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Review Article

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.

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[1], 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-

[1] 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[2] (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 microrganisms 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-

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

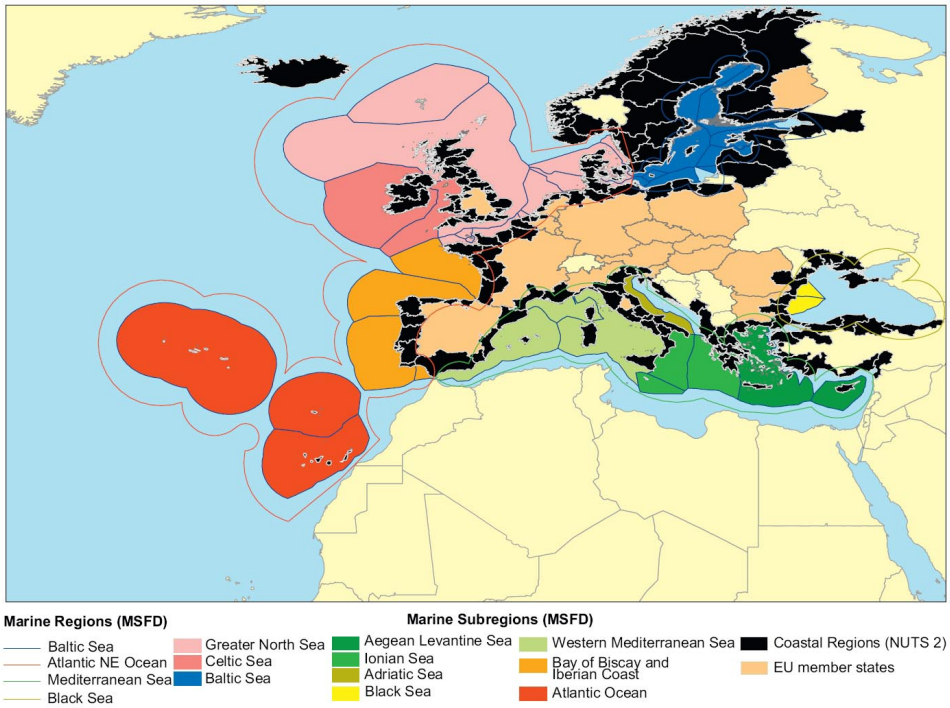

Fig. 1: European marine and coastal regions(source: SUREZ DE VERO *et al.,* 2009).

