
<i>Smittina malleolus</i>	(Hincks, 1884)	Circumtropical				est
<i>Tricellaria inopinata</i>	d'Hondt & Occhipinti, 1985	Indo-Pacific		est	est	
<b>Chaetognatha</b>						
<i>Aidanosagitta neglecta</i> *	Aida, 1897	Indo-Pacific				est
<i>Ferosagitta galerita</i> *	(Dallot, 1971)	Indian				est
<b>Chordata/Ascidiacea</b>						
<i>Ascidia cannelata</i>	Oken, 1820	Indo-Pacific				est
<i>Botrylloides violaceus</i>	Oka, 1927	NW Pacific			est	
<i>Cystodytes philippinensis</i>	Herdman, 1886	Circumtropical	cry	cry		
<i>Distaplia bermudensis</i>	Van Name, 1902	W Atlantic	est	est		
<i>Ecteinascidia styeloides</i>	(Traustedt, 1882)	Circumtropical	est	est		
<i>Ecteinascidia thurstoni</i>	Herdman, 1890	Indo-Pacific				est
<i>Herdmania momus</i>	(Savigny 1816)	Indo-Pacific				est
<i>Microcosmus exasperatus</i>	Heller, 1878	Indo-Pacific		est		est
<i>Microcosmus squamiger</i>	Hartmeyer & Michaelsen, 1928	Circumtropical	est	est		
<i>Perophora multiclathrata</i>	(Sluiter, 1904)	Circumtropical	est			
<i>Phallusia nigra</i>	Savigny, 1816	Circumtropical				est
<i>Polyandrocarpa zorritensis</i>	(Van Name, 1931)	E Pacific	est	est		
<i>Rhodosome turcicum</i>	(Savigny, 1816)	Circumtropical	cas	cas		est
<i>Styela clava</i>	Herdman, 1881	NW Pacific	cas			
<i>Symplegma brakenhielmi</i>	(Michaelsen, 1904)	Indo-Pacific				est
<i>Trididemnum cf. savignii</i>	(Herdman, 1886)	Circum(sub)tropical	est	cas		
<b>Cnidaria/Anthozoa</b>						
<i>Acabaria erythraea</i>	(Ehrenberg, 1834)	Indo-Pacific				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Diadumene cincta</i>	Stephenson, 1925	NE Atlantic			est	
<i>Haliplanella lineata</i>	(Verrill, 1870)	Circumboreal	est			
<i>Oculina patagonica</i>	De Angelis, 1908	?SW Atlantic	est			est
<b>Cnidaria/Hydrozoa</b>						
<i>Aequorea conica</i> *	Browne, 1905	Indo-Pacific				cas
<i>Amphogona pusilla</i> *	Hartlaub, 1909	Indo-Pacific	cas			
<i>Arctapodema australis</i> *		Antarctic/Indo-Pacific	cas		cas	
<i>Bougainvillia niobe</i>	Mayer, 1894	(sub)tropical W Atlantic				est
<i>Campalecium medusifera</i> *	Torrey, 1902	E Pacific/ Atlantic	est	cas		
<i>Cirrhovenia tetranema</i> *	Kramp, 1959	Circumtropical	est			cas
<i>Clytia hummelincki</i> *	(Leloup, 1935)	Circumtropical	est	est	est	
<i>Clytia linearis</i> **	(Thornely, 1900)	Circum(sub)tropical	est	est	est	est
<i>Clytia mccradyi</i> *	(Brooks, 1888)	Circumtropical	est			est
<i>Cordylophora caspia</i>	(Pallas, 1771)	Circumglobal	cry	cry	cry	cry
<i>Coryne eximia</i> *	Allman, 1859	Circum(sub)tropical	ques		ques	
<i>Diphasia digitalis</i>	(Busk 1852)	Circumtropical				cas
<i>Dynamena quadridentata</i>	(Ellis & Solander, 1786)	Circumtropical				est
<i>Eirene viridula</i> *	(Péron & Lesueur, 1810)	Circumtropical	est	est	est	est
<i>Euheilotia paradoxica</i> *	Mayer, 1900	Circumtropical	cas	cas	cas	est
<i>Eudendrium carneum</i>	Clarke, 1882	Circumtropical	est		cas	est
<i>Eudendrium merulum</i>	Watson, 1985	Circumtropical	est		cas	est
<i>Euphysora annulata</i> *	Kramp, 1928	Indo-Pacific			cas	cas
<i>Euphysora bigelowi</i> *	Maas, 1905	Indo-Pacific				cas
<i>Filellum serratum</i> *	(Clarke, 1879)	Circum(sub)tropical	cas			
<i>Garveia franciscana</i>	(Torrey, 1902)	Circum(sub)tropical	cas		est	
<i>Gonionemus vertens</i> *	A. Agassiz, 1862	Circumboreal	est		est	
<i>Kantiella enigmatica</i> *	Bouillon, 1978	Indian				cas
<i>Laodicea fijiana</i> *	Agassiz & Mayer, 1899	Indo-Pacific				cas
<i>Macrorhynchia philippina</i>	(Kirchenpauer, 1872)	Circumtropical				est
<i>Moerisia carina</i> *	Bouillon, 1978	Indo-Pacific				est
<i>Moerisia inkermanica</i> *	Paltschikowa-Ostroumova, 1925	Circum(sub)tropical	cas			cas
<i>Nubiella mitra</i> *	Bouillon, 1980	SW Pacific				cas
<i>Ocotiara russelli</i> *	Kramp, 1953	Indo-Pacific	cas			
<i>Olindias singularis</i> *	Browne, 1905	Indian				est
<i>Paracystaeis octona</i> *	Bouillon, 1978	W Indian				cas
<i>Russellia mirabilis</i>	Kramp, 1957	Antarctic	cas			
<i>Scolionema suvaensis</i> *	(Agassiz & Mayer, 1899)	Indo-Pacific	est			
<i>Sertularia marginata</i>	(Kirchenpauer, 1864)	Circum(sub)tropical	est			est
<i>Sertularia thecocarpa</i>	(Jarvis, 1922)	Indo-Pacific				est
<i>Tetrorchis erythrogaster</i> *	Bigelow, 1909	Circumtropical				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Trichydra pudica</i> *	Wright, 1858	Circumtropical			cas	cas
<b>Cnidaria/Scyphozoa</b>						
<i>Cassiopea andromeda</i>	(Forsskål, 1775)	Indo-Pacific		est?		est
<i>Marivagia stellata</i>	Galil & Gershwin, 2010	?Indo-Pacific Circumtropical				est
<i>Phyllorhiza punctata</i> *	von Lendenfeld, 1884	Circumtropical	cas	cas		est
<i>Rhopilema nomadica</i> *	Galil, Spanner & Ferguson, 1990	Red Sea		cas		est
<i>Stomolophus meleagris</i> *	(L. Agassiz, 1862)	Atlantic/Pacific	cas			
<b>Ctenophora</b>						
<i>Beroe ovata</i> *	Mayer, 1912	Circum(sub)tropical			est	est
<i>Mnemiopsis leidyi</i> *	A. Agassiz, 1865	NW Atlantic	est	est	est	est
<i>Sulculeolaria angusta</i> *	Totton, 1954	Indian				est
<b>Echinodermata</b>						
<i>Acanthaster planci</i>	(Linnaeus, 1758)	Indo-Pacific	ques			
<i>Amphiodia (Amphispina) oblecta</i>	Mortensen, 1940	Indo-Pacific				est
<i>Amphiplus (Lymanella) laevis</i>	(Lyman, 1874)	Indo-Pacific				cas
<i>Aquilonastra burtoni</i> **	(Gray, 1840)	W Indian				est
<i>Asterias rubens</i>	Linnaeus, 1755	NE Atlantic				est
<i>Diadema setosum</i>	(Leske, 1778)	Indo West Pacific				cas
<i>Eucidaris tribuloides</i>	(Lamarck, 1816)	(sub)tropical Atlantic:		est		
<i>Ophiactis macrolepidota</i>	Marktanner-Turneretscher, 1887	Circumtropical				est
<i>Ophiactis savignyi</i>	(Müller & Troschel, 1842)	Circumtropical	cas	est		est
<i>Protoreaster nodosus</i>	(Linnaeus, 1758)	Indo-Pacific	cas			
<i>Prionocidaris baculosa</i>	(Lamarck, 1816)	Indian		cas		
<i>Synaptula reciprocans</i>	(Forsskål, 1775)	Indo-Pacific				est
<b>Porifera</b>						
<i>Cinachyrella australiensis</i>	Carter, 1886	Indo-Pacific				ques
<i>Geodia micropunctata</i>	Row, 1911	Indo-Pacific				ques
<i>Haliclona spinosella</i>	(Thiele, 1905)	Indo-Pacific				ques
<i>Haliclona viridis</i>	(Keller, 1881)	Circum(sub)tropical				ques
<i>Hyrrios erecta</i>	(Keller, 1889)	Indo-Pacific				ques
<i>Lissodendoryx schmidtii</i>	(Ridley, 1844)	Indo-Pacific				ques
<i>Mycale erythraeana</i>	Burton, 1936	Indo-Pacific				ques
<i>Paraleucilla magna</i>	Klautau <i>et al.</i> , 2004	SW Atlantic	cry	cry	cry	
<b>Siphonophora</b>						
<i>Abyla trigona</i> *	Quoy & Gaimard, 1827	Indian				cas

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<b>Sipuncula</b>						
<i>Apionsoma (Apionsoma) misakianum</i>	(Ikeda, 1904)	Circumtropical	ques			ques
<i>Apionsoma (Apionsoma) tricocephalus</i>	(Sluiter, 1902)	Circumtropical				cas
<i>Aspidosiphon (Akrikos) mexicanus</i>	(Murina, 1967)	Circumtropical		ques	cas	cas
<i>Aspidosiphon (Aspidosiphon) elegans</i>	(Chamisso & Eysenhardt, 1821)	Circumtropical				est
<i>Phascolion (Isomya) convestitum</i>	(Sluiter, 1902)	Indo-Pacific	est			cas
<i>Phascosoma scolops</i>	(Selenka & de Man, 1883)	Indo-Pacific			est	est
<b>Platyhelminthes</b>						
<i>Allolepidapedon fistulariae</i> <sup>P</sup>	Yamaguti, 1940	Indo-Pacific	cas			
<i>Glyphidohaptor plectocirra</i> <sup>P</sup>	(Paperna, 1972)	Red Sea				est
<i>Hirudinella ventricosa</i> <sup>P</sup>	(Pallas, 1774)	Atlantic		cas		
<i>Hysterolecitha sigani</i> <sup>P</sup>	Manter, 1969	Indo-Pacific				ques
<i>Lecithochirium magnicaudatum</i>	Fischthal & Kuntz, 1963	Red Sea				cas
<i>Monilicaecum ventricosum</i> <sup>P</sup>	Yamaguti, 1942	Indo-Pacific				cas
<i>Neothoracocotyle acanthocybii</i> <sup>P</sup>	(Meserve, 1938) Hargis, 1956	Atlantic/Pacific		cas		
<i>Nosema ceratomyxa</i> <sup>P</sup>	Diamant & Paperna, 1985	Red Sea				est
<i>Polylabris cf. mamaevi</i> <sup>P</sup>	Ogawa & Egusa, 1980	Indo West Pacific				est
<i>Tetrancistrum polymorphus</i> <sup>P</sup>	(Paperna, 1972)	Red Sea		cas		cas
<i>Tetrancistrum strophosolenum</i> <sup>P</sup>	Kritsky, Galli & Yang, 2007	Red Sea				est
<i>Tetrancistrum suzicus</i> <sup>P</sup>	(Paperna, 1972)	Red Sea		cas		est
<b>F I S H</b>						
<b>Elasmobranchii</b>						
<i>Carcharhinus altimus</i>	(Springer, 1950)	Indo-Pacific	est			est
<i>Carcharhinus falciformis</i>	(Müller & Henle, 1839)	Circumtropical	est			
<i>Dasyatis marmorata</i>	(Smith, 1828)	Tropical Atlantic		ques		ques
<i>Galeocerdo cuvier</i>	(Peron & Le Sueur, 1822)	Tropical/subtropical	cas	cas		
<i>Himantura uamak</i>	(Forsskål, 1775)	Indo-Pacific				est
<i>Isurus paucus</i>	Guitart Manday, 1966	Circumtropical	cas			
<i>Rhizoprionodon acutus</i>	(Rüppell, 1837)	Circumtropical		cas		
<i>Sphyrna mokarran</i>	(Rüppell, 1837)	Circumtropical	cas			
<i>Torpedo sinuspersici</i>	Olfers, 1831	Indo-Pacific				ques
<b>Actinopterygii</b>						
<i>Abudefduf vaigiensis</i>	(Quoy & Gaimard, 1825)	Indo-Pacific	cas			cas

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Acanthurus monroviae</i>	Steindachner, 1876	Tropical Atlantic	est	cas		cas
<i>Alepes djedaba</i>	(Forsskål, 1775)	Indo-Pacific				est
<i>Aluterus monocerus</i>	(Linnaeus, 1758)	Atlantic	cas			
<i>Anarhichas lupus</i>	Linnaeus, 1758	N Atlantic	cas			
<i>Anguilla japonica</i>	Temminck & Schlegel, 1847	Pacific		ques		
<i>Apogon fasciatus</i>	(White, 1790)	Indo-Pacific				est
<i>Apogon pharaonis</i>	Bellotti, 1874	Indo-Pacific				est
<i>Apogon queketti</i>	Gilchrist, 1903	Indian				est
<i>Apogon smithi</i>	(Kotthaus, 1970)	Indian				est
<i>Arius parkii</i>	Gunther, 1864	Indo-Pacific				cas
<i>Atherinomorus forskalii**</i>	(Rüppell, 1838)	Tropical Atlantic		est		est
<i>Beryx splendens</i>	Lowe, 1834	Circumtropical	est	est		
<i>Bregmaceros atlanticus</i>	Goode & Bean, 1886	Tropical Atlantic	cas			est
<i>Callionymus filamentosus</i>	Valenciennes, 1837	Circumtropical				est
<i>Centrolabrus exoletus</i>	(Linnaeus, 1758)	Tropical Atlantic	cas			
<i>Cephalopholis taeniops</i>	(Valeciennes, 1828)	Subtropical Atlantic		est		cas
<i>Champsodon nudivittis</i>	(Ogilby, 1895)	Tropical Atlantic				cas
<i>Champsodon vorax</i>	Günther, 1867	Indo West Pacific				cas
<i>Chaunax suttkusi</i>	Caruso, 1898	Indo-Pacific	cas	cas		
<i>Cheilodipterus novemstriatus</i>	(Rüppell, 1838)	W Indian				cas
<i>Cheilopogon furcatus</i>	(Mitchill, 1815)	Circumtropical		cas		
<i>Chilomycterus reticulatus</i>	(Linnaeus, 1758)	Circumtropical	cas			
<i>Chirocentrus dorab</i>	Forsskål, 1775)	Indo-Pacific				cas
<i>Coryogalops ochetica</i>	(Norman, 1927)	Red Sea				est
<i>Crenidens crenidens</i>	(Forsskål, 1775)	Indian		est		est
<i>Cyclichthys spilostylus</i>	(Leis & Randall, 1982)	Indo-Pacific				est
<i>Cyclopterus lumpus</i>	Linnaeus, 1758	Atlantic			cas	
<i>Cynoglossus sinusarabici</i>	(Chabanaud, 1913)	Red Sea				est
<i>Decapterus russelli</i>	(Rüppell, 1830)	Indo-Pacific				est
<i>Diodon hystrix</i>	(Linnaeus, 1758)	Circumtropical		cas		ques
<i>Diplodus bellottii</i>	(Steindachner, 1882)	Tropical Atlantic	est			
<i>Dussumieria elopsoides</i>	Bleeker, 1849	Indo-Pacific				est
<i>Elates ransonetti</i>	(Steindachner, 1876)	Tropical Pacific		cas	cas	
<i>Enchelycore anatina</i>	(Lowe, 1839)	Tropical Atlantic				est
<i>Epinephelus coioides</i>	(Hamilton, 1822)	Indo-Pacific			cas	est
<i>Epinephelus malabaricus</i>	(Bloch & Schneider, 1804)	Indo-Pacific				est
<i>Equulites klunzingeri**</i>	(Steindachner, 1898)	Indian		cas	cas	est
<i>Etrumeus teres</i>	(DeKay, 1848)	Subtropical		est		est
<i>Favonigobius melanobranchus**</i>	(Fowler, 1934)	Indo West Pacific				cas

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Fistularia commersonii</i>	(Rüppell, 1835)	Indo-Pacific	est	est	est	est
<i>Fistularia petimba</i>	Lacepède, 1803	Tropical-Atlantic	cas			
<i>Gephyroberyx darwini</i>	(Johnson, 1866)	Tropical Atlantic	cas	ques		
<i>Glaucostegus halavi</i>	(Forsskål, 1775)	Indo-Pacific	cas			ques
<i>Gymnamodytes semisquamatus</i>	(Jourdain, 1879)	N Atlantic	est			
<i>Halosaurus ovenii</i>	Johnson, 1863	Tropical Atlantic	est			
<i>Hemiramphus far</i>	(Forsskål, 1775)	Indo-Pacific		est	cas	est
<i>Heniochus intermedius</i>	Steindachner, 1893	Indian				cas
<i>Herklotsichthys punctatus</i>	(Rüppell, 1837)	Red Sea				est
<i>Hippocampus fuscus</i>	Rueppell, 1838	Indian				est
<i>Hyporhamphus affinis</i>	(Gunther, 1866)	Indo-Pacific				cas
<i>Iniistius pavo</i>	Valenciennes, 1840	Indo-Pacific				cas
<i>Kyphosus incisor</i>	(Cuvier, 1831)	Tropical Atlantic	cas			
<i>Kyphosus sectator</i>	(Linnaeus, 1758)	Tropical Atlantic	est			
<i>Lagocephalus sceleratus</i>	(Gmelin, 1788)	Indo-Pacific		cas		est
<i>Lagocephalus spadiceus</i>	(Richardson, 1844)	Indo-Pacific				est
<i>Lagocephalus suezensis</i>	Clark & Gohar, 1953	Red Sea				est
<i>Liza carinata</i>	(Valenciennes, 1836)	Indian				est
<i>Liza haematocheila</i>	(Temminck & Schlegel, 1845)	Indo-Pacific				est
<i>Lutjanus argentimaculatus</i>	(Forsskål, 1775)	Indo-Pacific				cas
<i>Lutjanus jocu</i>	(Bloch & Schneider, 1801)	Atlantic	cas			
<i>Makaira indica</i>	(Cuvier, 1832)	Indo-Pacific	cas	cas		
<i>Microchirus boscanion</i>	Chabanaud, 1926	Tropical Atlantic	est	cas		
<i>Microchirus hexophthalmus</i>	(Bennet, 1831)	Tropical Atlantic	est	est		
<i>Monotaxis grandoculis</i>	(Forsskål, 1775)	Indo-Pacific				cas
<i>Muraenesox cinereus</i>	(Forsskål, 1775)	Indo-Pacific				cas
<i>Mycteroperca fusca</i>	(Lowe, 1838)	Tropical Atlantic				cas
<i>Nemipterus randalli</i>	Russell, 1986	Indian				est
<i>Omobranchus punctatus</i>	(Valenciennes, 1836)	Indo-Pacific				cas
<i>Oplegnathus fasciatus</i>	(Temminck & Schlegel, 1944)	Pacific		cas		
<i>Oxyurichthys petersi</i>	(Klunzinger, 1871)	Red Sea				est
<i>Pagellus bellottii</i>	Steindachner, 1882	Tropical Atlantic	est			cas
<i>Pagrus major</i>	(Temminck & Schlegel, 1843)	NW Pacific			cas	
<i>Pampus argenteus</i>	(Euphrasen, 1788)	Indo-Pacific			cas	
<i>Papilloculiceps longiceps</i>	(Ehrenberg in Valenciennes, 1829)	Indian				cas
<i>Parexocoetus mento</i>	(Valenciennes, 1846)	Indo-Pacific		est	est	est
<i>Parupeneus forsskali</i>	(Fourmanoir & Guézé, 1976)	Indian		ques		cas
<i>Pelates quadrilineatus</i>	(Bloch, 1790)	Indo-Pacific				est
<i>Pempheris vanicolensis</i>	Cuvier, 1831	Indo-Pacific		est		est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Petroscirtes ancylodon</i>	Rüppell, 1838	Indian				est
<i>Pinguipes brasilianus</i>	Cuvier & Valenciennes, 1829	W Atlantic	cas	cas		
<i>Pisodonophis semicinctus</i>	(Richardson, 1848)	Tropical Atlantic	est	est		cas
<i>Platax teira</i>	(Forsskål, 1775)	Indo-Pacific				cas
<i>Platycephalus indicus</i>	(Linnaeus, 1758)	Indo-Pacific		cas		est
<i>Plotosus lineatus</i>	(Thunberg, 1787)	Indo-Pacific				est
<i>Pomacanthus imperator</i>	(Bloch, 1787)	Indo-Pacific				cas
<i>Pomacanthus maculosus</i>	(Forsskål, 1775)	Indo-Pacific				cas
<i>Pomadasys stridens</i>	(Forsskål, 1775)	Indian	est			est
<i>Priacanthus hamrur</i>	(Forsskål, 1775)	Indo-Pacific		ques		ques
<i>Priacanthus sagittarius</i>	Starnes, 1988	Indo-Pacific				cas
<i>Psenes pellucidus</i>	Lutken, 1880	Tropical Atlantic	est	cas		
<i>Pseudupeneus prayensis</i>	(Cuvier, 1829)	Tropical Atlantic	cas			
<i>Pteragogus pelycus</i>	Randall, 1981	Indian				est
<i>Pterois miles</i>	(Bennet, 1803)	Indian				cas
<i>Rachycentron canadum</i>	(Linnaeus, 1766)	Circumtropical	cas			cas
<i>Rastrelliger kanagurta</i>	(Cuvier, 1816)	Indo-Pacific				cas
<i>Rhabdosargus haffara</i>	(Forsskål, 1775)	Indian				est
<i>Rhynchoconger trewavasae</i>	Ben-Tuvia 1993	Red Sea				cas
<i>Sargocentron rubrum</i>	(Forsskål, 1775)	Indo-Pacific		cas		est
<i>Saurida undosquamis</i>	(Richardson, 1848)	Indo-Pacific		est	est	est
<i>Scarus ghobban</i>	Forsskål, 1775	Indo-Pacific				est
<i>Sciaenops ocellatus</i>	(Linnaeus, 1766)	W Atlantic				cas
<i>Scomberomorus commerson</i>	Lacepède, 1800	Indo-Pacific	?	est		est
<i>Scorpaena stephanica</i>	Cadenat, 1943	Tropical Atlantic	cas			
<i>Selene dorsalis</i>	Gill, 1862	W Atlantic		cas		
<i>Seriola carpenteri</i>	Mather 1971	Tropical Atlantic		est		
<i>Seriola fasciata</i>	(Bloch, 1793)	Tropical Atlantic	est	est		cas
<i>Seriola rivoliana</i>	Valenciennes, 1833	Tropical Atlantic		cas		
<i>Siganus javus</i>	(Linnaeus, 1766)	Indo-Pacific				cas
<i>Siganus luridus</i>	(Rüppell, 1829)	Indian	cas	est		est
<i>Siganus rivulatus</i>	Forsskål, 1775	Red Sea		est	cas	est
<i>Silhouettea aegyptia</i>	(Chabanaud, 1933)	Red Sea				est
<i>Sillago sihama</i>	(Forsskål, 1775)	Indo-Pacific				est
<i>Solea senegalensis</i>	Kaup, 1858	Tropical Atlantic	est	ques		
<i>Sorsogona prionota</i>	(Sauvage, 1873)	Indian				cas
<i>Sphoeroides marmoratus</i>	(Lowe, 1838)	Atlantic	cas	cas		
<i>Sphoeroides pachygaster</i>	(Müller & Troschel, 1848)	Tropical Atlantic	est	est	est	est
<i>Sphyaena chrysotaenia</i>	Klunzinger, 1884	Indo-Pacific		est	est	est
<i>Sphyaena flavicauda</i>	Rüppell, 1838	Indian		est		est
<i>Spratelloides delicatulus</i>	(Bennett, 1831)	Indo-Pacific/Red Sea				est

