Mediterranean Marine Science

Vol 12, No 2 (2011)

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doi: [10.12681/mms.34](https://doi.org/10.12681/mms.34)

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available on line at http://www.medit-mar-sc.net

Review Article

An updated review of alien species on the coasts of Turkey

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Received: 02 March 2011; Accepted: 9 May 2011; Published on line: 30 May 2011

Abstract

This 2010 review of alien species along the coasts of Turkey represents a total of 400 alien species belonging to 14 systematic groups. The present paper also reports the first findings of *Vanderhorstia mertensi* in the Aegean Sea (Gökova Bay), *Chama adspersa* in the Sea of Marmara and *Mya arenaria* in the Aegean Sea. A total of 124 new alien species was determined within the last 5 years. Mollusca had the highest number of species (105 species), followed by Polychaeta (75 species), Crustacea (64 species) and Pisces (58 species). The highest number of alien species (330 species) were encountered on the Levantine coast of Turkey, followed by the Aegean Sea (165 species), Sea of Marmara (69 species) and Black Sea (20 species). The Suez Canal (66% of the total number of alien species) is the main vector for species introductions to the coasts of Turkey, followed by the ship-mediated transport (30%). The majority of species (306 species, 76% of total number of species) have become established in the area, while 59 species are classified as casual (15%), 23 species as questionable (6%) and 13 species as cryptogenic (3%). One new alien species was introduced to the coasts of Turkey every 4 weeks between 1991 and 2010. The majority of aliens were found on soft substratum (198 species) in shallow waters (0-10 m) (319 species). Some species such as *Caulerpa racemosa, Amphistegina lobifera, Amphisorus hemprichii, Rhopilema nomadica, Mnemiopsis leidyi, Hydroides* spp., *Ficopomatus enigmaticus, Charybdis longicollis, Rapana venosa, Asterias rubens, Siganus* spp. and *Lagocephalus sceleratus* show a highly invasive character, and have great impacts both on the prevailing ecosystems and humans.

Keywords: Alien species; Species list; Black Sea; Sea of Marmara; Aegean Sea; Levantine Sea; Turkey.

Introduction

There are probably no ecosystems on earth which may resist the introduction of an alien species. The worldwide vectors for alien marine species are diverse and can be listed under 15 broad categories, including prominent factors such as commercial shipping activities, canals, aquaculture and fisheries, drilling platforms and the aquarium industry (BAX *et al.,* 2003). Success of an introduced species in the new environment generally depends on a combination of several bio-ecological factors, but as experienced drastically in the Mediterranean Sea, some ecosystems are known to be more susceptible to invasion. In a recent review of the Mediterranean alien marine biota, the presence of 955 species is mentioned, where the eastern basin is still the favorite destination for aliens due to its proximity to the Suez Canal and dense maritime traffic (ZENETOS *et al.,* 2010b). The influx of a huge number of tropical species into the Mediterranean is doubtless the most remarkable bio-geographical phenomenon of today, but POR (2009) indicates in advance that what is happening now may be considered as a partial return to the original warm water biological conditions of the ancient Mediterranean Sea, possibly a normalization event from a geological perspective.

By means of quantitative occurrence of alien species, Turkey can be placed in the center of introductions (ZENETOS *et al.,* 2008). The most detailed analysis was hitherto conducted by ÇINAR *et al.* (2005a), who compiled a list of 277 alien species recorded from all seas surrounding Turkey, with the Suez Canal being the primary vector for species introductions. Due to lack of experts in definite systematic groups and the presence of a relatively low number of scientific research projects funded by the government, the available alien biodiversity figure is probably an underestimate, likely to be solved only by specific studies concentrating on this key diversity change. Only a few measures are currently being taken by the government, including a prohibition of human mediated species introductions to wetlands (within the framework of the Ramsar Convention) which came into force in May 2005 (Ministry of Environment and Forestry), and a fisheries ban on the two alien pufferfishes, *Lagocephalus sceleratus* and *L. spadiceus,* which appeared in November 2008 in the Fisheries Bulletin of Ministry of Agriculture and Rural Affairs.

The present study focuses on an updated list of alien species occurring on the Turkish coastline that have been gathered from research papers and results of scientific projects, especially intensified during the last decade.