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
Chondria pygmaea	Garbary & Vandermeulen	Indo-Pacific	est	est	est	
Chondrus giganteus f. *flabellatus*	Mikami	Pacific	est			
Chrysymenia wrightii	(Harvey) Yamada	Pacific	est			
Dasya sessilis	Yamada	Pacific	est			
Dasysiphonia sp. *(= Heterosiphonia japonica)*	Yendo	NW Pacific	est		est	
Galaxaura rugosa	(J. Ellis & Solander) J.V. Lamouroux	Red Sea				est
Ganonema farinosum	(J.V. Lamouroux) K.C. Fan & Yung C. Wang	Indian	cry/ques	cry/ques		cry/ques
Goniotrichiopsis sublittoralis	G.M. Smith	NW Pacific	est			
Gracilaria arcuata	Zanardini	Indo-Pacific/Red Sea		Requires confirmation		Requires confirmation
Gracilaria vermiculophylla	(Ohmi) Papenfuss	NW Pacific			est	
Grateloupia asiatica	Kawaguchi & Wang	NW Pacific	est			
Grateloupia lanceolata	(Okamura) Kawaguchi	Pacific	est	cas		
Grateloupia minima	P.L. Crouan & H.M. Crouan	Pacific	est			
Grateloupia patens	(Okamura) S. Kawaguchi & H.W. Wang	Pacific	cas			
Grateloupia subpectinata	Holmes	Pacific	est			
Grateloupia turuturu	Yamada	NW Pacific	est	est	est	
Griffithsia corallinoides	(Linnaeus) Batters	Atlantic/Pacific	est	est		est
Herposiphonia parca	Setchell	Indo-Pacific	est			
*Hypnea anastomosans***	Papenfuss, Lipkin & Silva	Red Sea		cas		est
Hypnea cornuta	(Kützing) J.Agardh	Cosmopolitan		est		est
Hypnea flagelliformis	Greville ex J. Agardh	Indo-Pacific				Requires confirmation
Hypnea flexicaulis	Yamagishi & Masuda	Indo-Pacific			est	
Hypnea spinella	(C. Agardh) Kützing	Pantropical	est	est	est	est
Hypnea valentiae	(Turner) Montagne	Red Sea	est	est	cas	est
Laurencia caduciramulosa	Masuda & Kawaguchi	SW Pacific	est	est		
Laurencia okamurae	Yamada	Pacific	est			
Lithophyllum yessoense	Foslie	Pacific	est			
Lomentaria flaccida	Tanaka	Pacific	cas			
Lomentaria hakodatensis	Yendo	Pacific	est		est	
Lophocladia lallemandii	(Montagne) F. Schmitz	Indo-Pacific	est	est	est	est
Nemalion vermiculare	Suringar	NW Pacific	est			
Neosiphonia harveyi	(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
Nitophyllum stellato-corticatum	Okamura	Pacific	est			
Osmundea oederi	(Gunnerus) G. Furnari	Atlantic	cry/ques	cry/ques		
Plocamium secundatum	(Kützing) Kützing	tropical/subtropical	est	est		
Polysiphonia atlantica	Kapraun & J.N. Norris	N Atlantic/N Pacific	cry/ques	cry/ques	cry/ques	cry/ques
Polysiphonia fucoides	(Hudson) Greville	N Atlantic	est	cry/ques	cry/ques	cry/ques
Polysiphonia morrowii	Harvey	NW Pacific	est		est	est
Polysiphonia paniculata	Montagne	E Pacific	est	cas	cas	
Polysiphonia stricta	(Dillwyn) Greville	NE Atlantic	est			
Porphyra yezoensis	Ueda	Pacific	est			
Pterosiphonia tanakae	Uwai & Masuda	Pacific	est			
Rhodophysema georgei	Batters	Atlantic/Pacific	cas			cas
Rhodymenia erythraea	Zanardini	Indo West Pacific				cas
Sarconema filiforme	(Sonder) Kylin	Indo West Pacific	cas			est
Sarconema scinaioides	Børgesen	Indian				est
Solieria dura	(Zanardini) F. Schmitz	Indo-Pacific				cas
Solieria filiformis	(Kützing) Gabrielson	N Atlantic	est	est	est	
*Spongoclonium caribaeum***	(Børgesen) M.J. Wynne	W Atlantic	est			
Symphyocladia marchantioides	(Harvey) Falkenberg	Indo-Pacific	est			
Womersleyella setacea	(Hollenberg) R.E. Norris	Indo-Pacific	est	est	est	est
POLYCHAETA						
Amphicorina pectinata	(Banse, 1957)	Pacific	cas	cas		
*Apoprionospio pygmaea***	(Hartman, 1955)	Pacific	cas			
Branchiomma bairdi	(McIntosh, 1885)	Atlantic/Pacific				est
Branchiomma boholensis	(Grube, 1878)	Indo-Pacific	est	est		est
Branchiomma luctuosum	(Grube, 1869)	Indo-Pacific	est	est	est	est
Capitellethus dispar	(Ehlers, 1907)	Indo-Pacific/Red Sea				ques
Ceratonereis mirabilis	Kinberg, 1866	Indo-Pacific		cas		est
Chaetozone corona	Berkeley & Berkeley, 1941	unknown				cry
Cirriformia semicincta	(Ehlers, 1905)	Red Sea				ques
Cossura coasta	Litamori, 1960	unknown				cry/ques
Dasybranchus carneus	Grube, 1870	Red Sea				ques
Desdemona ornata	Banse, 1957	Indo-Pacific	est		est	est
Dispio magnus	(Day, 1955)	Indian		ques		
Dispio uncinata	Hartman, 1951	W Atlantic	cas	cas		
Dodecaceria capensis	Day, 1961	Indian		ques		ques
Dorvillea similis	(Crossland, 1924)	Indo-Pacific				est
Eunice antennata	(Savigny, 1820)	Indo-Pacific	est	est		est
Eunice cf. *cariboea*	Grube, 1856	W Atlantic	ques			
Eunice floridana	(Pourtalès, 1867)	W Atlantic		ques		

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

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

Table 2 (continued)