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
<i>Stephanolepis diaspros</i>	Fraser-Brunner, 1940	Red Sea		est	cas	est
<i>Synagrops japonicus</i>	(Doderlein, 1884)	Indo-Pacific	cas			
<i>Synaptura lusitanica</i>	Capello, 1868)	Tropical Atlantic	est	est		
<i>Syngnathus rostellatus</i>	Nilsson, 1855	N Atlantic	cas			ques
<i>Terapon jarbua</i>	(Forsskål, 1775)	Indo-Pacific				cas
<i>Terapon puta</i>	(Cuvier, 1929)	Indo-Pacific/Red Sea				est
<i>Terapon theraps</i>	Cuvier, 1829	Indo-Pacific			cas	
<i>Tetrosomus gibbosus</i>	(Linnaeus, 1758)	Indo-Pacific				est
<i>Torquigener flavimaculosus</i>	Hardy & Randall, 1983	Indian				est
<i>Trachurus indicus</i>	Necrasov, 1966	Indian				cas
<i>Trachyscorpia cristulata echinata</i>	(Koehler, 1869)	Tropical Atlantic	est	est		
<i>Tridentiger trionocephalus</i>	(Gill, 1859)	Tropical Pacific				cas
<i>Trypauchen vagina</i>	(Bloch & Scheider, 1801)	Indo-Pacific				cas
<i>Tylerius spinosissimus</i>	(Regan, 1908)	Indo-Pacific				est
<i>Tylosurus choram</i>	(Rüppell, 1837)	Indo-Pacific				cas
<i>Tylosurus crocodilus</i>	(Peron & Le Sueur, 1821)	Indo West Pacific				cas
<i>Upeneus moluccensis</i>	(Bleeker, 1855)	Indo-Pacific		est		est
<i>Upeneus pori</i>	Ben-Tuvia & Golani, 1989	Indian		est		est
<i>Vanderhorstia mertensi</i>	Klausewitz, 1974	Indo-Pacific				est
<i>Zenopsis conchifera</i>	(Lowe, 1852)	Atlantic/Pacific	cas			

## 1. THE WESTERN MEDITERRANEAN

The WMED occupies a key position because it receives the influx of surface waters from the Atlantic, through the Strait of Gibraltar. It is further compartmentalized into fairly isolated sub-basins with different climatic and hydrologic conditions. These sub-basins have a different biogeographic character, which may affect invasion and settlement of aliens. The Alboran Sea, situated immediately east of Gibraltar, exhibits stronger Atlantic affinities, due to the continued penetration of Atlantic flora and fauna with the incoming influx of water (HARMELIN & D'HONDT, 1993). In return, most Mediterranean endemics are rare or missing. The incoming Atlantic

waters form a permanent clockwise gyre in the Alboran Sea, which is separated from the remainder of the WMED by a well-marked hydrographic front between Oran and Almería. As a consequence of the admixture of fauna and flora of different origins, the westernmost part of the Alboran Sea, from the Ceuta region to Punta de Calaburras on the coast of Malaga, constitutes a hot spot of biodiversity. Its enriched benthic environment includes some species linked with the tropical periods of the Mediterranean Sea (OCAÑA *et al.*, 2009; GARCÍA RASO *et al.*, 2010; URRÁ *et al.*, in press). The Tyrrhenian Sea is comparatively isolated from the rest of the WMED and is surrounded by mountains reducing the impact of the meteorological events

that strongly influence the internal conditions of the other Western Mediterranean basins (ASTRALDI *et al.*, 1995). The Gulf of Lions and the Ligurian Sea are the coldest parts of the WMED. They are characterized by a severe reduction of thermophilic species, while some cold temperate species, not found to the south, are present (BIANCHI & MORRI, 1993, 1994).

### **1.1. Alien protozoans in the Western Mediterranean**

Four pathogenic protozoans have been recorded in WMED. Three of them are pathogenic to shellfish: *Marteilia refringens* (RIERA *et al.*, 1993), *Bonamia ostreae* (MONTES & LAMA, 1993), and *Perkinsus olseni*, formerly *Perkinsus atlanticus* (SAGRISTÀ *et al.*, 1996). The fourth, *Photobacterium damsela*, formerly *Pasteurella piscicida*, causes pasteurellosis/photobacteriosis in fish: it was first isolated in mortalities occurring in natural populations of white perch and striped bass in 1963 in Chesapeake Bay, USA. From 1990 it has caused economic losses in different European countries. Cultured gilthead seabream (*Sparus aurata*) and seabass (*Dicentrarchus labrax*) are the most affected species in the WMED (TORANZO *et al.*, 1991).

Only four alien foraminiferal species occur in the WMED. *Planogypsina acervalis* (BLANC-VERNET, 1969, as *Planorbulina acervalis*) and *Cymbaloporeta plana* have been previously cited in the other sectors of the Mediterranean. Very rare specimens of *Sorites orbiculus* have been reported for the Gulf of Naples (HOFKER, 1930) and from the Ligurian Sea (BANCHETTI *et al.*, 2009, as *S. orbicularis*). *Schackoinella imperatoria*, probably cryptogenetic/casual, has been recorded

from the Gulf of Naples, South Tyrrhenian (SGARRELLA & MONCHARMONT, 1993), from the Ligurian Sea and north Tyrrhenian (BANCHETTI *et al.*, 2009) and from the coast of Vulcano, Aeolian Islands (CIMERMAN & LANGER, 1991, as *Conorbella imperatoria*).

### **1.2. Alien macrophytes in the Western Mediterranean**

A total of 91 alien macrophytes have been hitherto reported in the WMED, which represent 72% of the alien macrophytes reported from the Mediterranean Sea. The major vectors of introduction are the shellfish aquaculture industry and ship traffic (fouling, ballast waters). As much as 75 alien macrophyte species are well established, seven are casual, and nine are cryptogenic/questionable. Casual taxa (i.e. *Cladophora hutchinsioides*, *Fucus spiralis*, *Grateloupia patens*, *Lomentaria flaccida*, *Rhodophysema georgei*, *Saccharina japonica* and *Sarconema filiforme*) might attain established status in the future. The cryptogenic/questionable category includes *Acanthophora nayadiformis*, *Anotrachium okamurae*, *Antithamnionella boergesenii*, *A. elegans*, the Atlantic strain of *Asparagopsis taxiformis*, *Ceramium bisporum*, *Ganone-ma farinosum*, *Osmundea oederi* and *Polysiphonia atlantica*.

On the 21 invasive or potentially invasive macrophytes introduced in the Mediterranean (Table 3), 16 are present in the western basin mainly in coastal lagoons. *Codium fragile*, invasive in the last century, has become less abundant in the open sea.

The northern coasts are the most impacted region, with a maximum of alien macrophytes in France (78 taxa out of 91). On the other hand, the lowest number (23 taxa) was recorded along the northern Africa coast (Morocco and Algeria). Such

a difference is probably due to insufficient investigations in the south and the huge flood of introductions along with shellfish transfers in the French coastal lagoons harbouring shellfish aquaculture. VERLAQUE *et al.* (2007) listed up to 58 alien macrophytes in the Thau Lagoon (64% of alien macrophytes of the WMED and 46% of the total of alien macrophytes of the Mediterranean), which is the leading site of shellfish aquaculture in the Mediterranean Sea.

The majority of alien macrophytes of the WMED comes from temperate and cold regions (NE Atlantic and NW Pacific) in relation with the major vector of introduction (shellfish transfer). Only 10 putative Lessepsian immigrants (i.e. *Acanthophora nayadiformis*, *Chondria pygmaea*, *Ganonema farinosum*, *Halophila stipulacea*, *Hypnea spinella*, *H. valentiae*, *Lophocladia lallemandii*, *Padina boergesenii*, *Sarconema filiforme* and *Ulva fasciata*) have been hitherto recorded, mainly out of the coldest zones (Gulf of Lions and Gulf of Genoa). However, the only WMED report of *Sarconema filiforme* (France) requires confirmation. *Acanthophora nayadiformis*, *Ganonema farinosum*, *Hypnea spinella*, *Padina boergesenii* and *Ulva fasciata* could alternatively originate from the Atlantic Ocean. The strains of *Ulva fasciata* and *Hypnea valentiae* introduced in the Thau Lagoon most probably originate from the north-western Pacific (Japan or Korea). The invasive behaviour of *Lophocladia lallemandii* in the Balearic Islands contrasts with a non-invasive behaviour everywhere else in the Mediterranean, and a different origin for the western strain deserves to be considered. Thus, there are hitherto only two unquestionable Lessepsian macrophytes in the WMED: *Chondria pygmaea* and *Halophila stipulacea*.

### 1.3. Alien polychaetes in the Western Mediterranean

In the WMED, a total of only 49 alien polychaete species have been reported to date, which is about 39% of the alien polychaete species reported from the Mediterranean Sea. Among them, 26 species are established in WMED (see Table 2), 12 species are casual, 1 species (*Paraprionospio coora*) is cryptogenic and 10 species are questionable. Some species seem to have invasive character, forming dense populations in semi- or heavily polluted areas, including harbours (*Branchiomma luctuosum*, *Hydroides dianthus*, *H. elegans*, *Polydora cornuta*, and others), brackish waters (*Desdemonia ornata*, *Ficopomatus enigmaticus*, *Polydora cornuta*, etc.) or shallow-water benthic habitats (*Eunice antennata*, *Lumbrineris perkinsi*, *Notomastus mossambicus*, *Prionospio (Aquilaspio) krusadensis*, etc.). The WMED has a relatively low number of alien species, in comparison with the EMED, especially the Levantine Sea, which is densely colonized by alien polychaetes. The majority of the established alien species in the WMED are of Pacific, Indo-Pacific, Indian and/or Red Sea origin, whereas less originate in the tropical Atlantic (six species) or West Atlantic (six species).

A relatively low number of newcomers originating in tropical seas and anthropogenically introduced via the Gibraltar Strait are true alien species. Most of them appear to have arrived via shipping, especially in harbours, as also happens in the EMED. Although the polychaetes of the WMED are relatively well known, new reports are occurring continuously, making sometimes difficult to elucidate if they are true invaders, or unrecorded or overlooked species. This is especially evident with small, meiobenthic species; for exam-

ple, in a recent work (DEL-PILAR-RUSO *et al.*, in press) two small syllids (*Syllis mauritanica* and *Parapionosyllis macaronesiensis*; not included in Table) are reported for the first time in the Mediterranean; both species were described from NE Africa and Canary and Madeira islands, relatively close to the Strait of Gibraltar. There is no way to know if these species were accidentally introduced, were overlooked in previous papers, or simply never found.

#### **1.4. Alien crustaceans in the Western Mediterranean**

In total, 52 alien species of crustaceans have been found in the WMED, of which 20 have self-maintaining populations, 20 are casual records, eight are questionable and four are classified as cryptogenic. These species belong to amphipods (4), cirripedes (5), decapods (20), stomatopods (1), cumaceans (1), planktonic and parasitic forms of copepods (16), and isopods (5) (Table 2).

In the decapods, we have not considered alien the Atlantic species found in the Alboran Sea and whose historical presence is known in Morocco. For example, *Brachynotus atlanticus*, a tropical African species known in Morocco (FOREST & GANTÈS, 1960), was found in Europe for the first time in the littoral of Malaga (GARCÍA RASO, 1984a), and later in the Bay of Cadiz, in the Atlantic, where it forms a stable population (GARCÍA RASO, 1985). The Atlantic shrimps *Penaeopsis serrata* and *Hymenopenaeus debilis*, known in Moroccan waters (ZARIQUIEY, 1968; PÉREZ FARFANTE, 1979), were recently found in the western Mediterranean Sea (perhaps due to their deep-water habitat); apparently, they are being found in more areas of the Mediterranean; the former in the Alboran Sea

(ABELLÓ & TORRES, 1998) and Sardinia Channel (MURA *et al.*, 2003), the latter in Alboran Sea and Balearic Island (CARTES *et al.*, 2000). A similar consideration can be made for *Merhippolyte ancistrotata*, a species occurring in the Alboran Sea but also known in the Gulf of Cadiz and Morocco (GARCÍA RASO, 1996; UDEKEM D'ACÓZ & ĐURIŠ, 1996), and *Plesionika ensis* (A. Milne Edwards, 1881), cited in the Alboran Sea (GARCÍA RASO, 1981) and Gulf of Cadiz (GARCÍA RASO, 1996). However, new references from the island of Crete, Aegean Sea (LABROPOULOU & KOSTIKAS, 1999) and its absence in intermediate Mediterranean areas raise doubts about the status of the latter species in the EMED. There is an old citation of the species *Plagusia depressa* (Fabricius, 1775) and *Plagusia chabrus* (Linnaeus, 1758), now *Guinusia chabrus* (Linnaeus, 1758), brought to the port of Marseilles by an iron vessel in 1873 (STEBBING, 1893), but they have not been included in Table 2, because they have never again been captured (there are no later references).

Half the species originate in the Indo-Pacific, Pacific, Indian Ocean or Red Sea, while seven species are known to have a circumtropical distribution. The remainders have a tropical/subtropical Atlantic origin, many of them being known in the western Atlantic.

Two species, *Synalpheus tumidomanus africanus* and *Necora puber*, not included in earlier Mediterranean alien lists, are added in Table 2. *Synalpheus tumidomanus africanus* (syn. *S. hululensis africanus*) was first captured in Israel (LEWINSOHN & HOLTHUIS, 1964, as *Synalpheus hululensis*) and considered as alien; later it was found in the Alboran Sea (GARCÍA

RASO, 1984b; LÓPEZ DE LA ROSA & GARCÍA RASO, 1992; GARCÍA RASO, 1996), a characterization that subsequently changed following reclassification of the Mediterranean specimens within the subspecies *S. tumidomanus africanus* (or *S. africanus*?), known from Casablanca and Rabat, Morocco (LAGARDÈRE, 1971). The Alboran populations may represent a natural expansion of the distribution range of the species, which entered through the Strait of Gibraltar and colonized the southern coast of Spain (perhaps with the help of the Atlantic surface water inflow). The references from Greece and Turkey (KOUKOURAS & KATTOULAS 1974; KOCATAŞ, 1981) could indicate a separate advance in the EMED littoral from the Israeli populations. Recently it has been captured in Sicily (BACCI *et al.*, 2010). The unresolved question is whether the EMED populations are alien or not. At this time we have classified it as cryptogenic.

*Necora puber* is included as 'alien' species because (in agreement with ZIBROWIUS, 1992) we believe that its presence in several areas of the Mediterranean is due to introductions, most likely related to its widespread food use rather than an entry through ballast waters. Only the specimens collected west of Malaga (GARCÍA RASO *et al.*, 2010) could have entered the Mediterranean through the Strait of Gibraltar by their natural means of dispersion.

With regard to other groups of crustaceans we should note that the available data are scarce and often difficult to assess. This is partly due to the smaller number of taxonomic specialists and studies developed on these groups in the different Mediterranean sectors. These limitations lead to a) a downwards-biased estimation

of aliens in the groups of amphipods, cirripedes, cumaceans, isopods and tanaidaceans and b) a high number of questionable and cryptogenic species.

The amphipod *Elasmopus pecteniscrus* has a circumtropical distribution: Atlantic Ocean, Red Sea, Indian Ocean, Pacific Ocean (described from New Guinea); it has gradually colonized the EMED, the Adriatic and the CMED (ZAKHAMA-SRAIEB & CHARFI-CHEIKHROUHA, 2010). The latest finding could be clearly the result of increased scientific effort in the area.

In the WMED the only species markedly invasive is *Percnon gibbesi*, which shows a rapid expansion of its geographical distribution range, e.g. in the east Spanish coast (DEUDERO *et al.*, 2005): first recorded from the Balearic Archipelago in 1999 (GARCIA & REVIRIEGO, 2000), it established populations since 2002 in Barcelona, 2003 in Alicante and Murcia, 2006 in Almeria.

Among alien planktonic copepods reported in the WMED Sea, three are clearly Lessepsian immigrants (*Triconia hawii*, *T. rufa* and *T. umerus*) and were found in the Gulf of Naples. Two other Lessepsian immigrants, *Labidocera detruncata* and *Calanopia elliptica*, were reported from the Gulf of Naples (VIVES & SHMELEVA, 2007), but were never found in the more than 20 years time series of samples collected bi-weekly to weekly in the area (Mazzocchi, pers. comm.): therefore, their presence is considered as questionable. *Pseudocalanus elongatus* and *Paracalanus indicus* seem to be cryptogenic in the area; according to RAZOULS *et al.* (2005-2010) the latter species could be confounded with *Paracalanus parvus*, a very common native Mediterranean species.

Two copepods parasitic on oyster beds

(*Mycicola ostreae* and *Mytilicola orientalis*) are well established in the WMED, after their accidental introduction into the French coast with the Pacific oyster *Crassostrea gigas* (CLANZIG, 1989).

### **1.5. Alien molluscs in the Western Mediterranean**

The WMED has a low incidence of alien Mollusca with 34 recorded species (22 established, nine casual, two cryptogenic and one questionable) in a total of around 1500 native species. Two of these (*Cerithium scabridum* and *Brachidontes pharaonis*) are found only very close to the Strait of Messina and are merely outliers from the confirmed area where these species have established in the Ionian Sea. Others, like *Chromodoris quadricolor*, *Pinctada radiata*, *Rissoina spirata* and *Thais lacera*, had casual occurrences that are unlikely to persist, although they may be firmly established in the EMED. Leaving aside the outliers and these casual species, the cryptogenic species, and the questionable report of *Saccostrea cucullata* for Tunisia, we are left with not more than 25 alien molluscs definitely relevant to the basin.

The north coast of Tunisia represents a major step towards the colonization of the WMED. Two of the hardest Lessepsian immigrants are present there, having made their way across the WMED to the coast of Spain and are locally invasive. These are *Bursatella leachii* (WEITZMANN *et al.*, 2009; RAMOS-ESPLÁ *et al.*, 2010) and *Fulvia fragilis* (TAMAYO-GOYA, 2008). *B. leachii* also exists in the Atlantic, but the hypothesis that WMED populations entered through Gibraltar does not hold since the species does not exist in Morocco.

The largest pool of alien molluscs in the WMED includes species that are

actively cultured (for example *Crassostrea gigas* and *Ruditapes philippinarum*, to a lesser extent *Mercenaria mercenaria*) and species that were probably introduced accidentally along with aquaculture (*Crepidula fornicata*, *Gibbula albida*, *Musculista senhousia*, *Xenostrobus securis*), thereby comprising one-fourth of the reported aliens. *M. senhousia* and *X. securis* are locally invasive in the basin, but *C. fornicata*, which is one of the most invasive aliens in the NE Atlantic, has difficulty in surviving where it has been introduced in the Mediterranean. *Gibbula albida* was originally an Adriatic endemic, but is now introduced in the Ebro Delta (TRIGO, 1981) and the French Mediterranean lagoons (CLANZIG, 1989), as well as on the Atlantic coast of France.

A unique and certainly recent feature is the occurrence in the vicinity of Tunis (Tunisia) of two alien species (*Favorinus ghanensis*, *Mitrella psilla*) introduced through shipping from tropical West Africa (BEN SOUISSI *et al.*, 2004; ANTIT *et al.*, 2010). More generally, harbours are a focus for established populations of aliens, with random origins. Other examples are the bivalve *Theora lubrica* in Leghorn, Italy, and the gastropod *Bostrycapulus odites* in Alicante, Spain, which did not spread out to the neighbouring open sea.

On the whole, the incidence of alien mollusc species in the WMED is heavily concentrated in marginal marine environments such as the lagoons of the French Mediterranean coast, the Spanish Mar Menor and Ebro Delta, and the Italian lagoons of Caprolace and Fusaro on the Tyrrhenian coast. With the exception of the recent report of the nudibranch *Godiva quadricolor* from the large harbour of Algeciras (CERVERA *et al.*, 2010), the

Alboran Sea is free of alien Mollusca, a situation which may be related to its exceptionally high species richness estimated as about 1200 species. More generally, the open sea in the WMED is hardly, if at all, impacted by alien species of molluscs.

Although a couple of alien molluscs in the Mediterranean are of West African origin, there is no species yet that has gradually entered through the Strait of Gibraltar and become newly established in the Mediterranean. As already noted by GOFAS & ZENETOS (2003), all the prevalently Atlantic species found in the westernmost Mediterranean have a historical range since at least the 19<sup>th</sup> century and are, therefore, to be considered native species. The WMED is nevertheless a source area for such species as *Siphonaria pectinata*, native to Algeria and Spain but introduced in Greece and recently expanding its range towards northern Tunisia. Although not qualifying as 'aliens' and not included in the species counts, one must keep in mind the fact that such species as *Eastonia rugosa* (see ALBANO, 2006) are expanding their range.

### **1.6. Miscellaneous invertebrates in the Western Mediterranean**

Bryozoa include five alien species in the WMED, out of 23 known from the whole basin. *Arachnoidea protecta* is an Indo-Pacific species first recorded in the WMED by CHIMENZ GUSSO *et al.* (1998), further records being provided by D'HONDT & CHIMENZ GUSSO (2006). The morphological divergence observed between the Indo-Pacific and Mediterranean specimens led Harmelin (in ZENETOS *et al.*, 2005) to believe that they represent two distinct species. However, OCCHIPINTI-AMBROGI *et al.* (2010) maintain *A. protecta* as established.