Methods

The present work includes the reports of alien species on the coasts of Turkey. In the paper by ÇINAR *et al.* (2005a), a species list was presented considering species reports up to 2005. Here, we give the list of alien species based on the species reports up to December 2010, together with the first years of their collections, unlike ÇINAR *et al.* (2005a) who only mentioned the first years of their reports. Reports of some alien species along the coasts of Turkey that have not yet appeared in journals now (in press status) were also considered in the present study (i.e. AKAMCA *et al.,* 2011; ÇINAR *et al.,* 2011). The occurrences of *Chama adspersa* in the Sea of Marmara and *Mya arenaria* in the Aegean Sea were validated after personal communications with Drs. C. DELONGUEVILLE and P. OVALIS, respectively. Some species previously considered as aliens were excluded from the list of alien species in the Mediterranean Sea for a variety of reasons (i.e. misidentification, insufficient data for species). We did not include these species in the present list, unlike the paper by ÇINAR *et al.* (2005a). The present list also includes some species (i.e. *Sigambra parva, Podarkeopsis capensis, Aplysina parvula*) that were not previously considered as aliens or overlooked in the previous list presented in 2005.

Alien species were grouped into four main categories, namely established, casual, questionable and cryptogenic. The definition of the terms can be found in ZENETOS *et al.* (2010b). Briefly, established species are the alien species with self-maintaining populations; casual species are the species which were reported only once in the region; questionable species are the species which were reported without sufficient information and their taxonomic status is uncertain; cryptogenic species are the species with no definite evidence of their native or introduced status according to CARLTON (1996). Invasive species are the established aliens that have overcome biotic and abiotic barriers in the region and are able to expand their distributional ranges through the production of fertile offspring, with noticeable impact on the prevailing ecosystem.

Results and Discussion

List of species

The present study reports a total of 400 alien species belonging to 14 systematic groups up to the year 2010. The present paper also reports the first findings of *Vanderhorstia mertensi* in the Aegean Sea (Gökova Bay, 15 m) (M. BILECENOGLU pers. obs.), *Chama adspersa* in the Sea of Marmara (C. DELONGUEVILLE, pers. comm.) and *Mya arenaria* in the Aegean Sea (P. OVALIS, pers. comm.). In addition, the reports of 6 species that have not been published yet (in press status in journals) have also been added to the alien species list of Turkey. These species belong to Foraminifera (*Coscinospira arietina*), Polychaeta (*Laonice norgensis, Prionospio* (*Minuspio*) *pulchra* and *Spiophanes algidus*) and Pisces (*Trypauchen vagina* and *Tylerius spinosissimus*) (for references see Table 1). Table 1 gives the list of all species reported from the coasts of Turkey together with their possible date of introduction, establishment successes, possible origin and means of introductions, and their habitat and depth preferences. The literature emphasizing the first report of the species in the seas that border Turkey is also given with in superscript code.

In the first review of alien species on the coasts of Turkey, ÇINAR *et al.* (2005a) presented a list of 277 alien species belonging to 13 systematic groups, based on the species records up to December 2005. In contrast to the previous list, the present review also includes the species belonging to the systematic groups Sipuncula and Chaetognatha. Among the groups, Mollusca possessed the highest number of species (105 species), followed by Polychaeta (75 species), Crustacea (64 species) and Pisces (58 species). A total of 5 groups (Sipuncula, Pantopoda, Bryozoa, Chaetognatha and Tunicata) were represented by 1-3 alien species.

In the 2005 review, a total of 7 phytoplankton species were regarded as alien species. Apart from these species, *Ceratium breve* (Ostenfeld et Schmidt) Schröder (EKER & KIDEYS, 2000), *Proboscia indica* (Peragallo) Hernández-Becerril (POLAT *et al.,* 2000), *Gonyaulax pacifica* Kofoid (POLAT, 2007), *Histioneis elongata* Kofoid et Michener (POLAT & KORAY, 2007) and *Heterodinium angulatum* Kofoid et Michener (POLAT & KORAY, 2007) were also considered as alien species, which were reported on the coasts of the Levantine Sea.

Table 1

The list of alien species and their first year of observations from the Turkish coasts. The habitat and depth preferences of aliens along the coasts together with their possible origins and establishment success are also given. BS: Black Sea, SM: Sea of Marmara, AS: Aegean Sea, LS: Levantine Sea, ES: Establishment Success (E: Established, C: Casual, Q: Questionable, Cr: Cryptogenic), O: Origin (IP: Indo-Pacific, RS: Red Sea, AT: Atlantic, WA: Western Atlantic, ST: Subtropical, IO: Indian Ocean, PG: Persian Gulf, PO: Pacific Ocean, TA: Tropical Atlantic, CT: Circumtropical, BA: Boreal Atlantic, Cas: Caspian Sea, Co: Cosmopolitan) MI= Mode of Introduction (Su: Suez Canal, S: Shipping, G: Gibraltar, Aq: Aquaculture), H: Habitat [Hs: Hard Substratum (including algae, sponge), Ss: Soft Substratum (including phanerogames), P: pelagic, Pz: parasite], DR: Depth Range (I: 0–10 m, II: 11–50m, III: 51–100 m, IV: 101–200 m, V: 201–400, VI: 401–500 m). Ps= Present study, *ÇEVİK *et al.* (2011).