Species	Author	Origin	WMED	CMED	ADRIA	EMED
Stephanolepis diaspros	Fraser-Brunner, 1940	Red Sea		est	cas	est
Synagrops japonicus	(Doderlein, 1884)	Indo-Pacific	cas			
Synaptura lusitanica	Capello, 1868)	Tropical Atlantic	est	est		
Syngnathus rostellatus	Nilsson, 1855	N Atlantic	cas			ques
Terapon jarbua	(Forsskål, 1775)	Indo-Pacific				cas
Terapon puta	(Cuvier, 1929)	Indo-Pacific/Red Sea				est
Terapon theraps	Cuvier, 1829	Indo-Pacific			cas	
Tetrosomus gibbosus	(Linnaeus, 1758)	Indo-Pacific				est
Torquigener flavimaculosus	Hardy & Randall, 1983	Indian				est
Trachurus indicus	Necrasov, 1966	Indian				cas
Trachyscorpia cristulata echinata	(Koehler, 1869)	Tropical Atlantic	est	est		
Tridentiger trigonocephalus	(Gill, 1859)	Tropical Pacific				cas
Trypauchen vagina	(Bloch & Scheider, 1801)	Indo-Pacific				cas
Tylerius spinosissimus	(Regan, 1908)	Indo-Pacific				est
Tylosurus choram	(Rüppell, 1837)	Indo-Pacific				cas
Tylosurus crocodilus	(Peron & Le Sueur, 1821)	Indo West Pacific				cas
Upeneus moluccensis	(Bleeker, 1855)	Indo-Pacific		est		est
Upeneus pori	Ben-Tuvia & Golani, 1989	Indian		est		est
Vanderhorstia mertensi	Klausewitz, 1974	Indo-Pacific				est
Zenopsis conchifera	(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; URRA *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 damselae,* 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 *Cymbaloporetta 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, Anotrichium okamurae, Antithamnionella boergesenii, A. elegans,* the Atlantic strain of *Asparagopsis taxiformis, Ceramium bisporum, Ganonema 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 (*Desdemona 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 mauretanica* 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 ancistrota,* a species occurring in the Alboran Sea but also known in the Gulf of Cadiz and Morocco (GARCÍA RASO, 1996; UDEKEM D'ACOZ & ĎURIŠ, 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 pectenicrus* 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

(*Myicola 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 hardiest 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 19th 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. *Tridemnum* cf. *savignyi* was first recorded by LAFARGUE (1972) at Port-Cros, France. LAFARGUE (1974) revised the *Tridemnum tenerum* complex, assigning the record by PÉRÈS (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. dellechiajei,* 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 20th century. Here we report 45 species (20 established, 25 casual) inventoried in the 20th 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 (MATALLANAS, 1984). Some species, such as A*narhichas 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 damselae* 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 spinirostris, Sirpus monodi, Callinectes sapidus, Grapsus granulosus.* 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 bentho-planktonic 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 *Aspidoshiphon 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 SOUISSI *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 SOUISSI *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 damselae* (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, Cymbaloporetta 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, Dasysiphonia* 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: *Fabriciola 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. luctuosum,* 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. luctuosum,* 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 harrisii*) 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, Eriocheir 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. inaequivalvis*), *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 'mediterranization' (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 damselae* 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 foraminifers 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 foraminifers 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 (TRIANTAPHYLLOU *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 (TRIANTAPHYLLOU *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 (*Haddonia* 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, Cymbaloporetta squammosa, 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 *Glabratella 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 MERIÇ *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 coerulescens, 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 *Stypopodium 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 *Paraprionospio 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'ACOZ, 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 'crypogenic'.

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 *Erugosquilla 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 (Sphyraenidae).

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 pholadiformis, 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 (AÇ IK, 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 *Pomadasys stridens* (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 implied 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 loose their peculiar characteristics with common fixatives such as formalin and lugol. *Micromonas pusilla,* a 2-3 μm 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 l^{-3} in coastal Mediterranean waters in winter (THRONDSEN & 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 μm) 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 *Ostreospis* 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. subpacifica.* This species was relatively common in the 1984-1987 period in the Gulf of Naples, then it became rarer and eventually disappeared. Although *P. subpacifica* 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). The list was enriched with species such as the bigfin reefsquid *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.