Alien Ascidiacea are represented by eight species (out of 16), most of them established. Five species are circumtropical. *Trididemnum* cf. *savignyi* was first recorded by LAFARGUE (1972) at Port-Cros, France. LAFARGUE (1974) revised the *Trididemnum tenerum* complex, assigning the record by PÉRES (1954) from southern Tunisia to *T.* cf. *savignyi*. Subsequent records of this species include Catalonia and Columbretes Islands, Spain (RAMOS-ESPLÁ, 1988). *Perophora multiclathrata* and *Ecteinascia styeloides* have been reported from Corsica (MONNIOT, 1983) and the northern Tyrrhenian Sea (MASTROTOTARO & TURSI, 2010), respectively. *Microcosmus squamiger*, first recorded in Bizerte (as *M. exasperatus*) is widespread in the WMED (synthesis in TURÓN *et al.*, 2007). *Cystodytes philippinensis*, previously observed in southern Tunisia (MÉLIANE, 2002), has been recorded recently in the Balearic Islands (DÍAZ-VALDÉS & RAMOS-ESPLÁ, 2010). This cryptogenic species had probably been confused in the past with its congener *C. dellechiaiei*, widely distributed in the Mediterranean Sea (IZQUIERDO-MUÑOZ *et al.*, 2009). The Western Atlantic species *Distaplia bermudensis* and the Eastern Pacific species *Polyandrocarpa zorritensis* have been introduced by shellfish culture (TURÓN & PEREA, 1988; BRUNETTI & MASTROTOTARO, 2004; MASTROTOTARO & BRUNETTI, 2006). *Styela clava*, originating from the north-western Pacific, has been spreading along the European Atlantic coast since 1954 and has only recently been recorded in the WMED; however, its absence from harbours and marinas closed to Gibraltar may suggest that this species has also been accidentally transported into the Mediterranean Sea by shellfish trans-

fer (DAVIS & DAVIS, 2008).

Cnidaria are an exception to most taxa in that the majority of aliens occur in the WMED rather than in the EMED: 26 species (out of 46 listed for the whole basin). Alien Anthozoa are represented by two species, out of four reported for the whole Mediterranean. Although first recorded in the Ligurian Sea (ZIBROWIUS, 1974), *Oculina patagonica* is abundant in the southern part of the WMED, both in Spain (ZIBROWIUS & RAMOS, 1983; BALLESTEROS, 1998; IZQUIERDO *et al.*, 2007) and along the North African coast (SARTORETTO *et al.*, 2008). Eighteen alien species (out of 37) belong to Hydrozoa, a group well represented in the fouling assemblages (MORRI & BOERO, 1986) that colonize the large ports of the WMED. *Cordylophora caspia* has been reported only for the brackish lake of Fondi, Tyrrhenian Sea (MORRI, 1979). Two alien Scyphozoa were found in the WMED: a single specimen of *Phyllorhiza punctata* was seen in October 2009 off NE Sardinia (BOERO *et al.*, 2009), while *Stomolophus meleagris* is the only one recorded exclusively in the WMED: this may suggest it entered from the Atlantic, although the species is also known from the Pacific (MORAND & DALLOT, 1985).

Both species of alien Ctenophora reported for the Mediterranean occur in the WMED (BOERO *et al.*, 2009; FUENTES *et al.*, 2009; MILLS, 2009), while Sipuncula and Pycnogonida have one alien species each (PANCUCCI-PAPADOPOULOU *et al.*, 1999; BARTOLINO & CHIMENZ GUSSO, 2010).

The only alien echinoderms recorded in the WMED are two seastars and one ophiuroid of Indo-Pacific origin: *Acanthaster planci*, *Protoreaster nodosus*, and

*Ophiactis savignyi*. The former has been reported from Port Cros, France, in 2000 (ICES, 2006) with no further details (hence it is classified as questionable), whereas two individuals of *Protoreaster nodosus*, probably released accidentally from a private aquarium, have been caught by trawling off Majorca, Balearic Islands, Spain, in 1981 (ALVARADO *et al.*, 1986). Casual is considered the presence of *Ophiactis savignyi* in Banyuls (GUILLE, 1969).

The only alien Porifera in the WMED is *Paraleucilla magna*, which is proliferating across the Mediterranean (GUARDIOLA *et al.*, 2010). Platyhelminthes are represented by *Allolepidapedon fistulariae*, an endoparasite of *Fistularia commersonii* reported from Sardinia (PAIS *et al.*, 2007).

### 1.7. Alien fish in the Western Mediterranean

MASSUTI *et al.* (2010) reported 38 new fish in the WMED since the middle 20<sup>th</sup> century. Here we report 45 species (20 established, 25 casual) inventoried in the 20<sup>th</sup> century. Most of them are of tropical (subtropical) Atlantic origin.

The entrance of alien fish in the WMED has drawn the attention on the so-called effect of 'tropicalization'. This phenomenon has expanded geographically, reaching the EMED. Such is the case for the Atlantic origin species *Carcharhinus altimus*, *Acanthurus monroviae*, *Pisodonophis semicinctus*, *Sphoeroides pachygaster*, *Pagellus bellottii* and *Seriola fasciata*, which have recently entered the Mediterranean through the Strait of Gibraltar, and have already reached the EMED.

Documentation on some species is limited so that those here reported as casuals could have already established populations. This could be the case of a) benthic

species with limited swimming capacity such as *Microchirus boscanion*, which has been captured at different localities and times (MASSUTI *et al.*, 2010); b) confusion with others, such as the soleids *Microchirus hexophthalmus* and *Synaptura lusitanica* known for the Iberian Peninsula and the Gulf of Lions (MATALANAS, 1984). Some species, such as *Anarhichas lupus*, *Aluterus monocerus*, *Scorpaena stephanica*, *Fistularia petimba* and *Zenopsis conchifera*, are known only from single observations and are still limited to the WMED. The latest findings include *Lutjanus jocu* (VACCHI *et al.*, 2010) and *Kyphosus incisor* (ORSI-RELINI *et al.*, 2010), both in the Ligurian Sea.

Within the alien Indo-Pacific species, *Pomadasys stridens* was reported for the first time in the WMED and then it was known in the EMED, where it is common; *Abudefduf vaigiensis*, a casual species in the Levantine basin, has been reported three times in the WMED could be similar. By contrast, *Siganus luridus*, and *Fistularia commersonii*, which were first reported in the EMED, where they are now well known and even common, have expanded westwards and are considered established. *Fistularia commersonii* has expanded as far north as the Ligurian Sea (OCCHIPINTI-AMBROGI & GALIL, 2009) and as far west as Algeria (HEMIDA & CAPAPÉ, 2009) and Spain (SÁNCHEZ-TOCINO *et al.*, 2007).

In the WMED, only a few species appear regularly in the catches of some fisheries. That could be the case of *Solea senegalensis*, whose presence in the WMED was recorded in 1920 off the Iberian coast and has presently extended to Algeria, Tunisia and the Gulf of Lions, and *Gymnammodytes semisquamatus* reported only in the north-eastern Iberian coast,

where it is exploited in commercial fishery. *Diplodus bellottii* and *Pagellus bellottii*, reported at the Maghrebine and Iberian coasts of the Alboran Sea, are occasionally captured by commercial fisheries (MASSUTI *et al.*, 2010).

## 2. CENTRAL MEDITERRANEAN

The bulk of the CMED is represented by the Ionian Sea, the least known of all the Mediterranean sub-basins (ZENETOS *et al.*, 1997). Local endemics, mostly within molluscs, have been reported for its southern, non-European shores (SABELLI & TAVIANI, 1980) but also for Malta (EVANS *et al.*, 2010). The Ionian is connected to the WMED through the narrow Strait of Messina, a micro-sector that harbours a wealth of biogeographic peculiarities, including Pliocene Atlantic remnants and local endemisms (FREDJ & GIACCONE, 1995), and the larger Strait of Sicily, the meeting point of native Western and Eastern Mediterranean species (BIANCHI, 2007), as well as of aliens of either Atlantic or Indo-Pacific origin (COLL *et al.*, 2010). Reflecting this situation at the crossroads, the composition of the alien faunas is much more balanced between different sources than in the EMED. Its situation at the transition between the eastern and western basins make it a particularly sensitive place for monitoring the progression of the much more numerous aliens already established in the EMED.

### 2.1. Alien protozoans in the Central Mediterranean

Fish pasteurellosis from the protist *Photobacterium damsela* was reported from cultured seabass and seabream installations in the Greek Ionian Sea and

from Malta (BAKOPOULOS *et al.*, 1995, 1997).

Only 4 alien foraminiferal species are reported for the CMED: *Amphistegina lobifera*, which probably has established a population around the island of Malta (YOKES *et al.*, 2007), *A. lessonii* and *A. madagascariensis* documented along the coast of southern Tunisia (BLANC-VERNET, 1969; HOLLAUS & HOTTINGER, 1997). *Planogypsina acervalis* seems to have been recorded in this area only by BLANC-VERNET (1969).

## 2.2. Alien macrophytes in the Central Mediterranean

In the CMED, 57 alien macrophytes have been hitherto reported, which represent 46% of the alien macrophytes known for the Mediterranean Sea as a whole. The major vectors of introduction are the ship traffic (fouling, ballast waters), the Suez Canal, and, in the south Italian coastal lagoons, the shellfish aquaculture. Among them, 35 alien macrophytes are well established, four are casual, 16 are cryptogenic/questionable, and two require confirmation. Casual taxa (i.e. *Grateloupia lanceolata*, *Hypnea anastomosans*, *Polysiphonia paniculata* and *Undaria pinnatifida*) might turn into the established status in the future. The occurrence of *Batophora* sp. and *Gracilaria arcuata* in the CMED requires confirmation.

Of the 21 invasive or potentially invasive macrophytes introduced in the Mediterranean (Table 3), 13 have been reported in the CMED. *Undaria pinnatifida* that was only reported from the Mar Piccolo of Taranto (south Italy), seems to have disappeared from the region (GRAVILI *et al.*, 2010).

The Ionian coasts and Sicily are the most impacted regions, with 35 and 36

alien macrophytes respectively, followed by Tunisia (25) and Libya (12). Such differences are probably due to a lower investigation effort, particularly in Libya.

The alien macrophytes of the CMED come from temperate/cold regions (NE Atlantic and NW Pacific) and from tropical regions in almost equal proportions (51 and 49%, respectively). A total of 17 putative Lessepsian immigrants have been hitherto recorded in the region.

## 2.3. Alien polychaetes in the Central Mediterranean

The CMED includes 36 alien species of polychaetes (17 established, nine casual, and ten questionable). Aliens already established in the EMED have colonized this area to subsequently spread to the WMED: examples are provided by the three Indo-Pacific species, and likely Lessepsian immigrants, *Eunice antennata*, *Pseudonereis anomala* (both established) and *Protodorvillea egena* (questionable). By contrast, *Linopherus canariensis* and *Ophryotrocha japonica*, both established, could be indicative of a passage from west to east. The former is very abundant in the Faro Lake, on the Messina Strait (COSENTINO *et al.*, 2009), together with another alien species: *Syllis hyllebergi*, which is exclusively found in this area (COSENTINO, in press). Other exclusive species of the CMED are *Eunice floridiana*, *Epidiopatra hupferiana hupferiana*, *Epidiopatra hupferiana monroi* and *Isolda pulchella*, mostly collected in the Gulf of Noto (Sicily), all considered casual, non established taxa (OCCHIPINTI-AMBROGI *et al.*, 2010). On the contrary, *Ophryotrocha japonica* is very abundant in the Mar Piccolo of Taranto, an area considered a hot spot of alien species diversity within the Italian coasts (OCCHIPINTI-

AMBROGI *et al.*, 2010). In this locality one of the most conspicuous populations of *Branchiomma luctuosum* is present (LICCIANO *et al.*, 2002), and it seems here to compete with the native species *Sabella spallanzanii* (Giangrande, pers. observ.). Most of the other established species in this area are the same as those that are common in the whole basin such as *Ficopomatus enigmaticus*, *Hydroides dianthus*, *H. diramphus*, *H. elegans*, *Lysidice collaris*, *Metasychis gotoi*, *Neopseudocapitella brasiliensis*, and *Notomastus aberans*.

#### **2.4. Alien crustaceans in the Central Mediterranean**

A total of 46 alien crustacean are reported in the CMED (26 established, 13 casual, four questionable, three cryptogenic).

Three West Atlantic species are well established at least in some regions of the CMED: *Percnon gibbesi*, *Libinia dubia*, and *Rimapenaeus similis*, which was discovered on the trawling grounds of the Gulf of Gabès (BEN HADJ HAMIDA-BEN ABDALLAH *et al.*, 2010). *Percnon gibbesi* was first observed in 1999 at Linosa Island (RELINI *et al.*, 2000). It rapidly spread in other localities of the CMED: Pantelleria (GALIL *et al.*, 2002), Malta (BORG & ATTARD-MONTALTO, 2002), the shores of southern and north-western Sicily (MORI & VACCHI, 2002), the Strait of Messina (BELLANTONI & CORAZZA, 2003) and the Gulf of Taranto (FACCIA & BIANCHI, 2007).

Several Lessepsian immigrants, such as *Trachysalambria palaestinensis*, *Eucrate crenata*, *Metapenaeus monoceros* and *Metapenaeus stebbingi*, established in the EMED have spread westward as far as Tunisian waters. Their apparent absence

along the Libyan shores may well be consequence of a lower research effort, but they are also absent from Malta and the southern Italian shores. Another Indo-Pacific species is *Plagusia squamosa*.

The following species were recorded only once and with a single specimen: *Alpheus inopinatus*, *Dromia spirostris*, *Sirpus monodi*, *Callinectes sapidus*, *Grapsus granulatus*. The presence of one adult specimen of *Paralithoides camtschaticus*, a strictly boreal species, in this sector of the Mediterranean (FACCIA *et al.*, 2009) is really puzzling.

The number of alien copepods is low (five) in the CMED and only two are Lessepsian immigrants (*Euchaeta concinna*, *Triconia umerus*). The presence of the Antarctic to Subantarctic species *Spinocalanus terranovae* in the Malta area is questionable (SCIBERRAS & SCHEMBRI, 2007).

The benthoplanktonic calanoid copepod *Pseudocyclops xiphophorus* was previously recorded only in coastal waters of Mozambique. The Mediterranean *P. xiphophorus* specimens were collected from fouling attached to submerged mooring posts and ropes in the brackish Lake Faro, eastern Sicily. It is classified as cryptogenic because according to ZAGAMI *et al.* (2005) it could represent a relict population of Tethyan origin. The genus *Pseudocyclops* has a worldwide distribution from temperate to tropical shallow coastal and brackish waters.

#### **2.5. Alien molluscs in the Central Mediterranean**

The CMED has reports for 38 alien species of molluscs (19 established, 13 casual, two cryptogenic and four questionable) in a total of 1000 to 1500 native species. Among the species of Indo-Pacific origin,

there are 12 species that qualify as Lessepsian (e.g. *Pinctada radiata*, the earliest reported Lessepsian mollusc) and six that are definitely non-Lessepsian (e.g. *Melibe viridis* which was first detected on the Ionian coast of Greece), keeping the same proportion as in SE Turkey but far from the 90% of Lessepsians along the Levantine coast.

There are scattered reports of species from the temperate Atlantic (*Crepidula fornicata*, *Polycerella emertoni*, *Anadara transversa*, *Zygochlamys patagonica*) and North Pacific (*Crassostrea gigas* purposely introduced for farming, *Musculista senhousia*, *Ruditapes philippinarum*) but most are far less successful in this particular context, than in the northern part of the Mediterranean (Ligurian Sea, Adriatic Sea) where some of them are invasive (see Table 3). Considering the proximity of the EMED, the total numbers are nevertheless remarkably low. Few species are invasive, among them could be considered the bivalves *Pinctada radiata* and *Fulvia fragilis* and the opisthobranch *Bursatella leachii* in the Gulf of Gabès.

Tunisia holds altogether 24 alien species (13 established, three casual, three cryptogenic, five questionable) but a distinction must be made between the eastern and southern coasts bordering the Gulf of Gabès, which are a continuation of the virtually unknown Libyan coast, and the north coast west of Cap Bon, which is considered as part of the WMED. A cowry, *Erosaria turdus*, had a spectacular onset in recent years and is so invasive that it will probably displace the native *Zonaria pyrum*. The limpet *Cellana rota* may be the next spectacular invader in this part of the Mediterranean.

Malta has possibly one of the best studied molluscan faunas in the southern part of the EU, and has reports for 17

species. The Ionian coast of Greece has only nine species reported, of which two (*Bursatella leachii* and *Pinctada radiata*) are among the most widespread Lessepsian immigrants and five are non-Lessepsian species of tropical Indo-Pacific origin. The Ionian coast of Italy holds 14 species. These three areas share very much of their aliens including the most widespread Lessepsian species (*Bursatella leachii* and *Pinctada radiata*, *Cerithium scabridum* and *Fulvia fragilis* in Italy and Malta) which here are secondary introductions from the EMED. Also shared are some of the tropical Indo-Pacific species which started their spread in this area (*Aplysia dactylomela*, *Haminoea cyanomarginata*, *Melibe viridis*). Some species, like *Anadara transversa* or *Musculista senhousia*, which are invasive in the Adriatic, have spread towards the Italian Ionian coast.

## 2.6. Miscellaneous invertebrates in the Central Mediterranean

Bryozoa are comprised of eight species (out of 23 known for the whole Mediterranean), of various origins (three circumtropical, three Pacific, two Atlantic). The records of *Celleporaria aperta* and *C. pilaefera* at Malta have been considered questionable by SCIBERRAS & SCHEMBRI (2007).

Nearly half of the alien species of Ascidiacea inventoried in the Mediterranean (seven out of 16) are known for the CMED. These aliens are of various origins (Western Atlantic, circumtropical, Indo-Pacific, Eastern Pacific) and both the alien species of *Microcosmus*, the Indo-Pacific *M. exasperatus* and the circumtropical *M. squamiger*, occur in the CMED (IZQUIERDO-MUÑOZ *et al.*, 2009). Most records of alien ascidians come from Taranto harbour (BRUNETTI &

MASTROTOTARO, 2004; MASTROTOTARO *et al.*, 2004; MASTROTOTARO & BRUNETTI, 2006).

The CMED hosts nine out of 46 alien species of Cnidaria known for the whole basin. Hydrozoa include six species, all with a wide distribution in warm waters. The cryptogenic species *Cordylophora caspia* was found abundant in the low salinity waters of the 'Palude del Capitano', Gulf of Taranto (BIANCHI *et al.*, 1994). Scyphozoa are represented by the three species *Cassiopea andromeda* (SCHEMBRI *et al.*, 2010a), *Phyllorhiza punctata* (ABED-NAVANDI & KIKINGER, 2007) and *Rhopilema nomadica* (SIOKOU-FRANGOU *et al.*, 2006).

The only alien species of Ctenophora is *Mnemiopsis leidyi*, recorded from Isola di Capo Rizzuto, Gulf of Taranto (BOERO *et al.*, 2009), whereas the only alien species of Porifera is *Paraleucilla magna*, originating from the SW Atlantic (ZAMMIT *et al.*, 2009). In the case of Sipuncula, there are questionable records of the circumtropical *Aspidosiphon mexicanus* from Malta and Lampedusa (PANCUCCI-PAPADOPOULOU *et al.*, 1999; SCIBERRAS & SCHEMBRI, 2007).

Alien Echinodermata are represented by three species (out of 12 for the whole Mediterranean). The record of *Eucidaris tribuloides* from Malta was also the first of this species for the Mediterranean (TANTI & SCHEMBRI, 2006).

### 2.7. Alien fish in the Central Mediterranean

In the CMED, there are records of 50 alien fish. Of them, 25 seem to be established, 19 are casual, whilst the presence of six species is questionable. The bulk of these records comes from the Sicily Strait (see GUIDETTI *et al.*, 2010 and references

therein), especially from Pelagie Islands and Malta but also from Tunisia (BEN SOUSSI *et al.*, 2006a,b) and Libya (SHAKMAN & KINZELBACH, 2006; BEN ABDALLAH *et al.*, 2007). A few records are also available from the northern Ionian Sea (TORCHIO, 1963; MASTROTOTARO *et al.*, 2007) and the Messina Strait, as in the case of *Galeocerdo cuvier* (CELONA, 2000), *Pinguipes brasilianus* (ORSI-RELINI, 2002), *Platycephalus indicus* (CASTRIOTA *et al.*, 2009) and *Psenes pellucidus* (NAVARRA *et al.*, 2008).

Evidence of established populations in the CMED are mostly related to the occurrence of multiple records of the same species, such as for *Cephalopholis taeniops* (GUIDETTI *et al.*, 2010) and *Pisodonophis semicinctus* (RAGONESE & GIUSTO, 2000) while a few species such as *Siganus luridus*, *Fistularia commersonii*, *Seriola carpenteri*, *Stephanolepis diaspros*, *Sphoeroides pachygaster* have been collected or observed in large numbers (RAGONESE *et al.*, 1997; PIZZICORI *et al.*, 2000; AZZURRO & ANDALORO, 2004; BRADAI *et al.*, 2004; AZZURRO *et al.*, 2007). Latest records include *Selene dorsalis* (VELLA & DEIDUN, 2009) and *Opleognathus fasciatus* (SCHEMBRI *et al.*, 2010b).

The geographical partitioning of CMED alien species was: 19 of Atlantic origin, 25 of Indo-Pacific or Pacific origin, and three circumtropical. If we look only at the established species, the number of Indo-Pacific or Pacific fish (15) is almost double than the number of Atlantic newcomers (eight) indicating unbalanced ratio towards fish coming from the east. Indeed, the progressive penetration westwards of Lessepsian immigrants is a continuous phenomenon, which has accelerated during the last decades, as exemplified by *Upeneus pori*, *Pempheris vanicolensis*,

*Sphyraena chrysotaenia* and *Siganus rivulatus* (BRADAI *et al.*, 2004; BEN SOUSSI *et al.*, 2006a,b).

### 3. THE ADRIATIC SEA

The Adriatic Sea is a rather unique and differentiated area within the Mediterranean, with a strong contrast between the predominantly linear sandy shores along the western (Italian) side, and the opposite complex coasts of the eastern side (Slovenia, Croatia, Montenegro and Albania) forming a maze of islands and inlets with rocky shores. The hydrographic conditions are also peculiar, with very low winter temperatures in the northern part, which is also quite shallow (40 m depth), and very hot summers in the southern part, which is much deeper. All these features lead to differentiation between the northern and southern Adriatic areas.

From a biogeographic standpoint, the Adriatic Sea is divided in three sectors, arranged more or less latitudinally. The Northern Adriatic Sea is perhaps the most peculiar sector of the whole Mediterranean. Strong winter cooling, low salinity due to significant river input, and comparatively great tidal range make it more similar to the Northern Atlantic than to the rest of the Mediterranean. This is reflected in the biota, which includes disjunct Atlantic-Adriatic species whose occurrence contributes to what has been called the Northern-Adriatic 'sub-Atlanticism' (SACCHI *et al.*, 1985). Mediterranean endemics are scarce and the overall diversity is the lowest of the Mediterranean basin, so that the phrase 'North-Adriatic gap' has also been coined (SACCHI, 1983). In addition, peculiar to this sector are some taxa with Black Sea affinity (SACCHI *et al.*, 1985; BIANCHI *et al.*,

2004). The Central Adriatic is characterized by the lack of both Northern-Adriatic endemics and Atlantic-Adriatic disjunctions. Mediterranean endemics and thermophilic species are still scarce, so that this sector is less diverse than the Gulf of Lions and Ligurian Sea, to which it resembles. However, it is significantly richer in species than the Northern Adriatic. Finally, the Southern Adriatic exhibits a transitional character between the Adriatic and the Ionian Sea, with which it communicates through the Otranto Strait. Affinities with the WMED are strongly reduced.

#### 3.1. Alien protozoans in the Adriatic Sea

Three protozoans pathogenic to shellfish, namely *Marteilia refringens*, *Bonamia ostrea* and *Perkinsus olseni* (formerly *Perkinsus atlanticus*) have been reported from shellfish cultures in the Adriatic Sea. Serious outbreaks of pasteurellosis caused by *Photobacterium damsela* (formerly *Pasteurella piscicida*) in the Adriatic are reported by CESCHIA *et al.* (1991).