SPECIES	WMED	CMED	ADRIA	EMED
Foraminifera				
Amphistegina lobifera	+	+	+	++
Macrophyta				
Acrothamnion preissii	++	+	+	-
Asparagopsis armata	++	+	+	+
Asparagopsis taxiformis	++	++	+	++
Caulerpa distichophylla	-	++	-	++
Caulerpa racemosa var. *cylindracea*	++	++	++	++
Caulerpa taxifolia	++	++	++	-
Chrysonephos lewisii	++	-	-	-
Cladophora cf. *patentiramea*	-	-	-	++
Codium fragile subsp. *fragile*	++	+	++	++
Codium parvulum	-	-	-	++
Dasysiphonia sp.	+	-	+	-
Gracilaria vermiculophylla	-	-	++	-
Grateloupia turuturu	+	+	+	-
Halophila stipulacea	+	++	+	++
Lithophyllum yessoense	+	-	-	-
Lophocladia lallemandii	++	+	+	+
Sargassum muticum	++	-	++	-
Stypopodium schimperi	-	+	-	++
Ulva pertusa	+	-	-	-
Undaria pinnatifida	++	+	++	-
Womersleyella setacea	++	++	+	+
Polychaeta				
Branchiomma bairdi	-	-	-	++
Branchiomma luctuosum	+	++	+	++
Ceratonereis mirabilis	-	-	-	++
Desdemona ornata	+	-	++	++
Dorvillea similis	-	-	-	++
Eunice antennata	+	+	-	++
Ficopomatus enigmaticus	++	++	++	++
Hydroides dianthus	++	++	++	++
Hydroides elegans	++	++	++	++
Hydroides operculatus	-	-	-	++
Leonnates indicus	-	-	-	++
Leonnates persicus	-	-	-	++
Laonome triangularis	-	-	-	++
Notomastus mossambicus	+	-	-	++

Table 3 (continued)

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

Table 3 (continued)

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

Table 3 (continued)

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

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.

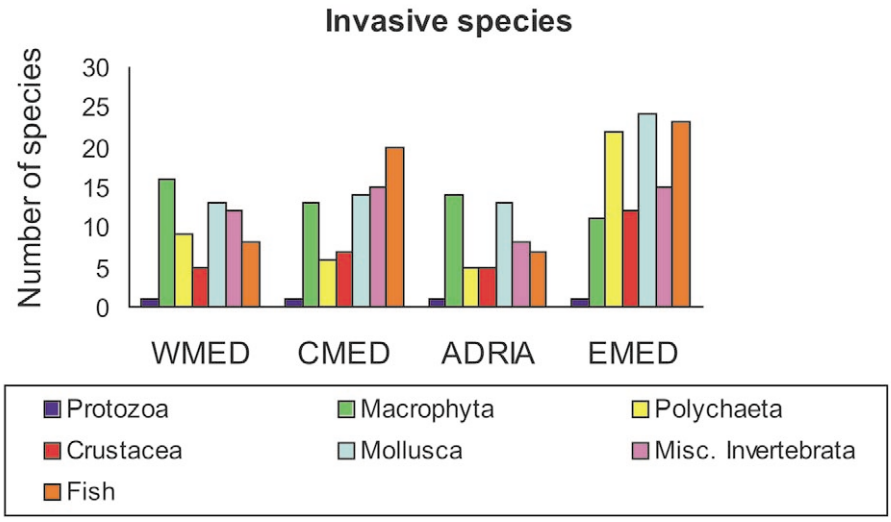

Fig. 2: Breakdown of invasive or potentially invasive species per taxonomic group.

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^{-2}, that of *S. gynobranchiata* as 60480 ind·m^{-2} and that of *P. paucibranchiata* as 6180 ind·m^{-2} 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^{-2} 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^2 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^{-2} 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 *Sepioteuthis 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.·m^{-2} 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 nigripinnis* (presently *Apogon pharaonis*) (0.02%) (HARMELIN-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