Foraminiferal aliens from the Adriatic are few (six species). Moreover, all of them have been reported based on single specimens, in only one publication or site and could be considered as cryptogenic/casual. This is the case for warm water alien species such as *Archais angulatus* (LANGER & HOTTINGER, 2000), *Clavulina angularis* (BANCHETTI *et al.*, 2009), *Coscinospira hemprichii*, *Cymbaloporeta plana* (as *Trethomphalus bulloides*) and *Sorites orbiculus* (CIMERMAN & LANGER, 1991). *A. angulatus* is only reported from the Adriatic (LANGER & HOTTINGER, 2000). *Schackoinella imperatoria*, described from the coast of central Adriatic (CIMERMAN & LANGER, 1991), could be cautiously considered a cryptogenic/casual form.

### 3.2. Alien macrophytes in the Adriatic Sea

A total of 49 alien macrophytes has been hitherto reported from the Adriatic Sea, which represent 39% of the alien macrophytes reported from the Mediterranean Sea. The major vectors of introduction are the shellfish aquaculture industry in northern coastal lagoons and the ship traffic (fouling, ballast waters). Among them, 35 alien macrophytes are well established, three are casual, and 11 are cryptogenic/questionable. Casual taxa (i.e. *Acrothamnion preissii*, *Hypnea valentiae* and *Polysiphonia paniculata*) might turn into the established status in the future. The cryptogenic/questionable category includes 11 species (Table 2).

Of the 21 invasive or potentially invasive macrophytes introduced into the Mediterranean (Table 3), 14 are present in the Adriatic Sea. Among them, cold temperate taxa (i.e. *Codium fragile*, *Gracilaria vermiculophylla*, *Grateloupia turuturu*, *Dasyphonia* sp., *Sargassum muticum* and *Undaria pinnatifida*) grow in north-western coastal lagoons, especially in the Lagoon of Venice and the lagoons of the Po Delta, while the warm temperate and tropical taxa (i.e. *Asparagopsis* spp., *Caulerpa racemosa* var. *cylindracea*, *Caulerpa taxifolia*, *Halophila stipulacea*, *Lophocladia lallemandii*, and *Womersleyella setacea*) invade the marine habitats of southern Italy and the east coasts of the Adriatic (Croatia, Albania), with the exception of *Acrothamnion preissii*. The invasive *Gracilaria vermiculophylla* is hitherto known only in the lagoons of the Po Delta.

Northern Adriatic coasts are the most impacted, with 34 aliens out of a total of 49 (69% of alien macrophytes of the Adriatic), while only 15 aliens were reported from the Central and Southern Adriatic. SFRISO *et al.* (2009 and unpublished data)

listed up to 33 aliens (67% of alien macrophytes of the Adriatic) in the Lagoon of Venice. Such a difference is probably due to a flood of introductions along with shellfish transfers (oysters, mussels, Manila clams) on the north-Italian coasts where aquaculture is extensively developed.

The majority of alien macrophytes of the Adriatic basin (35 taxa) come from temperate and cold regions (NE Atlantic and NW Pacific) in relation with the major vector of introduction (shellfish transfer). Only seven putative Lessepsian immigrants (i.e. *Acanthophora nayadiformis*, *Chondria pygmaea*, *Halophila stipulacea*, *Hypnea spinella*, *Hypnea valentiae*, *Lophocladia lallemandii* and *Ulva fasciata*) have been hitherto registered, mainly from the northern coasts. However, *Acanthophora nayadiformis* and *Hypnea spinella* could alternatively originate from the Atlantic Ocean. The strains of *Hypnea valentiae* and *Ulva fasciata* found in the Lagoon of Venice may originate from the north-western Pacific as in the Thau Lagoon.

### 3.3. Alien polychaetes in the Adriatic Sea

The Adriatic hosts only 22 alien polychaete species (11 established, six casual and five questionable), which represent 17% of the Mediterranean polychaete alien species. At least four species appeared exclusive of the Adriatic: *Fabriciella ghardaqa*, *Megalomma claparedei*, *Platynereis australis* and *Syllis alose*, the latter two being considered as questionable taxa.

The established species are among those well known and settled in the whole Mediterranean area, and most of them are also invasive, such as *Branchiomma luctuosum*, *Ficopomatus enigmaticus*, *Hydroides dianthus*, *H. elegans*, but also *Lysidice collaris*, *Metasychis gotoi*, *Neopseudocapitella brasiliensis*, and *Notomastus aberans*. The

most recently introduced species is *B. lucuosum*, present with very large populations along the Mediterranean coasts. At present this species seems to have reached also the Brazilian Coast of São Paulo, in the Bay of Santos, in the vicinity of the largest seaport in Latin America (DE MATOS NOGUEIRA *et al.*, 2006), underlining its ability to invade new areas, possibly transported by ships. An introduction via the Suez Canal and possible transfer via shipping, can be postulated not only for *B. lucuosum*, but also for the other two Red Sea sabellid species, exclusive of this area and collected on the hard bottoms of the Southern Adriatic coast: *M. claparedei* and *F. ghardaqa* that were, however, found only once with very few individuals and considered therefore casual (GIANGRANDE & MONTANARO, 1999; GIANGRANDE & LICCIANO, 2008). By contrast, the other sabellid *Novafabricia infratorquata* is a Caribbean species that must have been introduced from the Strait of Gibraltar, appearing established in the WMED and casual in the Southern Adriatic along the Apulian coast (LICCIANO & GIANGRANDE, 2006).

### 3.4. Alien crustaceans in the Adriatic Sea

A total of 24 alien crustacean are reported from the Adriatic (11 established, 11 casual, two cryptogenic).

The first records of alien species introduced in the Northern Adriatic by maritime traffic date back to the years before World War I, when STIASNY (1908) recorded the capture of *Plagusia squamosa* (Herbst, 1790), *Thenus orientalis* (Lund, 1793) and *Portunus sanguinolentus* (Herbst, 1796), respectively in the harbours of Trieste and Fiume (Rijeka), at that time the main harbours of the Austro-Hungarian Empire (BABIC, 1913). The latter two

species are excluded from our list following GALIL *et al.* (2002), whereas *P. squamosa* is kept as questionable because thriving populations were recently reported from elsewhere in the Mediterranean: Tunisia and Libya (ZAOUALI *et al.*, 2007).

Only three crabs (*Callinectes sapidus*, *Dyspanopeus sayi* and *Rhithropanopeus harrisi*) are definitely established in the area and all three originate from the Atlantic coast of USA. The spreading of the two panopeid crabs in the Adriatic Sea in recent years (FROGLIA & SPERANZA, 1993; MIZZAN & ZANELLA, 1996; ONOFRI *et al.*, 2008) has been facilitated by the development of mussel aquaculture both in lagoons and open sea, with transfer of mussels seed and half grown mussels among aquaculture plants.

The latest record is that of the Indo-Pacific crab *Charybdis lucifera*, caught six miles off the Venetian coast (MIZZAN & VIANELLO, 2009).

The following species were recorded only once and with single specimens: *Marsupenaeus japonicus*, *Scyllarus caparti*, *Callinectes danae*, *Charybdis lucifera*, *Eriocher sinensis*, *Hemigrapsus sanguineus*, and *Charybdis japonica* (FROGLIA, in press).

Only three planktonic copepod species were recorded as aliens in the Adriatic Sea, originating from the Atlantic and Indo-Pacific oceans.

### 3.5. Alien molluscs in the Adriatic Sea

The Adriatic Sea has possibly the oldest alien (treated as cryptogenic) marine species in the Mediterranean Sea, viz. *Littorina saxatilis*, originally described from Venice (OLIVI, 1792) before it could be suspected of being introduced from the NE Atlantic (JANSON, 1985). The Adri-

atic holds a few endemic species, one of which (*Gibbula albida*) has been introduced into the WMED and elsewhere.

The Adriatic holds only 27 alien species (15 established, nine casual and three cryptogenic) but the striking characteristic is the high proportion of them which have become invasive. Together with the Levantine basin, the Adriatic may be the part of the Mediterranean which has been most transformed by the onset of alien species. The most invasive species include *Anadara kagoshimensis* (formerly known as *A. inaequalis*), *Musculista senhousia*, *Rapana venosa* and *Ruditapes philippinarum*, all originating from the temperate North Pacific and therefore comfortable despite seasonal lows in sea water temperature. *Anadara kagoshimensis*, now coupled to the possibly Atlantic *Anadara transversa*, has formed spectacular accumulations on the NE Italian coast (RINALDI, 1985) and has profoundly impacted the sandy infralittoral bottoms which are a habitat for commercial species such as the venerid *Chamelea gallina*. Farmed species include *Crassostrea gigas* and *Ruditapes philippinarum*, and the activity related to farming may be responsible for an important part of the introductions to and from the Adriatic; the latter species is invasive and likely to displace or to drive locally extinct the native clam *Ruditapes decussatus*. The Sidney rock oyster *Saccostrea commercialis* was introduced to the Venice Lagoon in the 1980s but seems to have dwindled and has not been reported recently (MIZZAN, 1999).

Twenty-one of the alien species known from the Adriatic are recorded in Italy, and only the few tropical species *Brachidontes pharaonis*, *Cellana rota*, *Melibe viridis* and *Halgerda wileyi* have records exclusively along the eastern coast.

### 3.6. Miscellaneous invertebrates in the Adriatic Sea

Three alien species of Bryozoa (out of 23 known for the whole Mediterranean) have been recorded in the Adriatic. The Indo-Pacific species *Tricellaria inopinata* was originally described on material coming from the Lagoon of Venice by D'HONDT & OCCHIPINTI-AMBROGI (1985). It has been subsequently found in many European seas (DYRYNDA *et al.*, 2000). The alien status of *Bugula fulva* is supposed based on its patchy occurrence nearly restricted to harbours (HAYWARD & MCKINNEY, 2002).

The only alien species of Ascidiacea is *Botrylloides violaceus*, introduced in the Lagoon of Venice by the north-western Pacific by shellfish culture (ZANIOLO *et al.*, 1998).

Alien Anthozoa are represented only by the north-eastern Atlantic species *Diadumene cincta* (BIRKEMEYER, 1996), which in a sense reinforces the Northern-Adriatic 'sub-Atlanticism'.

Porifera are represented by *Paraleucilla magna* only (LONGO *et al.*, 2007).

Fourteen alien species of Cnidaria (out of 46 for the whole Mediterranean) are known for the Adriatic. Alien Hydrozoa are comprised of 13 species (out of 37). Most of them have circum(sub)tropical origin, but two estuarine species (*Cordylophora caspia* and *Gonionemus vertens*) prefer temperate waters. The first Mediterranean record of *Garveia franciscana* comes from the Venice Lagoon (MORRI, 1982). It is debatable whether *Coryne eximia* can be considered as alien species since the Mediterranean occurrence of this species seems to need re-confirmation (BOUILLON *et al.*, 2004).

Two of the three alien species of Ctenophora known for the Mediterranean

are established in the Adriatic: *Beroe ovata* and *Mnemiopsis leidyi* (SHIGANOVA & MALEJ, 2009). These authors refer earlier citations of *Beroe ovata* in the Mediterranean to the native species *B. cucumis*, and report the real *B. ovata* as a Western Atlantic species first introduced to the Black Sea and possibly from there to the Adriatic.

Sipuncula number two alien species: both are circum(sub)tropical (PANCUCCI-PAPADOPOULOU *et al.*, 1999). The only alien pycnogonid is *Ammothea hilgendorfi*, first reported for the Mediterranean from the Lagoon of Venice (KRAPP & SCONFIETTI, 1983).

### 3.7. Alien fish in the Adriatic Sea

Adding *Fistularia commersonii* (DULČIĆ *et al.*, 2008), 11 Lessepsian fish species had reached the Adriatic Sea by 2009 (DRAGIČEVIĆ & DULČIĆ, 2010). The occurrence of *Terapon theraps* in 2007 (LIPEJ *et al.*, 2008) is of particular interest since its record was the first for the Mediterranean; furthermore, it was found at great distance from its usual distribution area. Similar are the cases of *Pampus argenteus* and *Epinephelus coioides*.

The catch of *Elates ransonnetii* in March 2010 in the eastern Adriatic (DULČIĆ *et al.*, 2010) brought the number of Lessepsian fish immigrants that were recorded in the Adriatic Sea to 12. *Sphoeroides pachygaster*, of tropical Atlantic origin, has undoubtedly formed a well established population in the Adriatic (Albania, Slovenia, Montenegro, Croatia, Italy).

## 4. EASTERN MEDITERRANEAN

The EMED includes two major bodies of water: the Levant Sea and the Aegean

Sea, together with the smaller Sea of Marmara, which connects it to the Black Sea. The Levant Sea is warmer than the rest of the Mediterranean and harbours a significant number of circumtropical species. Atlantic-Mediterranean elements and Mediterranean endemics are comparatively scarce (MORRI *et al.*, 2009).

Since the construction of the Suez Canal, the Levant Sea is experiencing an important influx of Red Sea species. POR (1990) defined the geographical limits to the expansion of Red Sea immigrants in the Mediterranean as the 'Anti-Psara line' to the north (Anti-Psara being an island in the Aegean) and the Strait of Sicily to the west: these boundaries match the 15 °C surface isotherm for February (BIANCHI, 2007). The Aegean Sea has local endemics, but the typical Mediterranean biota is impoverished with respect to the WMED (BIANCHI & MORRI, 1983); this, however, may be partly due to insufficient inventory effort (MORRI *et al.*, 1999; KOUKOURAS *et al.*, 2001). The Sea of Marmara exhibits peculiar hydrological conditions, with low salinity waters coming from the Black Sea stratifying over saline waters of Mediterranean origin on the bottom (ÜNLÜATA *et al.*, 1990). This hydrological regime should facilitate the diffusion of Black Sea species into the Northern Aegean rather than vice-versa, but our knowledge on the exchanges between the two areas is limited and their biotic affinity is low (KOUKOURAS *et al.*, 2001). In recent times, climatic change favoured an increase of biotic penetration from the Sea of Marmara into the Black Sea, which therefore has been undergoing a process of 'mediterraneanization' (TOKAREV & SHULMAN, 2007).

Some scientists (e.g., TORTONESE, 1973; OLIVERIO & TAVIANI, 2003;

POR, 2009) have argued that this basin, particularly in its eastern stretches, suffered from an 'ecological vacuum' that is now being filled by Red Sea immigrants. This idea has been criticized by GALIL (2007).

#### 4.1. Alien protozoans in the Eastern Mediterranean

Fish pasteurellosis caused by *Photobacterium damsela* was reported from cultured seabass (*Dicentrarchus labrax*) in Turkey (CANDAN *et al.*, 1996).

Among the total of 50 alien foraminiferal species presently known for the Mediterranean, all except one are present in the EMED (LANGER & HOTTINGER, 2000). All of them have tropical affinity. Despite a significant number of species with circumtropical distribution (KOUKOUSIOURA *et al.*, 2010b), most have Indo-Pacific origin and their penetration in the EMED is likely to have been favoured by the opening of the Suez Canal (MERIÇ *et al.*, 2007a; LANGER, 2008). Off the west Turkish coast, alien foraminifera showed high abundance at hot submarine springs that allowed higher bottom water temperatures in winter (MERIÇ *et al.*, 2010). Similar observations on alien macrophytes in the Aegean (DE BIASI & ALIANI, 2003) and in the Tyrrhenian Sea (GAMBI *et al.*, 2008) suggest that shallow water hydrothermal vents in the Mediterranean Sea may act as stepping stones for the penetration of tropical aliens (BIANCHI *et al.*, in press).

Among the nine new taxa added to those recorded by ZENETOS *et al.* (2008), eight occur in the EMED (LANGER, 2008) and 4 of them have been reported only from single or few localities: *Brizalina simpsoni* and *Euthymonacha polita* from the coasts of Turkey (MERIÇ *et al.*, 2010),

*Pegidia lacunata* and *Pseudolachlanella slitella* (as *Quinqueloculina eburnea*) from north-eastern Africa (BLANC-VERNET *et al.*, 1979) and Cyprus (ABU TAIR & LANGER, 2010).

The new recovery of alien foraminifera mainly comes from recent researches carried out on living coastal assemblages of the EMED, which testify to the increasing scientific interest in alien and Lessepsian immigrants. These studies confirm the wide distribution of many large endosymbiont-bearing taxa, such as Amphisteginids, along the coasts of the Levantine basin (LANGER, 2008), Greece (TRANTAPHYLLOU *et al.*, 2009; KOUKOUSIOURA *et al.*, 2010a), Turkey (MERIÇ *et al.*, 2010) and Cyprus (ABU TAIR & LANGER, 2010). *Amphistegina lobifera* appears to have established successful populations in Greek coastal ecosystems (TRANTAPHYLLOU *et al.*, 2009; KOUKOUSIOURA *et al.*, 2010a,b). Taxa of Indo-Pacific origin, probably true Lessepsian forms, are represented by *Borelis* sp., *Coscinospira hemprichii*, *Cycloforina* sp., *Heterostegina depressa*, *Pegidia lacunata*, *Pseudolachlanella slitella* and *Sorites orbiculus*.

Taxa undetermined at the specific level (*Borelis* sp., *Cycloforina* sp.) have been included as alien forms only when described and figured in previous work on Red Sea or Indo-Pacific areas (HOTTINGER *et al.*, 1993; LANGER & HOTTINGER, 2000; LANGER, 2008 with references) or (*Haddonina* sp.) if pertain to endemic Indo-Pacific genera (LOEBLICH & TAPPAN, 1988).

At the present state of studies, it seems prudent to exclude some very seldom recorded species cited by ZENETOS *et al.* (2008), yet very rare or poorly preserved, but also known at various latitudes or as

fossils in the Mediterranean area. These species are here represented by *Acervulina inhaerens*, *Iridia diaphana*, *Cymbaloporella squamosa*, *Pyramidulina perversa* and *Triloculina affinis*.

*Schackoinella imperatoria*, a small species originally described from fossil material of the Tertiary Basin of Vienna, pertains to a genus now known only in the Indo-Pacific Ocean (LOEBLICH & TAPPAN, 1988). Rare specimens have been recorded along the eastern coasts of North Africa (BLANC-VERNET, 1969) as *Glabrattella imperatoria*. More data are needed to verify its introduction by shipping through the Suez Canal. Its rare occurrence suggests a cryptogenic/casual acclimatization status.

In addition to all these benthic species, planktonic foraminifers are represented only by *Pulleniatina obliquiloculata*, a thermocline dwelling species characteristic of equatorial Atlantic and Indo-Pacific Oceans (BE & TOLDERLUND, 1971; KENNETT & SRINIVASAN, 1983). Its occurrence has been reported only by MERIC *et al.* (2004) along the Turkish coasts and its introduction was inferred from the Atlantic Ocean via Gibraltar (ZENETOS *et al.*, 2008). Recently, *P. obliquiloculata* has been reported from Canary Islands, Eastern Atlantic (WILKE *et al.*, 2009). It is absent in the Red Sea, but it has been frequently reported from the Arabian Sea and Bay of Bengal (BE & TOLDERLUND, 1971; CHEN & FARRELL, 1991, *inter alii*). More data are required to interpret its occurrence and to exclude its transport within ballast waters.

#### **4.2. Alien macrophytes in the Eastern Mediterranean**

A total of 63 alien macrophytes have been hitherto reported in the EMED

which represent 50% of the alien macrophytes reported from the Mediterranean Sea. This high percentage is mainly due to the proximity to the Suez Canal and dense international ship traffic in the area. Among them, 35 alien macrophytes are well established, nine are casual, 15 are cryptogenic/questionable, and four require confirmation. Casual taxa (i.e. *Acrochaetium* spp., *Derbesia boergesenii*, *Padina antillarum*, *Rhodophysema georgii*, *Rhodymenia erythraea*, *Solieria dura* and *Spatoglossum variabile*) might turn into the established status in the future. The cryptogenic/questionable category includes both temperate taxa mainly registered in the north of the basin, i.e. the Sea of Marmara and the Northern Aegean Sea (*Anotrichium okamurae*, *Chondria coerulea*, *Cladosiphon zosterae*, *Ectocarpus siliculosus* var. *hiemalis*, *Halothrix lumbricalis*, *Polysiphonia atlantica*, *P. fucoides* and *Pylaiella littoralis*), and tropical taxa distributed in the Aegean Sea and the Levantine Basin (*Acanthophora nayadiformis*, *Antithamnionella elegans*, the Atlantic strain of *Asparagopsis taxiformis*, *Caulerpa racemosa* var. *turbinata*, *Ceramium bisporum*, *Ganonema farinosum* and *Ulva fasciata*). The presence of *Antithamnionella spirographidis*, *Asparagopsis armata*, *Gracilaria arcuata* and *Hypnea flagelliformis* in the EMED requires confirmation. The latest record is that of the seaweed *Codium parvulum*, recent blooms of which were observed on the northern shores of Israel (ISRAEL *et al.*, 2010).

On the 21 invasive or potentially invasive macrophytes introduced into the Mediterranean (Table 3), 11 are reported in marine benthic habitats of the EMED. No data are available for coastal lagoons. *Cladophora* cf. *patentiramea* and *Codium parvulum* are hitherto known only for the

EMED, for Cyprus and Israel, respectively.

The majority of alien macrophytes of the EMED (63%) come from tropical regions, mainly the Red Sea and the Indo-Pacific Ocean. The major vector of introduction is the Suez Canal. Hitherto 35 putative Lessepsian immigrants (56% of the total) have been registered, of which *Cladophora* cf. *patentiramea*, *Codium parvulum*, *Halophila stipulacea*, *Lophocladia lallemandii* and *Styopodium schimperi* are considered invasive. *Acanthophora nayadiformis*, *Ganonema farinosum* and *Ulva fasciata* were found in the Mediterranean before the opening of the Suez Canal in 1869, but the occurrence, at least in the EMED, of exotic strains coming from the Red Sea and the Indian Ocean via the Canal is highly probable today. The other alien macrophytes reported from the EMED come from cold temperate regions (NE Atlantic and NW Pacific) and were recorded along the north coasts of Greece and Turkey (Sea of Marmara and Northern Aegean Sea). Some of these last macrophytes, i.e. *Ectocarpus siliculosus* var. *hiemalis*, *Polysiphonia fucoides* and *Pylaiella littoralis*, also occur in the Black Sea (TAŞKIN *et al.*, 2008): so, a native status cannot be excluded in the northern part of the EMED.

#### **4.3. Alien polychaetes in the Eastern Mediterranean**

A total of 98 alien polychaete species have been reported to date from the EMED, almost 75% of the alien polychaete species reported from the Mediterranean Sea, mainly due to the proximity to the Suez Canal and dense international ship traffics in the area. Among them, 52 species have been well established in habitats of the EMED, 16 species are casual, two species (*Chaetozone corona* and *Para-*

*prionospio coora*) are cryptogenic and 28 species are questionable. 22 species seem to have invasive character (see Table 3), forming dense populations in semi- or heavily polluted areas (including harbours) or shallow water benthic habitats. There is a relatively high number of questionable species in the area. They include the species only listed in ecological papers (i.e. *Cossura coasta*, *Loimia medusa*), those identified as 'cf.' in the area (i.e. *Oenone* cf. *fulgida*, *Syllis* cf. *mayeri*) or whose descriptions based on the Mediterranean specimens were insufficient (i.e. *Lepidonotus carinulatus*), hindering us in deciding their real taxonomic positions. Future studies to be performed in the region would enable us to understand if these species really exist in the Mediterranean. A total of ten casual species (i.e. *Laonome elegans*, *Nereis gilchristi*) might turn into the established status if data regarding them are accumulated. The native species, *Chaetozone setosa* (in part) and *Paraprionospio pinnata*, previously widely reported from the Mediterranean Sea in polluted and deep waters, have been recently re-identified as *C. corona* and *P. coora*, respectively (ÇINAR & ERGEN, 2007; YOKOYAMA *et al.*, 2010). These species were regarded as cryptogenic because the data on their distributions are very limited; they are relatively newly described species and could have been in existence in the area for many years.

The Levantine Sea is densely colonized by alien polychaete species. In the region, a total of 77 species (79% of the alien polychaetes from the EMED) have been hitherto reported. A total of 11 species are categorized as questionable. The highest number of alien species (58 species) are known from the Levantine coast of Turkey, followed by the Israeli (29

species) and Egyptian (28 species) coasts. On the Syrian coast, only two alien species (*Spirobranchus tetraceros* and *Spirorbis marioni*) were encountered. The majority of species are Lessepsian immigrants (47 species, 61% of total species), the others were introduced to the area via ships, except for *Chaetozone corona* which is a cryptogenic species. A total of 66 species (86%) could have been originated in the Red Sea and Indo-Pacific areas. The others (11 species) were introduced to the area from the Atlantic Ocean (mainly from the western part).

The Aegean Sea is on the route of the Lessepsian species that have become well acclimatized to the Mediterranean environment and have a large dispersal capacity. Up to date, 39 alien polychaetes were reported from the Aegean Sea, of which 16 species are Lessepsian immigrants. In the area, 20 species have been well established, one species, *Prionospio (Minuspio) pulchra*, is casual, 16 species are questionable and two species, *Paraprionospio coora* and *Chaetozone corona*, are cryptogenic. Ship-transported species dominate semi- or highly polluted areas, especially near the large international harbours. The opportunistic species *Malacoceros fuliginosus* and *Capitella* spp. seem to have been replaced by the North Atlantic species *Polydora cornuta* and *Streblospio gynobranchiata* and the Pacific species *Pseudopolydora paucibranchiata* (ÇINAR *et al.*, 2005, 2006a). In the eastern part of the Aegean Sea, 19 alien polychaete species were found, of which two species are questionable. In the western part, 31 species were reported, of which 14 species are questionable.

Polychaetes from the Sea of Marmara have been recently reviewed by ÇINAR (2010). He postulated that a total of 17

species of alien status were reported from the region. However, three species were excluded from the list, eight species are questionable and six species (*Nereis persica*, *Paraprionospio coora*, *Polydora cornuta*, *Streblospio gynobranchiata*, *Desdemona ornata* and *Ficopomatus enigmatus*) have been established. The report of the Lessepsian species *N. persica* by RULLIER (1963) needs to be confirmed. The other species could have been introduced to the area by ships.

#### 4.4. Alien crustaceans in the Eastern Mediterranean

A total of 119 alien crustaceans have been reported in the EMED among which six are cryptogenic species (*Cymadusa filosa*, *Gammaropsis togoensis*, *Monocorophium sextonae*, *Pseudocalanus elongatus*, *Synalpheus tumidomanus africanus* and *Thalamita poissonii*). Introduced crustaceans belong to Amphipoda (10), Cirripedia (5), Copepoda (33), Cumacea (3), Decapoda (58), Isopoda (7), Tanaidacea (1) and Stomatopoda (2). These numbers include both benthic and pelagic forms of copepods as well as parasites among cirripedes, copepods and isopods. The vast majority of them occur in the Levantine Sea (e.g. 68% of the benthic forms, all planktonic taxa and all parasites). Two thirds of the species have colonized the Levantine and are spreading to the Aegean, while almost one third is known from single records. Very few species, such as the decapods *Calappa pelii*, *Metapenaeus affinis* and *Sirpus monodi*, are limited to the Aegean Sea. Reasoning for the relatively high number of questionable copepod species (ca. 10%) is provided in ZENETOS *et al.* (2005, 2008).

With the exception of a few species originating in the Atlantic (*Calappa pelii*,

*Callinectes sapidus*, *Farfantepenaeus aztecus*, *Necora puber*, *Percnon gibbesi*, *Processa macrodactyla*, *Sirpus monodi*, *Synalpheus tumidomanus africanus* and *Thalamita indistincta*), the native range of four-fifths of the alien crustacean in the Mediterranean is in the Indo-Pacific Ocean, Indian Ocean and Red Sea. The pathway of introduction of decapod species is the Suez Canal, but penetration has been either unintentional (Lessepsian migration) or ship-mediated. Shipping appears to be also responsible for the immigration of species of Atlantic origin. However, spreading of self maintaining populations from the CMED appears to be the mode of introduction of the west Atlantic crab, *Percnon gibbesi* now present in Greece, Turkey, Syria, Cyprus, Israel (KATSANEVAKIS *et al.*, in press and references therein) and Egypt (AZZURRO *et al.*, in press). *Thalamita poissonii* could be a Lessepsian species, but there are records of it before the Suez Canal opening (UDEKEM D'ACQZ, 1999), which could support a pre-Messinian Mediterranean presence. If so, the alien status should be downgraded to 'questionable'. Perhaps at this moment it is best to consider it as 'cryptogenic'.

The latest additions to the inventory of the marine decapod species in the EMED are the pilumnid crab *Eurycarcinus integrifrons* (ÖZCAN *et al.*, 2010), the red swimming crab *Gonioinfradens paucidentata* (CORSINI-FOKA *et al.*, 2010), both of Indo-Pacific origin, and the western Atlantic shrimp *Farfantepenaeus aztecus* (CENZIG *et al.*, 2010).

The Indo-Pacific stomatopod *Erygosquilla massavensis* thrives along the Levantine coast and is expanding in the Aegean (ÖZCAN *et al.*, 2009).

Among the planktonic crustaceans,

information is available almost exclusively for copepods, since it is the most studied group (as in the entire Mediterranean Sea). Most of the newcomers are Lessepsian immigrants, two originating in the Atlantic (*Calanopia biloba*, *Paracartia grani*), while the origin of *Acartia tonsa*, *Arietellus pavoninus*, *Centropages furcatus* and *Parvocalanus crassirostris* is questionable, since they are distributed in tropical to subtropical waters both of the Atlantic and Indian oceans and even of the Pacific. The species *Pontellina plumata*, *Corycaeus speciosus* and *Subeucalanus crassus* were excluded from the list of alien species given by ZENETOS *et al.* (2005) after reconsideration of the available information on their distribution (RAZOULS *et al.*, 2005-2010). The consideration of *Subeucalanus subcrassus* as alien is questionable because it is present in most areas of the Mediterranean Sea as well as in the temperate to tropical waters of the Atlantic and Pacific oceans. The presence of *Spinocalanus terranovae* in the EMED seems questionable, given its restricted distribution in Antarctic and subantarctic areas. Regarding the records of *Triconia rufa* (originating from the Red Sea) in the EMED (Lebanon) by MALT *et al.* (1989), BÖTTGER-SCHNACK & SCHNACK (2009) assumed that the previous authors may have confounded the specimens with *Triconia* sp. 8. Finally, *Pseudocalanus elongatus* should be considered as cryptogenic in the Mediterranean Sea: it has been interpreted as a boreal relict species (FURNESTIN, 1979) or an immigrant, either from the Black Sea (SIOKOU-FRANGOU, 1985) or the north-eastern Atlantic (VIVES *et al.*, 1981).

Two introduced cymothoid species of Indo-Pacific origin, *Anilocra pilchardi* and *Cymothoa indica*, typically parasitic of

teleost fish, have been reported from Lebanon (BARICHE & TRILLES, 2006; TRILLES & BARICHE, 2006) parasitizing mainly barracudas (Sphyrnidae).

Three parasitic copepods new to the Mediterranean fauna were reported in waters off the Egyptian coast near Alexandria by EL-RASHIDY & BOXSHALL (2009). Two of them, *Mitrapus oblongus* and *Clavellisa ilishae*, are of Indo-Pacific origin and are considered to have co-invaded the Mediterranean through the Suez Canal on Red Sea immigrant hosts. The third parasite, *Nothobomolochus fradei*, was previously known from the Gulf of Guinea and the Arabian Gulf.

A rhizocephalan barnacle, *Heterosaccus dollfusi*, followed its portunid host crab, *Charybdis longicollis*, from the Red Sea through the Suez Canal to the Mediterranean Sea.

#### **4.5. Alien molluscs in the Eastern Mediterranean**

The EMED has the lion's share of alien molluscs, building up impressive numbers and by far the highest proportion worldwide. To date there are 190 alien molluscs reported (105 established, 64 casual, 15 questionable and six cryptogenic), to be added to around one thousand native species. This represents more than 90% of all alien mollusc species reported in the Mediterranean as a whole, a percentage that remains remarkably stable if we consider established species only. Six species are classified as cryptogenic (*Alvania dorbignyi*, *Aplysia parvula*, *Atys angustatus*, *Discodoris lilacina*, *Parviturbo dibellai*, *Teredo navalis*), as there are doubts on whether they are native or introduced or perhaps represent very old introductions.

Predictably, the vast majority of these

species are of Indo-Pacific origin and their presence is related to the proximity of the Red Sea and to the Suez Canal connection. Only six species (*Siphonaria pectinata*, *Mya arenaria*, *Cerithium litteratum*, *Anadara transversa*, *Mytilopsis sallei*, and *Petricola pholadiformis*) are Atlantic or Atlanto-Mediterranean in origin. Examples of Indo-Pacific species yet non-Lessepsians, among the now well-established species, are the strombid *Conomurex persicus*, first recorded in Turkey and only later arrived on the Levantine coast, or the opisthobranch *Melibe viridis*, first recorded in Greek waters. Some of these species, like *Conomurex persicus*, are not even known from the Red Sea and their introduction must therefore have involved maritime traffic at some stage.

POR (2009, 2010) expressed the view that the thermophilic species of Indo-Pacific origin should not be viewed as aliens but rather as a restoration of the Tethyan faunal realm as it existed previously to the closure of the communication with the Indian Ocean in the late Miocene.

Another quite distinct pool is made up by species which originate from the temperate North Pacific, rather than from the tropical areas, and whose introduction is linked with transfers of living molluscs for aquaculture and/or maritime traffic.

The EMED has comparatively limited aquaculture activity and this category would hold, apart from the cultured species proper *Crassostrea gigas* and *Ruditapes philippinarum*, very few species such as *Rapana venosa*, *Anadara kagoshimensis* or *Musculista senhousia*.

A particular aspect regarding molluscs is the high incidence of unsupported records, often based on single shells and carried perpetuated in subsequent checklists. The rationale for their exclusion has

been detailed in GOFAS & ZENETOS (2003). We have not considered in this report the records for 32 additional species, including those found on an oil rig (MIENIS, 2004), among them oysters and other bivalves firmly attached to their substrate, considering that these have not yet been found in the wild.

The Levantine Sea is the area which holds the highest number of reports, with 149 species (83 established, 45 casual, 5 cryptogenic, 16 questionable); historically this is the area where pioneer reports were made on alien species of Indo-Pacific origin (e.g. GRUVEL & MOAZZO, 1931; HAAS, 1937).

There are 48 of the species recorded from Israel, Lebanon and Syria, which have a record in the Suez Canal and may be safely qualified as Lessepsian, against only seven (*Melibe viridis*, *Murchisonella columna*, *Sticteulima* cf. *lentiginosa*, *Smaragdia souverbiana*, *Conomurex persicus*, *Zafra savignyi*, *Zafra selasphora*) species of tropical Indo-Pacific origin which are proven non-Lessepsians (whose progression started elsewhere than on the Levantine coast and have no Suez Canal record). The remainder cannot be positively assessed but the ratio of Lessepsian to non-Lessepsian among them should probably remain high.

The coasts of southern Turkey and Cyprus are the next largest centres where alien species have been reported, but there the exploration is much more recent and the fauna had remained virtually unknown until the 1980s. Here the totality of the species is of tropical Indo-Pacific origin (save the cryptogenic species) but the share is more balanced between Lessepsian and non-Lessepsian. For the coast of southern Turkey, we have 32 proven Lessepsians previously recorded in the

Suez Canal and along the Levantine coast, all established except the casual *Psammotreta praerupta* versus 20 species of the tropical Indo-Pacific which are definitely not Lessepsian and started their Mediterranean settlement in the area.

The Aegean Sea is the natural route of progression for the most successful Indo-Pacific invaders, both Lessepsian and those introduced first in the southern Turkey/Cyprus area. Nevertheless it has also its own pools of species introduced through other pathways. Contrary to the south coast of Turkey, there are several species that originate from the Atlantic (*Anadara transversa*, *Crepidula fornicata*, *Cerithium litteratum*, *Petricola pholadi-formis*, *Mya arenaria*) or the temperate North Pacific (*Ruditapes philippinarum*, *Rapana venosa*) and are involved neither in the Lessepsian migration nor in the SE Turkey focus of introductions. *Siphonaria pectinata*, introduced in the Gulf of Saronikos, is a clear example of intra-Mediterranean introduction.

As may be derived from this, the importance of Lessepsian species is moderate, and even the proven Lessepsian species found there may be secondary introductions from populations settled elsewhere in the EMED.

Among the 18 species which could hold as Lessepsian because they were recorded in the Suez Canal, species like *Cellana rota*, *Fulvia fragilis*, *Murex forskoehlii*, first showed up in the Saronikos Gulf heavily impacted by maritime traffic: *Cerithium scabridum* appeared in Greece (ZENETOS *et al.*, 2009) much later than in Sicily, where it was obviously a secondary introduction. Only a few Lessepsian species such as *Pinctada radiata* or *Trochus erithreus* may have arrived in the Aegean as a result of

regular progression inside the Mediterranean.

#### 4.6. Miscellaneous invertebrates in the Eastern Mediterranean

Fourteen alien species of Bryozoa, out of the 23 recorded in the whole Mediterranean, are known for the EMED. Most of them are of Indo-Pacific origin, and most are established. Three recently described species from Lebanon have presumably penetrated from the Red Sea: this seems sufficiently documented for *Parasmittina serruloides* and *P. spondylicola* (HARMELIN *et al.*, 2009) but the status as a Levantine endemic cannot be excluded for *Schizoretepora hassi* (HARMELIN *et al.*, 2007).

Seven of the 16 alien species of Ascidiacea known for the Mediterranean are established in the EMED. They are in majority Indo-Pacific, or alternatively circumtropical. *Rhodosoma turcicum*, *Ecteinascidia thurstoni*, *Phallusia nigra*, *Ascidia cannellata*, *Symplegma brakenhielmi*, *Herdmania momus*, and probably *Microcosmus exasperatus* are regarded as Red Sea immigrants (ÇINAR *et al.*, 2006b; BITAR *et al.*, 2007; IZQUIERDO-MUÑOZ *et al.*, 2009; KATSANEVAKIS *et al.*, 2009; SHENKAR & LOYA, 2009; KONDILATOS *et al.*, 2010).

Cnidaria are represented by 32 alien species out of 46 known for the whole Mediterranean. Anthozoans are represented by two species: the Indo-Pacific gorgonian *Acabaria erythraea* has been found in the harbour of Hadera, Israel (FINE *et al.*, 2004), whereas the scleractinian coral *Oculina patagonica*, possibly originating from the SW Atlantic, has been recorded from many sites through the whole basin (BITAR & ZIBROWIUS, 1997; FINE *et al.*, 2001; ÇINAR *et al.*,

2006b; SALOMIDI *et al.*, 2006). Paradoxically no Red Sea coral species has yet penetrated in the EMED (BIANCHI *et al.*, 2010). In the case of the Hydrozoa, the EMED harbours two thirds of the alien species hitherto known for the Mediterranean (26 out of 37) in accordance with what is known for virtually all the other groups of organisms, which typically show a preponderance of aliens in that basin. Among the 26 alien planktonic hydrozoa, 17 were recorded in the EMED. *Clytia linearis* and *Eirene viridula* are the only established alien species in the entire Mediterranean Sea. Most of the alien Hydrozoa in the EMED have a circumtropical distribution, the remainders have Indo-Pacific origin. *Macrorhynchia philippina* is the most widespread and abundant (MORRI, 2008). Four Scyphozoa aliens known for the Mediterranean supposedly came in through the Suez Canal and are now established along the coast of Israel (GALIL *et al.*, 1990, 2010). *Cassiopea andromeda* has extended its penetration range to Turkey (ÖZGÜR & ÖZTÜRK, 2008) and Greece (ZENETOS *et al.*, in press). *Abyla trigona* is the single alien siphonophore in the Mediterranean Sea, found in Egypt (ZAKARIA, 2006).

After having successfully invaded the Black Sea, with severe impact on both the native ecosystem-functioning and the fishery yield, the Western Atlantic combjelly *Mnemiopsis leidyi* started to spread in the Marmara and North Aegean Sea and reached Israel in 2009 (GALIL *et al.*, 2009). Its predator *Beroe ovata* followed the same path and arrived in the Aegean Sea (SHIGANOVA *et al.*, 2007). Among the three alien ctenophore species in the entire Mediterranean Sea, *Sulculeolaria angusta* was found only in the Egyptian coasts (ZAKARIA, 2006).

Seven species of alien Porifera with Indo-Pacific origin have been traditionally considered as Red Sea immigrants (TSURNAMAL, 1969). More recently, this has been questioned by VACELET *et al.* (2007), who evidenced taxonomic problems with all of them except perhaps *Geodia micropunctata*. According to VACELET *et al.* (2007), sponges with tropical affinities hitherto known only for the EMED are more likely to be remnants of the thermophilic biota that thrived in the Mediterranean during warmer periods of the late Pliocene or Pleistocene and that disappeared from the rest of the basin during the Würmian cooling (BIANCHI *et al.*, 2010).

All six alien species of Sipuncula occurring in the Mediterranean have been recorded for the EMED. *Phascolion (Isomya) convestitum* and *Phascolosoma scolop* are of Indo-Pacific origin, the remaining four are circumtropical (PANCUCCI-PAPADOPOULOU *et al.*, 1999). All are known from a single or few localities, where they can however be abundant (AÇIK, 2007; 2008).

KRAPP *et al.* (2008) reviewed the Pycnogonida of the EMED: three species are alien, although the status of *Pigrogromitus timsanus* is questionable. *Anoplodactylus californicus* and *A. digitatus* are established.

The echinoderm fauna of the EMED includes eight alien species (out of twelve for the whole Mediterranean). Most of them are likely to have penetrated through the Suez Canal, but *Asterias rubens* originated from the North Atlantic and was first introduced in the Black Sea (KARHAN *et al.*, 2008). Two conspicuous Indo-Pacific species, *Diadema setosum* (YOKES & GALIL, 2006) and *Synaptula reciprocans* (ANTONIADOU &

VAFIDIS, 2009) might exert a considerable impact on Mediterranean ecosystems.

The EMED hosts the vast majority of the alien platyhelminthes, all reported as fish parasites, all with an Indo-Pacific and/or Red Sea origin. Of the nine monogeneids introduced into this basin, five are considered established. Both host and parasite are Lessepsian immigrants that have co-invaded the Mediterranean Sea via the Suez Canal. The first documented case of a monogeneid invading a new biogeographical region by 'natural' extension of its host range is that of the gill ectoparasite *Polylabris cf. mamaevi* infecting the rabbitfish *Siganus rivulatus*. The greater abundance of *P. cf. mamaevi* in the invading (Mediterranean) populations is probably due to the changed, new environment, possibly impacting on host resistance to the parasite and encouraging heavier infections (PASTERNAK *et al.*, 2007). A possible explanation for the unexpected colonization success of immigrant fish parasite species belonging to the class Myxosporea, despite their putative complex life cycles, is discussed in DIAMANT (2010).

#### **4.7. Alien fish in the Eastern Mediterranean**

A total of 106 alien fish (nearly 70% of the alien fish known in the Mediterranean) has been reported from the EMED, the majority of which originate from the Indo-Pacific and Red Sea regions. Details on their distribution per country, origin and mode of introduction are provided in GOLANI & APPELBAUM-GOLANI (2010). New data extending the distribution of already reported alien species in the Levantine basin include: *Pisodonophis semicinctus* and *Pomadasystridens* (BILECENOGLU *et al.*, 2009); *Apogon*

*smithi* and *A. queketti* (GOREN *et al.*, 2008); *Enchelycore anatina*, *Lagocephalus spadiceus* and *Lagocephalus suezensis* (KATSANEVAKIS *et al.*, 2009).

The complicated flood of confamilial species is prominent and deserves special interest, as it is unlikely to be coincidental. Alien cardinal fishes represent a good example of this, since only a single species was known for over 60 years and four species have been added to the fauna within the last five years (GOREN *et al.*, 2009a; GOREN *et al.*, 2010; TURAN *et al.*, 2010). Two species of the family Champsodontidae were observed from Turkey (*Champsodon nudivittis*) and Lebanon (*Champsodon vorax*), interestingly both without records from the Red Sea (ÇIÇEK & BILECENOGLU, 2009; BARICHE, 2010a). Among recent alien gobies, *Vanderhorstia mertensi* was found off southern Turkish coasts and became quite common shortly after its first observation (BILECENOGLU *et al.*, 2008; YOKES *et al.*, 2009), while the far-east chameleon goby *Tridentiger trigonocephalus* is reported from Israel (GOREN *et al.*, 2009b). Sudden occurrence of two alien angelfishes, *Pomacanthus imperator* and *Pomacanthus maculosus*, from the Israeli and Lebanese coasts, respectively, is also noteworthy (BARICHE, 2010b; GOLANI *et al.*, 2010). Among the latest records is that of the Indo-Pacific goby *Trypauchen vagina* in Israel (SALAMEH *et al.*, 2010).

The appearance of *Mycteroperca fusca*, a large Atlantic fish, in Israel in 2010, and without having been spotted on the way, raises the question of the route of its arrival. A reasonable possibility is that *M. fusca* entered the Mediterranean through the Strait of Gibraltar, as many Atlantic species do, then expanded its distribution along the North African coast but was

overlooked or confused with *Mycteroperca rubra*. Alternatively, it was introduced in the ballast waters of a ship (HEEMSTRA *et al.*, 2010).

## 5. PHYTOPLANKTON

The introduction of marine microalgae in the Mediterranean Sea is hard to document. Theoretically, these microscopic organisms can easily be transported by currents, but also by the feet of migratory birds, or introduced through human commerce of marine animals, ship's ballast waters or fouling organisms. The consequences of a microalgal invasion are only evident if there are conspicuous changes in an area, e.g. water discoloration or mucilage, or where the species is implicated in toxicity events or other harmful impacts (ZINGONE & WYATT, 2005), while invasions go totally unobserved in case of rare species, which are a conspicuous part of the phytoplankton biodiversity in all seas. In addition, to prove that a species is an alien requires very sound background knowledge of the species of a given area.