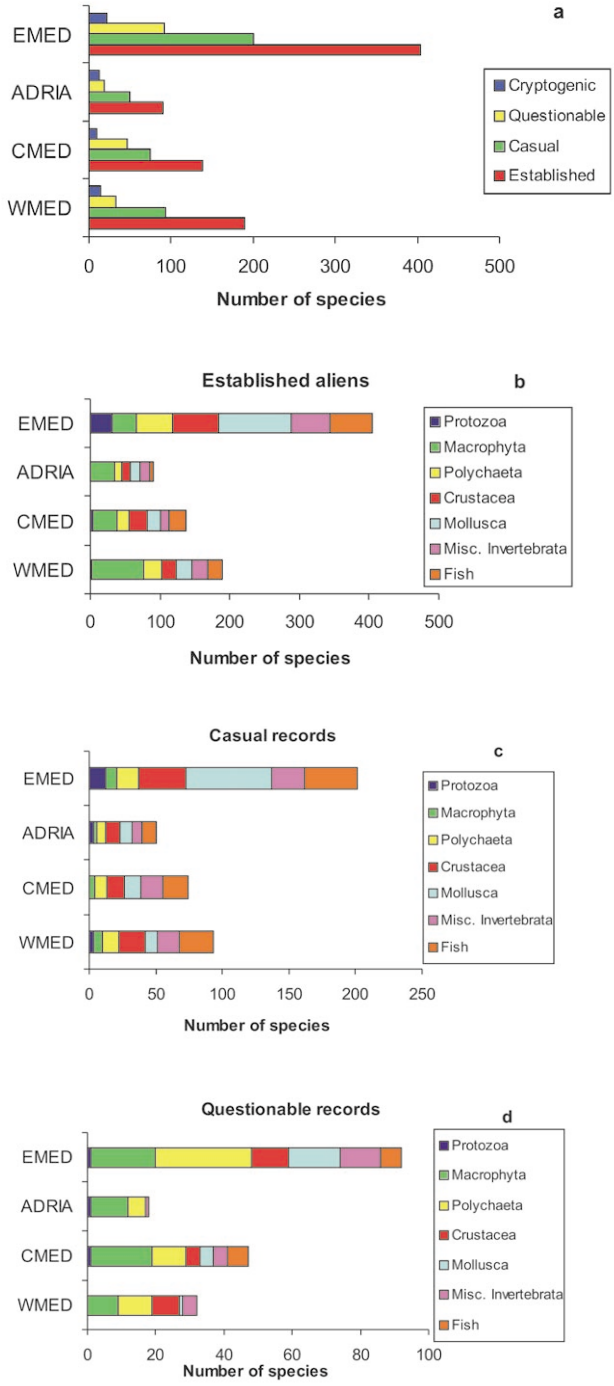

Fig. 3: **a:** Establishment success per basin (all taxa); **b, c, d:** Partitioning of alien taxa per establishment success.

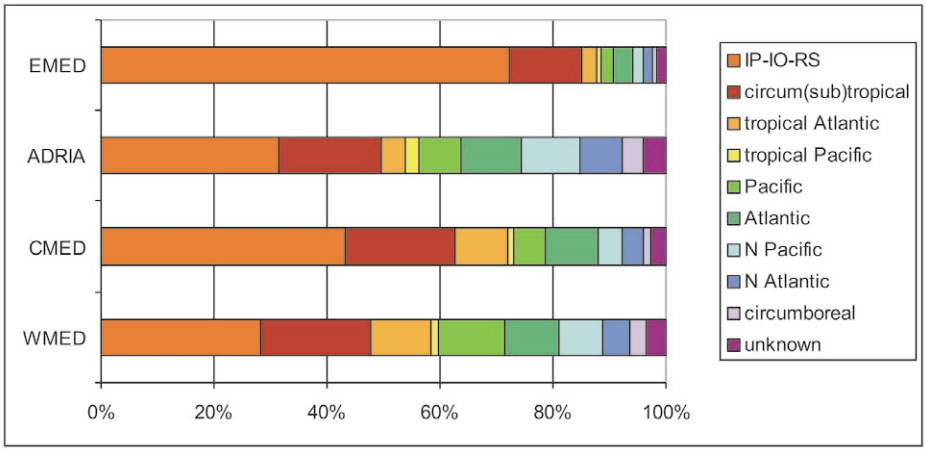

Fig. 4: Origin of species per basin. IP-IO-RS: Indo-Pacific, Indian Ocean, Red Sea.

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 responsibles 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 assemblages, 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 Fucophyceae, 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 *Paraprionospio 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 questionable (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 *Branchiomma 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 harrisii, 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 circumtropical 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 ingression 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 were 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 γ diversity, cases of local replace-

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

	COLL *et al.*, 2010			This work	
Taxon	**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 α diversity. In addition, the spatial overlap between alien and native species causes biotic homogenization (BEN RAIS LASRAM & MOUILLOT, 2009), and hence a depression in β 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 silververstripe 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 established, 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

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

ANNEX (continued)

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

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