Unfortunately, the diversity of marine microalgae is scarcely known in wide areas of the Mediterranean Sea, e.g. the southern shores, where only a few sites have been investigated, or the offshore waters, where studies are limited to occasional sampling during cruises. Even in the northern Mediterranean waters the knowledge of the distribution of these unicellular organisms in a given area is far from being exhaustive, for several reasons. First, phytoplankton is difficult to sample properly, as most species have an ephemeral occurrence and a discontinuous spatial distribution. The resolution of sampling programs rarely matches the space and time scale of occurrence of microalgae, and new species

show up when more detailed or integrative sampling approaches are applied. For example, many cysts of the toxic dinoflagellate *Alexandrium andersonii* were found in sediment traps deployed in the Gulf of Naples (MONTRESOR *et al.*, 1998). The species was not known from the Mediterranean Sea before, and has never been recovered in any other plankton study in the area since. Probably *Alexandrium andersonii* appears in the plankton for very short periods, or it is restricted to specific depths of the water column that are not covered during investigations. Another major problem concerns all organisms that are difficult to preserve and either break or lose their peculiar characteristics with common fixatives such as formalin and lugol. *Micromonas pusilla*, a 2-3  $\mu\text{m}$  naked prasinophyte, is easily identifiable when it grows in cultures due to a very typical swimming pattern. It can reach concentrations of up to  $10^6$  cells  $\text{l}^{-3}$  in coastal Mediterranean waters in winter (THRONDSSEN & ZINGONE 1994; ZINGONE *et al.*, 1999). However, its cells generally burst upon preservation. This is also the case for much larger flagellates, e.g. the raphidophyte *Chattonella subsalsa* (30-40  $\mu\text{m}$ ) or naked dinoflagellates, which explode or lose their shape when fixed. Finally, many species require particular skills or methods to be identified. This is the case for cryptomonads, generally very abundant in inshore waters, which require cultivation, electron microscopy and at times molecular techniques to be identified at the species level. While their abundance as a group can be traced with pigment analyses (HPLC) that allow alloxanthin to be detected, or by flow-citometry, individual species are only identified by combining a number of different techniques (CERINO & ZINGONE, 2006).

For the reasons stated above, it can rarely be excluded that a suspected microalgal invader was already present as part of the rare, hidden and unsampled phytoplankton. These factors are probably at the origin of the extremely low number of proven invaders among phytoplankton species (WYATT & CARLTON, 2002).

Nonetheless, a number of cases of possibly introduced microalgal species in the Mediterranean Sea have been brought to the general attention over the last few years. One of the first cases was provided by the toxic planktonic dinoflagellate *Alexandrium catenella*, appearing in high concentrations in a French coastal lagoon, the Thau Lagoon, in 1998 (LILLY *et al.*, 2002). Based on the molecular similarity of the species with strains from Japan, it was proposed that the species had been transported recently to the Mediterranean Sea. The species had been seen before in the Balearic Sea in 1983 (MARGALEF & ESTRADA, 1987), along the Spanish coast since 1996 (VILA *et al.*, 2001) and along the Sardinian coast in 1999 (LUGLIÈ *et al.*, 2003). Apparently its range is expanding across the Mediterranean Sea, as it has been found recently on the Tunisian coast (TURKI & BALTI, 2007). On the other hand, more recent studies using alternative molecular tools have questioned the close relationships between Japanese and Mediterranean populations, and hence the identification of Japan as the source area of *A. catenella* (MASSERET *et al.*, 2009).

While the knowledge of planktonic species distribution poses many problems in terms of sampling and detection, benthic and epiphytic microalgae should be easier to collect. Yet these organisms have been studied very rarely in the Mediterranean Sea until the end of the last century, when they became popular mainly due

to health and environmental problems caused by a toxic species *Ostreopsis* cf. *ovata*, which forms conspicuous blooms in many coastal areas (e.g., TOTTI *et al.*, 2010; MANGIALAJO *et al.*, in press). Also in this case, the sudden emergence of a conspicuous problem was initially attributed to a new invasion, probably in relation to climate change, as *Ostreopsis* species were previously known mainly from tropical areas. However, an *Ostreopsis* species did form a conspicuous bloom in Villefranche Bay in 1972, where macroalgae appeared to be covered by a brown mucous layer (Taylor, pers. comm.), but it was just recorded due to the curiosity of an expert taxonomist swimming in the area. The species was reported as *O. siamensis*, the only species known at the time (TAYLOR, 1979), but it was likely to be the same as the one reported in more recent years in the same area, i.e. *O. cf. ovata*. From the molecular point of view, the Mediterranean populations of this species were known to be similar only to Brazilian populations (PENNA *et al.*, 2010), but comparable ribotypes have very recently been found also in Japanese waters (SATO *et al.*, 2010). Molecular analyses on other markers are required to establish where, among the three sites, the molecular diversity of *Ostreopsis* cf. *ovata* is the highest, which would indicate the source site for these different populations around the world.

Species of the benthic dinoflagellate genus *Gambierdiscus*, which produce toxins that are responsible for the neurological syndrome ciguatera, had never been recorded in the Mediterranean Sea until 2003, when specimens were found in Greek waters off Crete (ALIGIZAKI & NIKOLAIDIS, 2008). No other record is confirmed from anywhere else in the Mediterranean Sea, despite the intensive

microphytobenthos sampling carried out to study *O. ovata* at several sites over the last decade. In this case, an introduction from the Indian Ocean could be hypothesised, but the source population would be missing for the time being, as the taxonomic identity of the species is still uncertain. On the other hand, data on benthic microalgae are now more complete than 10 years ago, which would allow one to test a predictable range expansion westward. Indeed, marginal range expansion have been observed for other species, such as *Alexandrium catenella* (LUGLIÈ *et al.*, 2003), *G. catenatum* (GÓMEZ, 2003), and a number of diatom species (GÓMEZ, 2008), which could be related to the climatic changes observed in the Mediterranean Sea or to other unexplained long-term fluctuations in species abundance.

A sounder background knowledge on phytoplankton distribution is available for places where time series exist and accurate identification is performed over a long-term period. At the LTER-MC station in the Gulf of Naples, two species never recorded despite their relatively easy identification, have suddenly appeared in recent years. These were *Skeletonema tropicum* (ZINGONE *et al.*, 2003; KOOISTRA *et al.*, 2008), which is easily identifiable as it is the only species in the genus having many chloroplasts, and *Pseudo-nitzschia multistriata* (ZINGONE *et al.*, 2003), which has a typical sigmoid shape. The two species had never been recorded before 1995 and 2002, respectively, and have shown increasing concentrations since their first finding. In both cases, an introduction could be hypothesised but it cannot be excluded that these are other examples of marginal range expansion from the southern Mediterranean Sea shore northward, or that these species were extremely

rare for many years, suddenly finding appropriate environmental conditions to increase their abundance. The latter hypothesis takes into consideration long-term fluctuations in species abundance and is partially supported by the absence of discoveries since 1992 of another *Pseudonitzschia* species, *P. subpacific*. This species was relatively common in the 1984-1987 period in the Gulf of Naples, then it became rarer and eventually disappeared. Although *P. subpacific* could still be in the Gulf of Naples, this case indicates that there is always the possibility of unexplained local extinctions, and more generally points to important changes in species abundance over the long term.

Another relevant case is that of species showing discontinuous geographical ranges. The dinoflagellate *Alexandrium balechii* is only found in the Gulf of Mexico and in Tyrrhenian waters, suggesting that the species originated in one of the two places and was transported to the other, although there are no data to establish where the species should be considered an alien. Several other dinoflagellates are only found in the Indo-Pacific area and in the Mediterranean Sea so far (GÓMEZ, 2006), but the suspicion that they were introduced through the Suez Canal should be substantiated when their absence corresponds to their actual absence in the Atlantic Ocean and not to our limited knowledge of protist biogeography. For similar reasons, the high number of flagellate species that have been described in the Mediterranean Sea and never recorded elsewhere cannot be considered as proof of their endemism in the Mediterranean Sea (THRONDSEN & ZINGONE, 1994).

In synthesis, in the Mediterranean Sea a number of planktonic and benthic microalgae has appeared over the last

decades and continue to do so, forming conspicuous blooms in places where they were not recorded at all before. However, whether these species are really alien should be tested effectively, considering at least two alternative hypotheses: 1) that they belong to the rare component of the plankton and that they were missed in previous studies; 2) that their range expanded from unexplored southern or eastern Mediterranean areas.

## 6. INVASIVE SPECIES

The ongoing incoming of immigrants and their increasing success in the Mediterranean basin imply a profound and continuous alteration in the species distribution patterns that seems to have accelerated in the last decade. Up to recent times the influence of these immigrants was geographically limited to the areas close to the source of introduction, but today the idea of biogeographical boundaries to Lessepsian invasions (POR, 1981; QUIGNARD & TOMASSINI, 2000) seems to be overcome.

The most invasive species per MSFD are listed in Table 3; their share per taxonomic group is depicted in Figure 2.

A total of 134 species are classified as invasive or potentially invasive in the Mediterranean. The present list is based on data on worst invasive marine species collated from various sources for the Mediterranean (STREFTARIS & ZENETOS, 2006; GALIL, 2007; STREFTARIS *et al.*, 2008), European Seas (EEA, 2007b; DAISIE: VILÀ *et al.*, 2008), and globally (Global Invasive Species Database), managed by the Invasive Specialist Species Group (ISSG: [www.issg.org](http://www.issg.org)). The list was enriched with species such as the bigfin reef-squid *Sepioteuthis lessoniana*, an invader

**Table 3**  
**Distribution of invasive (++) or potentially invasive alien species (+) in the Mediterranean MSFD**  
**areas. (-) Species absent from the area, \*marketable species.**

<b>SPECIES</b>	<b>WMED</b>	<b>CMED</b>	<b>ADRIA</b>	<b>EMED</b>
<b>F o r a m i n i f e r a</b>				
<i>Amphistegina lobifera</i>	+	+	+	++
<b>M a c r o p h y t a</b>				
<i>Acrothamnion preissii</i>	++	+	+	-
<i>Asparagopsis armata</i>	++	+	+	+
<i>Asparagopsis taxiformis</i>	++	++	+	++
<i>Caulerpa distichophylla</i>	-	++	-	++
<i>Caulerpa racemosa</i> var. <i>cylindracea</i>	++	++	++	++
<i>Caulerpa taxifolia</i>	++	++	++	-
<i>Chrysonephos lewisii</i>	++	-	-	-
<i>Cladophora</i> cf. <i>patentiramea</i>	-	-	-	++
<i>Codium fragile</i> subsp. <i>fragile</i>	++	+	++	++
<i>Codium parvulum</i>	-	-	-	++
<i>Dasyisiphonia</i> sp.	+	-	+	-
<i>Gracilaria vermiculophylla</i>	-	-	++	-
<i>Grateloupia turuturu</i>	+	+	+	-
<i>Halophila stipulacea</i>	+	++	+	++
<i>Lithophyllum yessoense</i>	+	-	-	-
<i>Lophocladia lallemandii</i>	++	+	+	+
<i>Sargassum muticum</i>	++	-	++	-
<i>Styopodium schimperi</i>	-	+	-	++
<i>Ulva pertusa</i>	+	-	-	-
<i>Undaria pinnatifida</i>	++	+	++	-
<i>Womersleyella setacea</i>	++	++	+	+
<b>P o l y c h a e t a</b>				
<i>Branchiomma bairdi</i>	-	-	-	++
<i>Branchiomma luctuosum</i>	+	++	+	++
<i>Ceratonereis mirabilis</i>	-	-	-	++
<i>Desdemonia ornata</i>	+	-	++	++
<i>Dorvillea similis</i>	-	-	-	++
<i>Eunice antennata</i>	+	+	-	++
<i>Ficopomatus enigmaticus</i>	++	++	++	++
<i>Hydroides dianthus</i>	++	++	++	++
<i>Hydroides elegans</i>	++	++	++	++
<i>Hydroides operculatus</i>	-	-	-	++
<i>Leonnates indicus</i>	-	-	-	++
<i>Leonnates persicus</i>	-	-	-	++
<i>Laonome triangularis</i>	-	-	-	++
<i>Notomastus mossambicus</i>	+	-	-	++

Table 3 (continued)

SPECIES	WMED	CMED	ADRIA	EMED
<i>Polydora cornuta</i>	+	-	-	++
<i>Pomatoleios kraussii</i>	-	-	-	++
<i>Prionospio (Aquilaspio) krusadensis</i>	-	-	-	++
<i>Prionospio (Prionospio) saccifera</i>	-	-	-	++
<i>Pseudonereis anomala</i>	-	+	-	++
<i>Pseudopolydora paucibranchiata</i>	-	-	-	+
<i>Spirorbis (Dexiospira) marioni</i>	++	-	-	++
<i>Streblospio gynobranchiata</i>	-	-	-	++
<b>Crustacea</b>				
<i>Callinectes sapidus*</i>	+	+	++	++
<i>Charybdis helleri</i>	-	-	-	++
<i>Charybdis longicollis</i>	-	-	-	++
<i>Dyspanopeus sayi</i>	-	-	++	-
<i>Erugosquilla massavensis</i>	-	-	-	++
<i>Heterosaccus dollfusi</i>	-	-	-	++
<i>Marsupenaeus japonicus*</i>	+	+	+	++
<i>Melicertus hathor</i>	-	-	-	++
<i>Metapenaeus monoceros*</i>	-	+	-	++
<i>Metapenaeus stebbingi*</i>	-	+	-	++
<i>Penaeus semisulcatus*</i>	-	-	-	++
<i>Percnon gibbesi</i>	++	++	+	++
<i>Portunus segnis*</i>	+	+	-	++
<i>Rhithropanopeus harrisi</i>	+	+	++	-
<b>Mollusca/Bivalvia</b>				
<i>Anadara kagoshimensis</i>	+	-	++	+
<i>Anadara transversa</i>	+	+	++	++
<i>Brachidontes pharaonis</i>	+	+	+	++
<i>Chama pacifica</i>	-	-	-	++
<i>Dendrostrea frons</i>	-	-	-	++
<i>Fulvia fragilis</i>	++	++		++
<i>Musculista senhousia</i>	++	+	++	+
<i>Pinctada radiata*</i>	+	++	+	++
<i>Ruditapes philippinarum*</i>	+	+	++	+
<i>Septifer forskali</i>	-	-	-	++
<i>Spondylus spinosus</i>	-	-	-	++
<i>Xenostrobus securis</i>	++	-	++	-
<b>Mollusca/Cephalopoda</b>				
<i>Sepioeuthis lessoniana*</i>	-	-	-	++
<b>Mollusca/Gastropoda</b>				
<i>Aplysia dactylomela</i>	++	+	++	
<i>Bursatella leachii</i>	++	++	++	++

Table 3 (continued)

SPECIES	WMED	CMED	ADRIA	EMED
<i>Cellana rota</i>	+	+	++	
<i>Cerithium scabridum</i>	+	+	-	++
<i>Conomurex persicus*</i>	+	+	++	
<i>Crepidula fornicata</i>	+	+	-	+
<i>Ergalatax junionae</i>	-	-	-	++
<i>Erosaria turdus</i>	-	++	-	+
<i>Melibe viridis</i>	+	++	++	++
<i>Pseudominolia nedyma</i>	-	-	-	++
<i>Rapana venosa</i>	+?	-	+	+
<i>Rhinoclavis kochi</i>	-	-	-	++
<b>Porifera</b>				
<i>Paraleucilla magna</i>	++	+	+	-
<b>Cnidaria/Anthozoa</b>				
<i>Oculina patagonica</i>	++			+
<b>Cnidaria/Hydrozoa</b>				
<i>Chytia hummelincki</i>	++	++	++	-
<i>Chytia linearis</i>	++	++	++	++
<i>Garveia franciscana</i>	+	-	++	-
<i>Macrorhynchia philippina</i>	-	-	-	++
<b>Cnidaria/Scyphozoa</b>				
<i>Cassiopea andromeda</i>	-	+	-	+
<i>Phyllorhiza punctata</i>	-	+	-	+
<i>Rhopilema nomadica</i>	-	+	-	++
<b>Ctenophora</b>				
<i>Mnemiopsis leidyi</i>	+	+	+	++
<b>Bryozoa</b>				
<i>Bugula fulva</i>	+	+	+	+
<i>Tricellaria inopinata</i>	-	+	++	-
<b>Echinodermata</b>				
<i>Aquilonastra burtoni</i>	-	-	-	++
<i>Asterias rubens</i>	-	-	-	+
<i>Synapta reciprocans</i>	-	-	-	++
<b>Ascidacea</b>				
<i>Botrylloides violaceus</i>	-	-	+	-
<i>Distaplia bermudensis</i>	+	+	-	-
<i>Microcosmus exasperatus</i>	-	+	-	+
<i>Microcosmus squamiger</i>	++	+	-	-
<i>Phallusia nigra</i>	-	-	-	++
<i>Polyandrocarpa zorritensis</i>	+	+	-	-
<i>Rhodosoma turcicum</i>	+	+		+
<i>Styela clava</i>	+	-	-	-

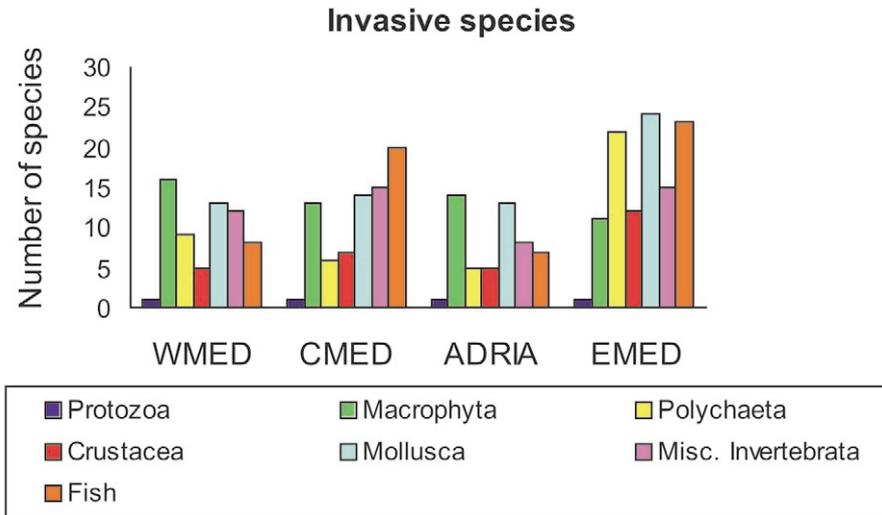
Table 3 (continued)

SPECIES	WMED	CMED	ADRIA	EMED
<i>Symplegma brakenhielmi</i>	-	-	-	+
<b>F i s h</b>				
<i>Apogon pharaonis</i>	-	-	-	++
<i>Atherinomorus forskalii*</i>	-	++	-	++
<i>Diplodus bellottii*</i>	++	-	-	-
<i>Etrumeus teres*</i>	-	++		++
<i>Fistularia commersonii</i>	+	++	+	++
<i>Gymnammodytes semisquamatus</i>	++	-	-	-
<i>Lagocephalus scleraterus</i>	-	+	-	++
<i>Pagellus bellottii*</i>	++	-	-	+
<i>Parexocoetus mento</i>	-	+	+	++
<i>Pempheris vanicolensis</i>	-	+	-	++
<i>Plotosus lineatus</i>	-	-	-	++
<i>Pteragogus pelycus</i>	-	-	-	++
<i>Sargocentron rubrum*</i>	-	+	-	++
<i>Saurida undosquamis*</i>	-	+	+	++
<i>Scomberomorus commerson*</i>	-	++	-	++
<i>Seriola carpenteri*</i>	-	++	-	-
<i>Seriola fasciata</i>	+	+	-	+
<i>Siganus luridus*</i>	+	++	-	++
<i>Siganus rivulatus*</i>	-	++	+	++
<i>Sillago sihama*</i>	-	-	-	++
<i>Solea senegalensis*</i>	++	+	-	-
<i>Sphoeroides pachygaster</i>	++	++	+	++
<i>Sphyaena chrysotaenia*</i>	-	++	+	++
<i>Sphyaena flavicauda*</i>	-	+	-	++
<i>Stephanolepis diaspros</i>	-	++	+	++
<i>Upeneus moluccensis*</i>	-	+	-	++
<i>Upeneus pori*</i>	-	+	-	++

of the last decade that presented a population explosion within 2010 (ZENETOS *et al.*, in press).

A total of 108 species are locally invasive or merely present in the EMED, 75 in the CMED, 53 in the Adriatic and 64 in the WMED (Fig. 2). The WMED hosts most macrophytes, whereas the EMED has the lion's share in polychaetes, crustaceans, molluscs and fish.

The share of invasive species does not support POR's (2009, 2010) statement that species from the tropical Indo-Pacific should behave more like one more element of the native fauna and be less aggressive in their onset than real aliens, e.g. those originating from the temperate Atlantic or Pacific. Rather, it would conform to the rule of thumb that one out of every ten established alien species becomes invasive.



**Fig. 2:** Breakdown of invasive or potentially invasive species per taxonomic group.

In addition to documented impacts on biodiversity, some of the invasive species, among decapods, molluscs and fish, have turned to be beneficial to man and be commercially exploited in several countries (Table 3). Though no extinction of a native species is known, sudden decline in abundance, and even local extirpations, concurrent with proliferation of aliens, has been recorded (GALIL, 2007).

Yet, there is no way to predict invasibility of ecosystems. However, community ‘invasibility’ appears to be the result of the relationship between native species richness and alien species ability to colonize new habitats (BULLERI *et al.*, 2008). This concept implies that habitats with high levels of diversity are difficult to invade. In contrast, species-poor communities, or stressed ecosystems, are arguably more prone to invasion, primarily due to lack of biotic resistance (OCCHIPINTI-AMBROGI & SAVINI, 2003). At Mediterranean basin scale, this appears to be true (see chapter 7).

Little has been done to evaluate the risk posed by the introduction and spread of invasive species, or to minimize the risk of introducing additional alien species. Effective legislation on alien species exists only in few countries and for selective vectors e.g. in EU countries for aquaculture introductions; Egypt, France, Spain and Syria for introductions in ballast waters (IMO/ BWC, Ballast Water Convention).

### 6.1. Macrophytes

Most spectacular has been the arrival of several invasive exotic varieties of green and red algae. These algae have flourished at the expense of benthic Mediterranean organisms. Their dense and creeping meadows - which feature up to 27,000 erected blades per square meter in *Caulerpa racemosa* var. *cylindracea* - overwhelm the benthic assemblages. Their success is usually explained by a fast growth, permanent meadows and synthesis of secondary metabolites active against natural enemies (herbivorous, epiphytes, pathogens, etc.).

Once they have spread, species like this are impossible to eliminate.

Among the 125 alien macrophytes, 21 are invasive or potentially invasive (17% of total taxa) (Table 3). The total number of invasive or potentially invasive alien macrophytes decreases eastwards: WMED (16 taxa), ADRIA (14 taxa), CMED (13 taxa), and EMED (11 taxa). Only six invasive alien macrophytes have colonized the four basins: the Indo-Pacific strain of *Asparagopsis taxiformis*, *Caulerpa racemosa* var. *cylindracea*, *Codium fragile*, *Halophila stipulacea*, *Lophocladia lallemandii* and *Womersleyella setacea*.

## 6.2. Polychaetes

A total of 22 species (17% of the total alien polychaetes) seem to have invasive character, dominating shallow-water benthic habitats, estuarine areas, polluted areas and harbour environments. All of them are invasive in the EMED, five are present in the CMED, six in the Adriatic and nine in the WMED.

Polluted soft bottoms especially near harbours greatly facilitate the establishment of ship-mediated species such as *Polydora cornuta*, *Streblospio gynobranchiata* and *Pseudopolydora paucibranchiata* (ÇINAR *et al.*, 2005, 2006a; DAGLI & ÇINAR, 2008). Polluted environments, where competition among species is low and food is ample, provided these species with an excellent opportunity to build up dense populations. The maximum density of *P. cornuta* was calculated as 3170 ind·m<sup>-2</sup>, that of *S. gynobranchiata* as 60480 ind·m<sup>-2</sup> and that of *P. paucibranchiata* as 6180 ind·m<sup>-2</sup> in Izmir Bay (ÇINAR *et al.*, 2005; DAGLI & ÇINAR, 2008).

In a study by ÇINAR (2006), alien species comprised more than 95% of the serpulids found on hard substrata (rocks,

molluscs, dock's pilings, ropes and tires) along the Levantine coast of Turkey. *Pomatoleios kraussii* formed a densely populated belt in shallow-water areas in Mersin Bay (ÇINAR, 2006). The invasive nereid species *Pseudonereis anomala* is a dominant component of the algal communities in the Levant Sea, attaining a population density of 2475 ind·m<sup>-2</sup> on the alga *Jania rubens* in Iskenderun Bay (ÇINAR & ALTUN, 2007). BEN-ELIAHU (1989) reported that a native nereidid species of the Mediterranean, *Perinereis cultrifera* (Grube), was excluded from the habitats of the Levant Sea by *P. anomala*. This species expanded its distributional range to Izmir Bay, North Aegean Sea (ÇINAR & ERGEN, 2005) and the coasts of Greece (KAMBOUROGLOU & NICOLAIDOU, 2006). The eunicid worm *Eunice antennata* was found to be a common species on the southern coast of Turkey (KURT SAHIN & ÇINAR, 2009) and was also previously reported from the coasts of Italy (CANTONE, 1993).

## 6.3. Crustacea

The Indo-Pacific prawns, in particular *Marsupenaeus japonicus*, *Metapenaeus monoceros*, and *Penaeus semisulcatus*, are highly prized and are considered a boon to the Levantine fisheries (DURUER *et al.*, 2008). *Portunus segnis*, formerly known as *P. pelagicus*, is commercially exploited in Egypt (ABDEL-RAZEK, 1987). It is also commercially important but caught in small quantities in Turkey (DURUER *et al.*, 2008). The latest record of *P. segnis* is from the northern Tyrrhenian Sea (CROCETTA, 2006).

The invasive crab *Percnon gibbesi* is one of the most recent and successful invaders in the Mediterranean Sea. Its distribution has been recently updated by

KATSANEVAKIS *et al.* (in press) who report that the relative abundance of the species in the Kaş-Kekova Marine Protected Area (SE Turkey) reached 112 individuals in 2010, from two individuals in 2006.

The blue crab *Callinectes sapidus* was transported into the Mediterranean in ballast tanks from the north-east coast of the USA. After the first Mediterranean record (Venice, Italy, 1949), this species has been widely recorded in different Mediterranean regions, especially in the EMED (Turkey, Greece, Syria, Lebanon, Israel and Egypt) where it became invasive and is commercially exploited (STREFTARIS & ZENETOS, 2006; DURUER *et al.*, 2008).

A decade after its introduction, *Heterosaccus dollfusi*, a parasite on *Charybdis longicollis*, became invasive in the south Levantine coast. Despite the high prevalence of the parasite and its injurious impact on the host reproduction, the invasive host-parasite pair reached a *modus vivendi* with no noticeable reduction in the host population (INNOCENTI & GALIL, 2007).

#### 6.4. Mollusca

The gastropods *Cerithium scabridum*, *Rhinoclavis kochi*, *Conomurex persicus* and *Bursatella leachi* and the bivalves *Pinctada radiata*, *Brachidontes pharaonis*, *Fulvia fragilis*, *Chama pacifica* and *Spondylus spinosus* have been reported as locally invasive in the EMED by ZENETOS *et al.* (2005, 2008). *Conomurex persicus* has been reported to achieve densities of tens of specimens per m<sup>2</sup> at some sites (FISHELSON, 2000) on the Israeli coast. To these may be added the limpet *Cellana rota*, reported as thriving to the point of displacing the native limpet *Patella caerulea* (MIENIS, 2002, 2003).

*Rapana venosa*, one of the most invasive species worldwide, has been rapidly increasing in the Adriatic Sea, thus enhancing the risk of invasion and further spreading. Maximum estimated population densities of > 500 ind.km<sup>-2</sup> were reached near the shores of Cesenatico (SAVINI *et al.*, 2007).

The spread of the alien species across the Mediterranean is not easy. Only six of the ca. 50 Lessepsian species have crossed the Sicily Strait westwards and only two (*Bursatella leachii* and *Fulvia fragilis*) have reached the Spanish coast so far.

None of the other species of Indo-Pacific origin, so successful in the EMED, have a real invasion success in the western basin. Some of the tropical Indo-Pacific species which started in the CMED (*Aplysia dactylomela*, *Haminoea cyanomarginata*, *Melibe viridis*) are now spreading to Malta (BORG *et al.*, 2009; SCHEMBRI, 2009) or have even reached the western Mediterranean. Several individuals of *Melibe viridis* were recently observed in Gulf Aranci, NE Sardinia (DONEDDU & TRAINITO, 2008).

The case history of the forerunners indicates that the spread across the Mediterranean involves a complex history of natural spread with larvae and transport via shipping from the original point of introduction. In any case the distribution of these aliens in the western and central parts of the Mediterranean is patchy and does not suggest a continuous progression. The limiting factors may be on the one hand, the natural species richness of the western basin; on the other, the severe difference in sea surface temperatures (POR, 2009, 2010) which may make it inhospitable to thermophilic species such as *Pinctada radiata*.

The impact of invasive species is com-

parable within these two main poles of alien molluscs in the Mediterranean, but the pool of invasive species is not the same. To the south, an aggressive onset is seen for some tropical Indo-Pacific species such as *Conomurex persicus*, *Cellana rota* or (at the beginning of the invasion) *Pinctada radiata*, which fail to become massively established in other parts of the basin. One of the latest introductions is *Septoteuthis lessoniana*, a commercially important squid species for inshore fisheries throughout its distributional range, which was observed in Iskenderun Bay (SALMAN, 2002) and has rapidly spread in the Levant and Aegean seas (KATSANEVAKIS *et al.*, 2009; LEFKADITOU *et al.*, 2009; ZENETOS *et al.*, in press). In the northern parts (Northern Aegean, Adriatic, and French Mediterranean lagoons) invasive species like *Anadara kagoshimensis*, *Ruditapes philippinarum* or *Rapana venosa* originate from temperate areas, and none of these are reported as invasive in the southern parts of the Mediterranean. Therefore the climatic gradient in the Mediterranean is likely to promote natural boundaries for the alien species, which should reach a stable range at some time.

### 6.5. Miscellaneous invertebrates

The ascidian *Microcosmus squamiger*, first recorded at 1963 in Tunisia, is widely spread in the Western Mediterranean (France, Spain, Italy, North Africa: see synthesis in TURÓN *et al.*, 2007), and locally in the CMED (Malta: IZQUIERDO-MUÑOZ *et al.*, 2009). This species forms dense populations reaching up to 2300 ind. $\cdot$ m<sup>-2</sup> and its presence has strong implications in the structure and functioning of the native communities (RIUS *et al.*, 2009). *Microcosmus squamiger* is considered a global

marine invader with a high invasive potential.

A recent immigrant, *Styela clava*, among the worst invasives in Europe, has been accidentally transported into the Western Mediterranean by shellfish transfer (DAVIS & DAVIS, 2008). *Styela clava*, a solitary, hermaphroditic ascidian, is considered to be an aggressive invader throughout the world; this species is a major pest to the mussel farming industry of Canada (ARSENAULT *et al.*, 2009). Its recent discovery in the Mediterranean Sea caused a considerable alarm to mussel farms.

*Phallusia nigra* is an old invader in the Mediterranean Sea. The quite sudden appearance of the species in the Aegean Sea and the extended distribution that it demonstrated within a short time along the coasts of Rodos and Kriti (KONDILATOS *et al.*, 2010; ZENETOS *et al.*, in press) support the invasive character of the species, as already pointed out by IZQUIERDO-MUÑOZ *et al.* (2009).

Other species such as *Botrylloides violaceus*, *Symplegma brakenhemi* and possibly *Polyandrocarpa zorritensis* and *Distaplia bermudensis* are locally invasive in altered habitats (harbours, aquaculture rafts, Po and Ebro deltas).

The scleractinian coral *Oculina patagonica*, a species of uncertain, but probably Atlantic origin, has taken advantage of the warming sea and has explosively expanded around the southern Mediterranean during the last years, building coral pavements (see latest updates in SARTORETTO *et al.*, 2008).

Of the 37 alien hydrozoan species recorded for the Mediterranean, four can be considered invasive. The occurrence of *Clytia hummelincki* in the Mediterranean Sea was only discovered in 1996 in the

northern Ionian (BOERO *et al.*, 1997), and within the subsequent decade further records came from the Southern Adriatic and the Tyrrhenian seas (BOERO *et al.*, 2005; GRAVILI *et al.*, 2008). At present, *C. hummelincki* is extremely abundant in the summer in shallow rocks and is rapidly expanding its range thanks to the dispersal capacity with currents of the medusa stage. *Clytia linearis* was recorded in the Suez Canal as early as in the 1930s (BILLARD, 1938) and rapidly spread through the whole Mediterranean to get its north-western reaches by the 1950s (PICARD, 1951): thus, it is probably one of the first and most successful Lessepsian immigrants. The medusae of the two species of *Clytia* are relatively large and are produced in great number: their voracious predatory behaviour on coastal zooplankton may imply a significant impact on native Mediterranean ecosystems by these two invasive species (GRAVILI *et al.*, 2008).

The first Mediterranean record of *Garveia franciscana* came from the Lagoon of Venice in 1978, where it showed among the most abundant hydroids (MORRI, 1981). In subsequent years it was also found in other estuarine habitats of the North Adriatic and Catalonia, NE Spain (MORRI, 1982; GILI, 1986). Its spread in many brackish environments world-wide and its occurrence in ship-hull fouling (MORRI & BOERO, 1986), suggest high invasive potential for this species: lack of recent studies on Mediterranean brackish-water hydroids, however, prevents any solid evaluation of its present degree of success.

*Macrorhynchia philippina* has occurred in the EMED since at least the early 1990s, when has been found in polluted waters near Beirut (BITAR &

BITAR-KOULI, 1995). It is now widespread and frequent in the whole Levant Sea (ÇINAR *et al.*, 2006b). Its diffusion on coastal rocks from just below the surface to more than 40 m and the frequent reproductive status (MORRI *et al.*, 2009) suggest a high invasive potential. Its colonies, up to 30 cm tall and stinging to the touch, are easily recognizable, so that its further expansion in the Mediterranean should be easily tracked (MORRI, 2008).

One of the top 100 worldwide invasive species, the comb jelly, *Mnemiopsis leidyi*, was first seen in the Saronikos Gulf (EMED) in 1990 (SHIGANOVA *et al.*, 2001). Sporadic sightings ever since from the Turkish and Greek coasts raised no concern about its notorious impacts on the ecosystem and the fisheries, until 2009 when swarms if it spread across the Mediterranean, from Israel to Spain (FUENTES *et al.*, 2010). Each summer since the mid-1980s swarms of the invading jellyfish, *Rhopilema nomadica*, have appeared along the Levantine coast. These swarms of voracious planktotrophs can stretch up to 100 km long. As they draw nearer to shore, they adversely affect tourism, fisheries, and coastal installations.

## 6.6. Fish

Classically, Lessepsian species were expected to be limited to the EMED, due to hydrological conditions, but the spread to the western basin is now a reality. So far, only a few Lessepsian fish species have been observed in the Western Mediterranean: *Abudefduf vaigiensis*, *Siganus luridus*, and *Fistularia commersonii*. This latter is probably the fastest-spreading species in the Mediterranean: since the first record in Mediterranean ten years

ago, *F. commersonii* is now reported more or less in the whole Mediterranean (Table 2). The very recent records of *F. commersonii* and *S. luridus* in the north-western Mediterranean (SÁNCHEZ-TOCINO *et al.*, 2007; DANIEL *et al.*, 2009) could then be the hint of future extensive spreading of Lessepsian species. The opposite direction was followed by Atlantic invaders such as *Seriola fasciata* (SONIN *et al.*, 2009), *Pagellus bellottii* (SAAD & SBAIHI, 1995) and *Sphoeroides pachygaster* (GOLANI, 1996) that have reached the Levantine basin.

Today, some of these species constitute an important part of local fishery catches; 16 such species are listed (Table 3) among the most invasive species in the Mediterranean, *Siganus luridus* and *Siganus rivulatus* though marketable, they are classified as venomous species in FishBase. Lessepsian immigrants constituted 19% of the total abundance of fish captured at the Lebanese rocky coast. In decreasing order of importance, were *Atherinomorus lacunosus* (11.5%), *Siganus luridus* (2.3%), *S. rivulatus* (2.3%), *Pempheris vanicolensis* (1.6%), *Sargocentron rubrum* (1.0%), *Stephanolepis diaspros* (0.2%), and *Apogon nigrispinnis* (presently *Apogon pharaonis*) (0.02%) (HARME-LIN-VIVIEN *et al.*, 2005). *Siganus luridus* and *S. rivulatus* contributed 23% to the species composition captured in purse seine operating during the daytime in Abu-Qir and El-Mex Bays, Alexandria (Egypt) (AKEL, 2005).

Invasive species such as: *Apogon pharaonis*, *Fistularia commersonii*, *Gymnammodytes semisquamatus*, *Parexocoetus mento*, *Pempheris vanicolensis*, *Pteragogus pelycus*, *Sphoeroides pachygaster*, *Stephanolepis diaspros*, are just a nuisance to fisheries. Others as the highly venomous

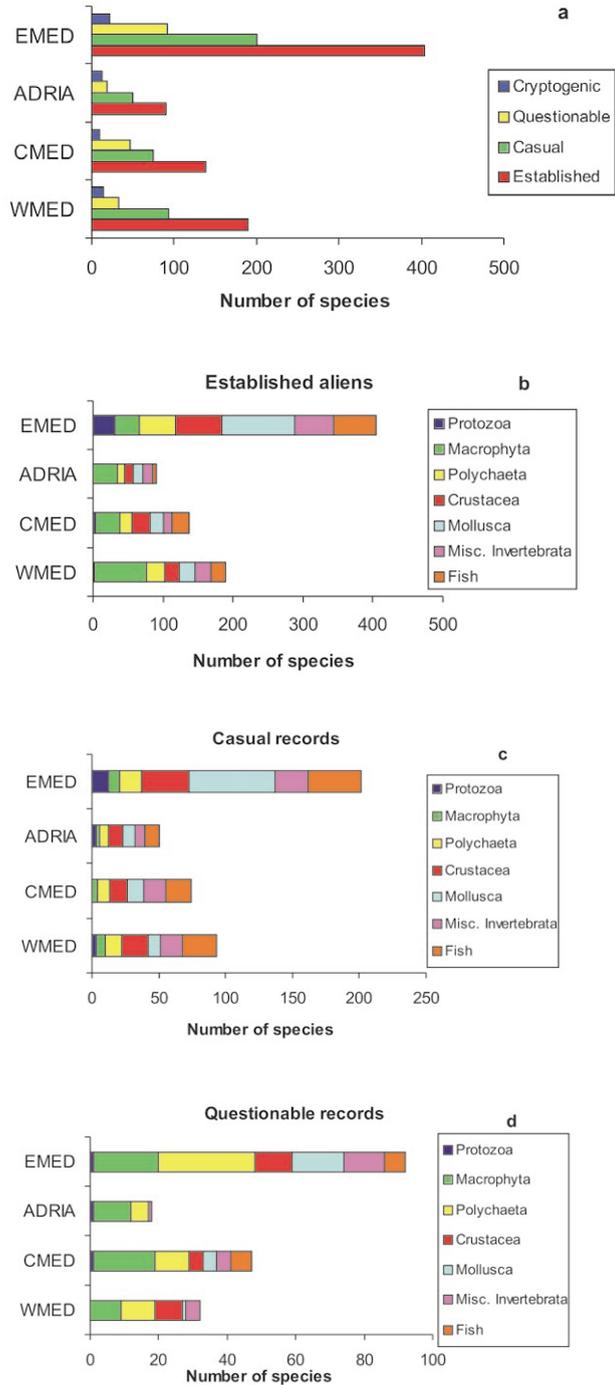
striped catfish, *Plotosus lineatus*, and the pufferfish *Lagocephalus sceleratus* are a threat to human health.

## 7. SYNTHESIS: STATUS AND GEOGRAPHICAL ORIGIN

A total of 955 alien species occur in the Mediterranean, the vast majority of them having being introduced in the EMED (718), fewer in the WMED (328) and CMED (267), and least in the Adriatic (171). Of these, 535 species (56%) have been established in at least one area. We calculated that the established species accounted for 57.6% of the total number of alien species in the WMED, 51.5%, in the CMED, 52.6% in the Adriatic Sea and 56.3% in the EMED. The casual records constitute 27-29% of the alien species at each basin. On the contrary, the number of questionable species in the EMED is three times as many as those of the WMED. Macrophytes, polychaetes and crustaceans have the highest number of questionable species. The questionable status for macrophytes is generally due to the uncertainty regarding their origin. For polychaetes and crustaceans, the reason for the high percentage is the lack of precise taxonomic works in the area and the corollary that these species were largely reported from ecological studies and seldom documented by museum specimens or illustrations.

The number of species per establishment success category along with the contribution of alien taxa distributed at each MSFD area is illustrated in Figure 3. Further details per taxonomic group are provided below.

Figure 4 shows the origin of alien species for each sub-basin. Species originally distributed either in the Indo-Pacific



**Fig. 3:** **a:** Establishment success per basin (all taxa); **b, c, d:** Partitioning of alien taxa per establishment success.

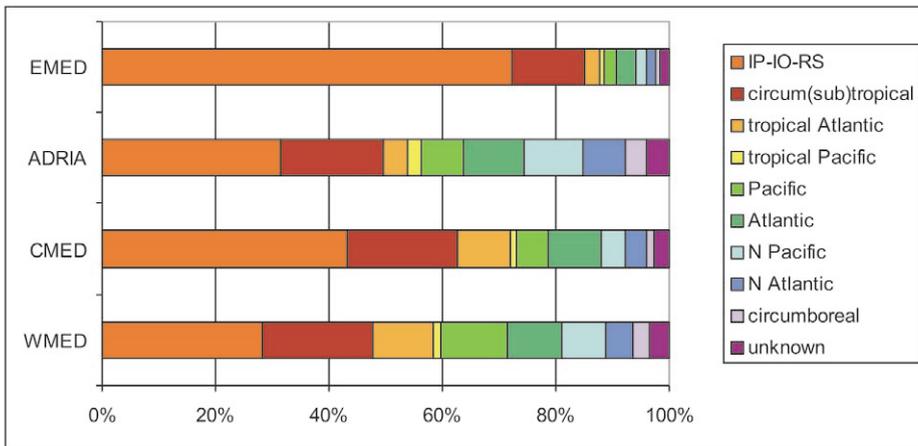


Fig. 4: Origin of species per basin. IP-IO-RS: Indo-Pacific, Indian Ocean, Red Sea.

or Indian or Red Sea are clustered together. Similarly, species originating in either the east or west of the tropical Atlantic are grouped together, and so are those originating from the North Atlantic or the North Pacific.

It is estimated that almost 60% of the alien species in the Mediterranean Sea come from the Suez Canal. By adding those species introduced via shipping and/or aquaculture and trade, it is quite clear that most of the alien species in the Mediterranean are warm water species, originating in (sub)tropical seas. In particular, thermophilic species, (Indo-Pacific, Indian Ocean, Red Sea, tropical Atlantic, tropical Pacific, circum(sub)tropical), account for 88.4% of the introduced species in the EMED, 72.8% in the CMED, 59.3% in the WMED and 56.1% in the Adriatic. The respective figures for Indo-Pacific species only are 47.5% for EMED, 24.9% for CMED, 22.8% for the Adriatic and 20% for WMED, whereas tropical Atlantic species show a sharp decrease from WMED (10.1%) to EMED

(2.7%) (Fig. 4). Cold water species, circumboreal, N Atlantic, N Pacific, make up a small percentage ranging between 4.2% and 21.6%, being more pronounced in the Adriatic and less so in the EMED.

While maritime traffic and other human activities such as aquaculture are important vectors for the introduction of alien species worldwide (RUIZ *et al.*, 2000), in the Mediterranean they are not the main responsible for the large differences observed among the four basins. In the EMED the human intervention responsible for most of the aliens is the re-establishment of the connection with the Indo-Pacific through the Suez Canal (1869), rather than the actual transfer of the invaders. In addition, with the present climate change (BELKIN, 2009), the tropical features and temperature of the waters are increasing more quickly in the EMED, implying dramatic modifications of the biota (POR 2009, 2010). As a consequence, Indo-Pacific species (regardless of the mode introduction) have found optimal environment for settlement in the EMED.

On the contrary, the Adriatic Sea, which is topographically a dead end, is the area with the lowest number of aliens, receiving them among those already established in the EMED and CMED that spread northwards, or among those introduced via shipping or aquaculture in hot spot areas such as the Venice Lagoon (OCCHIPINTI-AMBROGI *et al.*, 2010).

A significant number of Indo-Pacific species reaches the WMED, which is enriched by ship-transferred species of Pacific origin mostly among macrophytes. The Strait of Gibraltar is essentially different from the Suez Canal as a potential pathway for alien species. First of all, it is an ancient waterway, believed to have originated 5.33 million years ago (HILGEN & LANGEREIS, 1993), compared to the 142 years of the Suez Canal. Therefore, the current distribution of Atlantic species, tropical or not, with part of their range in the Mediterranean is the result of a natural process over a long time; these species do not in any case qualify as aliens, even if their discovery in the Alboran Sea comes later than their first description in the Atlantic. Secondly, the Atlantic coast of Morocco is swept by a prevalently southward oceanic circulation that prevents many potential newcomers to approach the Strait of Gibraltar.

### **7.1. Alien foraminiferans in the Mediterranean**

A total of 50 foraminiferan species are reported in this work, all of them being warm water species. The high diversity of Indo-Pacific species in the EMED probably implies that many of them are Lessepsian immigrants. Data on shallow water foraminifers are very few and scattered. Most works concern deeper assem-

blages, almost totally made up by taxa of Atlantic affinity, more useful for the biostratigraphical and paleobathymetrical applications that make foraminifers so important for micropaleontologists. As a consequence, it is very difficult to recognize new Atlantic immigrants entering the Mediterranean. On the basis of the (scarce) geological data the assumption that some more tolerant large foraminifers, such as amphisteginids, could have survived during the Pleistocene in the southern Mediterranean cannot be ruled out.

### **7.2. Alien macrophytes in the Mediterranean**

Compared to previous lists of alien macrophytes in the Mediterranean Sea (RIBERA & BOUDOURESQUE, 1995; BOUDOURESQUE & VERLAQUE, 2002; RIBERA SIGUÁN, 2002; CORMACI *et al.*, 2004; ZENETOS *et al.*, 2008), the present revised checklist has taken into account all the possible introductions of exotic genotypes. Several species already represented in the Mediterranean Sea by putative native populations, such as *Cladosiphon zosterae*, *Desmarestia viridis*, *Ectocarpus siliculosus* var. *hiemalis*, *Pylaiella littoralis*, have been only considered here if introduction events are locally evident (e.g. Thau Lagoon, Lagoon of Venice). A total of 125 taxa (79 Rhodophyta, 24 Fuco-phyceae, 20 Chlorophyta, 1 Pelagophyceae and 1 Magnoliophyta) has been listed on the basis of recent works (FURNARI *et al.*, 2010; SFRISO *et al.*, 2010; TSIAMIS *et al.*, 2010; CECERE *et al.*, in press; VERLAQUE *et al.*, in press) and on-going researches. Among them, 97 taxa (78% of alien macrophytes) are established in at least one of the four

Mediterranean basins, the remainders (22%) belong to casual and cryptogenic/questionable categories.

As far as the major vectors of introduction are concerned, the transfer of shellfish stands the first (46% of alien macrophytes), followed by the shipping and the Suez Canal (29% and 27%, respectively each). Some species have been probably introduced several times by different vectors. The predominantly donor regions are temperate and cold regions (54% of alien macrophytes) vs tropical regions (46%). Such a result may be an artefact due to the unequal effort of investigation between the WMED and the EMED. Introductions along with shellfish transfers from north-eastern Atlantic and north-western Pacific have been thoroughly studied in the north-western basin and the Adriatic, while in the EMED smallest alien macrophytes remain probably insufficiently studied (most of reported Lessepsian migrants are large-sized species).

### 7.3. Alien polychaetes in the Mediterranean

Compiling data on alien polychaete species reported from the Mediterranean Sea revealed a total of 129 species belonging to 26 families, of which 59 species have become established in the region, 31 species are casual, 37 species are questionable and 2 species (*Chaetozone corona* and *Parapriopio coora*) are cryptogenic. The majority of alien polychaete species have been found in the EMED (97 species), followed by the WMED (49 species), the CMED (35 species) and the Adriatic Sea (22 species). In the Sea of Marmara, 14 alien polychaete species are known, of which 6 species have become established in the area and 8 species are question-

able (ÇINAR, 2010).

The Mediterranean Sea is largely under the siege of polychaete species, mainly introduced from the Red Sea/Indo-Pacific areas (99 species, 77% of total species) and Atlantic Ocean (24 species). The Suez Canal is one of the main vectors for the introduction of the species. The EMED habitats are largely dominated by the Red Sea immigrants. Polychaete species that, most probably, entered the Mediterranean Sea via the Suez Canal and expanded their distribution to the WMED are *Nereis jacksoni*, *Lysidice collaris*, *Lumbrineris perkinsi*, *Notomastus aberans*, *N. mossambicus*, *Metasychis gotoi*, *Pista unibranchiata*, *Streblosoma comatus* and *Branchiommata luctuosum*.

The knowledge about alien polychaete species in the Mediterranean Sea has greatly increased recently. A total of 59 species were reported after 2005. This number also includes some species (i.e. *Sigambra constricta*, *S. parva*, *Dasybranchus carneus*) that were not classified as alien species by ZENETOS *et al.* (2005, 2008). Due to the lack of precise taxonomic works on polychaetes, there is a high number of questionable species. These species were largely reported from ecological studies. The future taxonomical studies to be held in the whole basin would enable us to realize the real number of alien polychaete species in the Mediterranean Sea.

### 7.4. Alien crustaceans in the Mediterranean

A total of 153 alien crustacean species have entered the Mediterranean. The majority are decapods (78 species), followed by copepods (42), amphipod (11), isopods (8), cirripedes (7), cumaceans (3), stomatopods (3) and tanaids (1).

Approximately 77% of all alien Mediterranean decapod species have an Indo-Pacific/Indian/Red Sea origin, while only 23% are from the Atlantic. The dominance of these 'eastern alien species' over the total is obvious; it mainly reflects the situation (environment characteristics mainly) in the EMED and CMED where 82% of all Mediterranean alien species could be found (only the following alien species are not present: *Actumnus globulus*, *Charybdis feriata*, *Charybdis japonica*, *Charybdis lucifera*, *Cryptosoma cristatum*, *Dyspanopeus sayi*, *Eriocheir sinensis*, *Hemigrapsus sanguineus*, *Herbstia nitida*, *Menaethius monoceros*, *Scyllarus caparti*, *Scyllarus posteli* and *Thalamita gloriensis*). In the WMED, the situation is more balanced, where only 52.6% of the alien decapods are Indo-Pacific and the remainders are Atlantic. The Adriatic is a peculiar sector with 13 alien species, six of which (*Callinectes danae*, *Charybdis japonica*, *Charybdis lucifera*, *Dyspanopeus sayi*, *Herbstia nitida* and *Scyllarus caparti*) are exclusive to this sector. The EMED and WMED share only 10 species (12.8%), three of which inhabit estuarine environments or are related to aquaculture or food (*Rhithropanopeus harrisi*, *Marsupenaeus japonicus* and *Necora puber*) and other two are invasive (*Callinectes sapidus* and especially *Percnon gibbesi*).

The contribution of Indo-Pacific species reaches 86% in copepods vs 11.6% of Atlantic origin and one debatable case: the Antarctic visitor (*Spinocalanus terranovae*). Recent taxonomic studies have shed some light on alien microcopepods in the Mediterranean (BÖTTGER-SCHNACK & SCHNACK, 2009). The contribution of warm water species is also high among alien amphipods, excepting

*Parhyale explorator*, a NE Atlantic species found in 2005 on the coast of Iskenderun Bay (BAKIR *et al.*, 2008). Yet, the lack of studies to determine the actual original distribution of species such as *Cymadusa filosa*, *Gammaropsis togoensis* and *Monocorophium sextonae* has led to the assignment of the cryptogenic status to almost 30% of the species.

### 7.5. Alien molluscs in the Mediterranean

Molluscs are one of the major groups in the marine fauna worldwide and continue as the first contributors to the alien fauna in the Mediterranean Sea. The total number of reported alien species amounts to 212, a small but steady increase of about 8% since the recent review of ZENETOS *et al.* (2005). More than half of the species (115 in total) are established in at least one of the four basins, 74 are casual and the remaining 24 are questionable or cryptogenic.

There is a clear decrease in the importance of aliens from the Levantine coast where extra-Mediterranean species may represent 10 to 20% of the local fauna, towards the Alboran Sea where only one species (*Godiva quadricolor*) is reported, i.e. less than 1% of the total. Nevertheless the numbers drop dramatically if we disregard as aliens the Lessepsian immigrants, following POR's (2009, 2010) view that these species have made their way by their own means following the restoration of an ancient waterway, and therefore should not be regarded as aliens. In this perspective, there are hardly some thirty aliens in the Mediterranean which originate from donor regions other than the tropical Indo-Pacific. These have arrived mainly as a consequence of shipping and transfers of living spat for aquaculture, and the most heavily impacted areas are not the Levan-

tine basin, but the marginal marine environments of the northern part of the basins, including the Adriatic and the lagoons of the WMED.

It is noteworthy that the Adriatic Sea shares more established species of molluscs (12 out of 16) with the WMED than with any of the other parts of the Mediterranean, even the neighbouring Ionian Sea (8 shared established species and 2 casual). This reflects not only the climatic similarity, with colder sea water temperature in the northern parts, but also the fact that most of these aliens are estuarine species having some connections with aquaculture, therefore likely to be transported from the Venice area to the French Mediterranean lagoons or vice versa.

#### **7.6. Alien miscellaneous invertebrates in the Mediterranean**

The prevailing taxa among alien invertebrates other than polychaetes, crustaceans and molluscs, are the cnidarians (46 species: 37 hydrozoans, 4 anthozoans, 5 scyphozoans) followed by bryozoans (23), ascidians (16), echinoderms (12), flatworms (12), sponges (8), sipunculans (6), pycnogonids (4), ctenophores (3), chaetognaths (2) and siphonophores (1). With the exception of ascidians, the remaining taxa were poorly treated by COLL *et al.* (2010), if addressed at all.

The current information is always proportional to the degree of expertise in the area. Along this line, cnidarians and bryozoans appear to be the best studied taxa represented by many alien species, while sponges, although well studied in the region, have relatively few representatives, and the reported ones are either questionable or cryptogenic forms.

Alien Anthozoa are represented by

four species, the most widespread of which is *Oculina patagonica*. It is a species of presumably temperate SW Atlantic origin, probably introduced into the Mediterranean by shipping. Invasive in natural and artificial habitats, especially along the southern WMED and EMED coasts (SARTORETTO *et al.*, 2008). Five species coming from the subtropical eastern Atlantic which have recently expanded their range into the Mediterranean and are presently restricted to the Alboran Sea (OCAÑA *et al.*, 2007, 2009) are excluded from our list; yet we keep some reservations on their mode of introduction. *Dendrophyllia laboreli* is a coral in expansion at the Canaries and also the continental Atlantic coast of Africa. *Paramuricea grayi*, *Eunicella gazella* and *Eunicella labiata* are mainly known from the Atlantic coast of Africa including a wide tropical area (GRASSHOFF, 1992), but have not been recognized as part of the Mediterranean fauna by SHUCHERT *et al.* (2003). According to recent observations, boats have borne larvae of *Eunicella* spp. from the Atlantic coast of Africa in their ballast waters. *Antipathella wollastoni* is a typical Macaronesian faunal element with clear tropical affinities (BRITO & OCAÑA, 2004). Its recent settlement in the Alboran Sea may have been favoured by the present climate warming.

The 16 alien ascidian species hitherto recorded in the Mediterranean basin represent about 7% of the known species in the whole basin. In many cases (13 out of 16 species) the introduced ascidian species form established populations in antagonism with the endemic species of the Mediterranean benthos (ascidian or not). The species *Phallusia nigra*, *Herdmania momus*, *Symplegma brakenhielmi*, *Rho-*

*dosoma turcicum*, *Ascidia cannellata* and probably *Microcosmus exasperatus* are considered immigrants via the Suez Canal (IZQUIERDO-MUÑOZ *et al.*, 2009), while species such as *Botrylloides violaceus*, *Polyandrocarpa zorritensis*, *Distaplia bermudensis* and *Styela clava* have been recently introduced by shellfish culture (BRUNETTI & MASTROTOTARO, 2004; MASTROTOTARO & BRUNETTI, 2006; DAVIS & DAVIS, 2008; IZQUIERDO-MUÑOZ *et al.*, 2009). In many cases the first record has been reported when the species was already present with dense populations often in antagonism with native species (e.g. BRUNETTI & MASTROTOTARO, 2004; MASTROTOTARO & BRUNETTI, 2006; DAVIS & DAVIS, 2008).

The majority of echinoderms originate in the Indo-Pacific or are circum-tropical species and their distribution is limited to the EMED; only *Ophiactis savignyi* reaches the WMED. *Asterias rubens*, originating in the N Atlantic, is limited to the Marmara Sea where it was introduced from an established population in the Black Sea (KARHAN *et al.*, 2008). Chaetognaths are represented by two species, both of Indo-Pacific origin, limited to the innermost part of the EMED.

The presence of the parasitic nematode *Anisakis simplex* s.str., in some individual hosts (*Gaidropsarus granti*) from the WMED, which seemed to be the result of immigration of these fish from the Atlantic into the WMED (MATTIUCCI & NASCETTI, 2006), has been excluded, because, according to MANFREDI *et al.* (2000), it is a common parasite in many Mediterranean fishes.

### 7.7. Alien fish in the Mediterranean

In terms of number of species, fish

form a significant portion of the Mediterranean marine alien species list. The rate of introduction is significantly high, where 25 species were added since April 2008 (ZENETOS *et al.*, 2008), bringing the total number of alien fish species to 149.

This figure reflects the relevance of Mediterranean invasion that has no equivalents on other seas. The richness of Mediterranean alien fish species is impressive if compared with native ones. Even if there is no general consensus on the total number of Mediterranean fish - for example FREDJ & MAURIN (1987) listed 612 species while QUIGNARD & TOMASINI (2000) numbered 664 species - this review can give a more precise idea of how the original identity of Mediterranean fish fauna has changed following the arrival of these immigrants.

So far, no species extirpation has been documented. Therefore the ingress of new species generates an increase of species richness, the main routes contributing to Mediterranean fish diversity being the Suez Canal and the Strait of Gibraltar. Almost half of the alien fish species that have been recorded in the Mediterranean have given origin to permanent populations. The magnitude of the phenomenon of fish invasion in the Mediterranean Sea raises concern on the ecological and economic consequences and solicits the urgent need of ongoing monitoring, especially over the southern rim of the basin where research effort is less intense.

## 8. THE STATE OF THE ART IN MEDITERRANEAN MARINE ALIEN SPECIES

Species of tropical/subtropical affinity, favoured by climate warming, are intro-

duced and colonize the Mediterranean at a fast rate, while cold water species are settling at a lower rate. The net outcome is a jump in species richness.

Compared to the latest lists of alien biota (COLL *et al.*, 2010; COSTELLO *et al.*, 2010) the present work includes a larger number (954) of species (Table 4). The divergence in numbers is more obvious in fish (149 this work vs. 116 in COLL *et al.*, 2010), polychaetes (129 this work vs. 75 in COLL *et al.*, 2010), bryozoans (23 this work vs. one in COLL *et al.*, 2010), and cnidarians (46 this work vs three in COLL *et al.*, 2010) (Table 4). Here, we also include aliens among Porifera, Platyhelminthes and Foraminifera, taxa not

treated by COLL *et al.* (2010). In contrast to ZENETOS *et al.* (2008), we do not address microalgal species (either pelagic or benthic) for the reasons described in chapter 5. This implies that despite the collective effort of experts attempted in this work, the number of introduced species remains underestimated. It is clear that the introduced species have increased the biodiversity of the Mediterranean Sea, as an entity, by 5.9% excluding phytoplankton and microzooplankton (Table 4). The figure is even higher reaching 27.9% in fish and 9% on average for the studied taxa. While species richness is increasing at whole basin scale, leading to a higher  $\gamma$  diversity, cases of local replace-

**Table 4**  
**The number of alien species in the Mediterranean by taxonomic group.**

Taxon	COLL <i>et al.</i> , 2010			This work	
	all	aliens	native	aliens	% aliens
Protozoa (excluding Foraminifera)		0	0	4	
Foraminifera	>600	0	600	50	8.3
Rhodophyta	657	73	584	79	13.5
Phaeophyta & Pelagophyceae	277	23	254	24+1	9.8
Chlorophyta	190	17	173	20	11.6
Magnoliophyta	7	1	6	1	16.7
Polychaeta	1172	75	1097	129	11.8
Crustacea	2239	106	2133	153	7.2
Mollusca	2113	200	1913	212	11.1
Cnidaria	757	3	754	46	6.1
Bryozoa	388	1	387	23	5.9
Ascidiacea	229	15	214	16	7.5
Echinodermata	154	5	149	12	8.1
Porifera	681	0	681	8	1.2
Platyhelminthes	1000	0	1000	12	1.2
Other Invertebrates	2168	2	2166	16	0.7
Fish	650	116	534	149	27.9
Total		637*		954*	
Average %		3.3%			5.9%

\*excluding monocellular algae

ment have been reported (GALIL, 2007), which may imply an alteration of  $\alpha$  diversity. In addition, the spatial overlap between alien and native species causes biotic homogenization (BEN RAIS LASRAM & MOUILLOT, 2009), and hence a depression in  $\beta$  diversity. Thus, the relationship between the entering of alien species and threats to biodiversity is not straightforward (BIANCHI *et al.*, 2010).

While biodiversity is currently a key indicator of an ecosystem's health, statistics tell too simple a story in the Mediterranean Sea. In a recent study (2008) assessing fish assemblages associated with *Posidonia oceanica* meadows in the Rodos Island (EMED), the silverver-stripe blaasop, *Lagocephalus sceleratus*, ranked among the 10 most abundant species, totalling 2% of total biomass, while bluespotted cornetfish, *Fistularia commersonii*, and reticulated leatherjacket, *Stephanolepis diaspros* contributed 0.6% and 0.3%, respectively (KALOGIROU *et al.*, 2010). Of the nearly 30000 specimens collected by commercial benthic trawler off the central Israeli coast at depths between 15 and 30 m, in October 2008 (OCCHIPINTI-AMBROGI & GALIL, 2010), only 9% were native Mediterranean species, the rest consisted of Erythrean aliens, such as the highly venomous striped catfish, *Plotosus lineatus* (11437 specimens), the blotchfin dragonet, *Callionymus filamentosus* (5745), the silver sillago, *Sillago sihama* (1423), the kuruma prawn, *Marsupenaeus japonicus* (1154) and the velvet shrimp *Metapenaeopsis consobrina* (1138).

The faunal survey of large harbours has been largely neglected and is likely to yield many more localized, but estab-

lished, aliens if undertaken seriously.

The application of molecular methods recently developed will be of great help in the definition of the relationships between populations from different areas, and in the assessment of possible routes of introduction and immigration. In addition, metagenomic techniques will presumably allow a much more complete if not exhaustive knowledge of the microbial species in given areas through their molecular signatures. In the meantime, classical taxonomic studies should be intensified to investigate the still wide proportion of unreported alien species of small-sized taxa in the Mediterranean Sea including microalgae.

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**ANNEX: Name changes**

<b>Current name</b>	<b>Old /others name(s) used</b>
<b>Protozoa</b>	
<i>Perkinsus olseni</i> Lester & Davis	<i>Perkinsus atlanticus</i>
<b>Macrophytes</b>	
<i>Caulacanthus okamurae</i> Yamada	<i>Feldmannophycus okamurae</i>
<i>Codium fragile</i> subsp. <i>fragile</i> (Suringar) Hariot	<i>Codium fragile</i> subsp. <i>tomentosoides</i>
<i>Hypnea anastomosans</i> Papenfuss, Lipkin & Silva	<i>Hypnea esperi</i>
<i>Saccharina japonica</i> (Areschoug) C.E. Lane, C. Mayes, Druehl & G.W. Saunders	<i>Laminaria japonica</i>
<i>Spongoconium caribaeum</i> (Børgesen) M.J. Wynne	<i>Pleonosporium caribaeum</i>
<b>Polychaeta</b>	
<i>Apoprionospio pygmaea</i> (Hartman, 1955)	<i>Prionospio pygmaea</i>
<i>Linopherus canariensis</i> Langerhans, 1881	<i>Pseudeurythoe acarunculata</i>
<i>Lumbrineris perkinsi</i> Carrera-Parra, 2001	<i>Lumbrineris inflata</i>
<i>Prosphaerosyllis longipapillata</i> (Hartmann-Schroeder, 1979)	<i>Sphaerosyllis longipapillata</i>
<i>Streblosoma comatus</i> (Grube, 1856)	<i>Streblosoma hesslei</i>
<b>Crustacea</b>	
<i>Austrominius modestus</i> Darwin, 1854	<i>Elminius modestus</i>
<i>Amphibalanus eburneus</i> (Gould, 1841)	<i>Balanus eburneus</i>
<i>Glabropilumnus laevis</i> (Dana, 1852)	<i>Heteropanope laevis</i>
<i>Linguimaera caesaris</i> Krapp-Schickel, 2003	<i>Maera hamigera</i>
<i>Parvocalanus crassirostris</i> Dahl, 1894	<i>Paracalanus crassirostris</i>
<i>Pilumnus minutus</i> De Haan, 1835	<i>Pilumnus hirsutus</i>
<i>Portunus segnis</i> (Forsskål, 1775)	<i>Portunus pelagicus</i>
<i>Subeucalanus subcrassus</i> Giesbrecht, 1888	<i>Eucalanus subcrassus</i>
<i>Sternodromia spinirostris</i> (Miers, 1881)	<i>Dromia spinirostris</i>
<i>Synalpheus tumidomanus africanus</i> Crosnier & Forest, 1966	<i>Synalpheus hululensis</i>
<b>Mollusca</b>	
<i>Anadara kagoshimensis</i> (Tokunaga, 1906)	<i>Anadara inaequivalvis</i> / <i>Arca</i> / <i>Scapharca</i>
<i>Anadara transversa</i> (Say, 1822)	<i>Anadara demiri</i>
<i>Anteaeolidiella foulisi</i> (Angas, 1864)	<i>Aeolidiella indica</i>
<i>Bostrycapulus odites</i> Collin, 2005	<i>Crepidula calyptraeiformis</i> <i>Bostrycapulus aculeatus</i>
<i>Bulla arabica</i> Malaquias & Reid, 2008	<i>Bulla ampulla</i>
<i>Diplodonta bogii</i> Van Aartsen, 2004	<i>Diplodonta</i> cf. <i>subrotunda</i>
<i>Canarium mutabile</i> (Swainson, 1821)	<i>Strombus mutabilis</i>
<i>Cerithidium diplax</i> (Watson, 1886)	<i>Clathrofenella fusca</i> <i>Clathrofenella ferruginea</i>
<i>Cerithidium perparvulum</i> (Watson, 1886)	<i>Cerithiopsis tenthrenois</i>
<i>Conomurex persicus</i> (Swainson, 1821)	<i>Strombus persicus</i> <i>Strombus decorus raybaudii</i>

ANNEX (continued)

Current name	Old /others name(s) used
<i>Doxander vittatus</i> (Linnaeus, 1758)	<i>Strombus vittatus vittatus</i>
<i>Ergalatax junionae</i> Houart, 2008	<i>Ergalatax obscura/ Monula martensi</i>
<i>Haminoea japonica</i> (Pilsbry, 1895)	<i>Haminoea callidegenita</i>
<i>Leucotina natalensis</i> Smith, 1910	<i>Adelactaeon amoenus/ Monotygma amoena</i>
<i>Melibe viridis</i> (Kelaart, 1858)	<i>Melibe fimbriata</i>
<i>Monotygma lauta</i> (A. Adams, 1853)	<i>Adelactaeon fulvus/ Monotygma fulva</i>
<i>Notocochlis gualteriana</i> (Recluz, 1844)	<i>Natica gualteriana</i>
<i>Symola lendix</i> (A. Adams, 1863)	<i>Styloptygma beatrix</i>
<i>Zygochlamys patagonica</i> (King & Broderip, 1832)	<i>Chlamys lischkei</i>
<b>Miscellaneous invertebrates</b>	
<i>Clytia linearis</i> (Thornely, 1899)	<i>Clytia gravieri</i>
<i>Aquilonastra burtoni</i> (Gray, 1840)	<i>Asterina burtoni</i>
<b>Fish</b>	
<i>Atherinomorus forskalii</i> (Ruppell, 1838)	<i>Atherinomorus lacunosus</i>
<i>Equulites klunzingeri</i> (Steindachner, 1898)	<i>Leiognathus klunzingeri</i>
<i>Favonigobius melanobranchus</i> (Fowler, 1934)	<i>Papillogobius melanobranchus</i>

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