	BS	SM	AS	LS	ES	O	MI	H	D
PHYTOBENTHOS									
Cyanophyta (=Cyanobacteria)									
Trichodesmium erythraeum Ehrenberg, 1830	-	-	1990[92]	-	E	RS/IP	Su	Hs/Ss	I
Rhodophyta									
Acanthophora nayadiformis (Delile) Papenfuss, 1968	-	1970[288]	1970[163]	1989[43]	Cr,Q	RS/IO	Su	Hs	I,II
Acanthophora muscoides (Linnaeus) Bory de Saint-Vincent, 1753	-	-	1977[289]	-	Q	AT	S	Hs	I,II
Asparagopsis armata Harvey, 1855	1973[287]	1984[289]	1973[287]	1969[285]	E	AT/PO	S	Hs	I
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon, 1845	-	1984[46]	2001[53]	-	E	CT	Su	Hs	I
Bonnemaisonia hamifera Hariot, 1891	-	1984[289]	1998[53]	1989[43]	E	IP	?S	Hs	I
Botryocladia madagascariensis G. Feldmann, 1945	-	-	-	1995[266]	E	AT/PO	S	Hs	I
Chondria curvilineata F.S. Collins & Hervey, 1917	-	1984[289]	-	-	E	AT	S	Hs	II
Colaconema codicola (Børgesen) H.Stegenga, J.J.Bolton, & R.J.Anderson, 1997	1994[54]	1984[289]	1990[92]	1988[42]	E	AT/PO	S	Hs/Ss	I
Ganonema farinosum (Lamouroux) Fan & Wang, 1974	1992[44]	1899[148]	1972[52]	1989[42]	Cr	RS/IP	Su	Hs/Ss	I
Gracilaria arcuata Zanardini 1858	-	1984[289]	-	-	Q	RS/IP	Su	Hs	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Griffithsia corallinoides (Linnaeus) Trevisan, 1845	-	1986[46]	-	-	E	AT/IP	G	Hs	I
Hypnea spinella (C. Agardh) Kützing, 1847	-	-	1983[41]	1989[42]	E	CT	S	Hs	I
Lophocladia lallemandii (Montagne) Schmitz, 1893	-	-	1970[163]	1986[88]	E	IP	Su	Hs	I,II
Polysiphonia fucoides (Hudson) Greville, 1824	1973[287]	-	1973[287]	-	E	AT/IO	S	Hs	I,II
Polysiphonia morrowii Harvey, 1857	-	2007[132]	-	-	E	PO	S	Hs	I
Polysiphonia paniculata Montagne, 1842	1972[52]	-	2001[224]	1998[223]	E	AT/PO	S	Hs	I
Polysiphonia kampsaxiii Boergesen, 1939	-	-	1977[40]	1989[43]	Q	IP	S	Hs	I
Rhodophysema georgii Batters, 1900	-	1984[289]	-	-	C	AT/PO	?S	Hs	I
Heterokontophyta=Ochrophyta									
Cladosiphon zosterae (J.Agardh) Kylin, 1940	-	1984[46]	1983[165]	1989[43]	Cr	AT	S	Hs	I
Chorda filum (Linnaeus) Stackhouse 1797	-	1984[289]	-	-	C	AT/PO	?S	Hs	I,II
Colpomenia peregrina Sauvageau, 1927	-	1998[51]	-	-	E	IP	S	Hs	I
Ectocarpus siliculosus var. *hiemalis* (Crouan frat.ex Kjellman) T.Gallardo 1992	1973[286]	1972[47]	1899[148]	1986[241]	Cr	AT	S	Hs	I
Halothrix lumbricalis (Kützing) Reinke, 1888	1998[55]	1984[46]	1980[289]	1993[240]	E	AT/PO	S	Hs	I
Microspongium globosum Reinke 1888	-	2003[256]	-	-	Q	AT	S	Hs	I
Pylaiella littoralis (Linnaeus) Kjellman, 1872	1984[48]	1984[46]	1983[166]	1983[166]	Cr	AT/PO	S	Hs	I
Punctaria tenuissima (C.Agardh) Greville, 1830	1993[54]	-	-	-	E	AT	S	Hs	I
Sargassum latifolium (Turner) C.Agardh, 1820	-	1984[289]	1984[289]	-	Q	RS	?Su	Hs	I,II
Sphaerotrichia firma (Gepp) A.D.Zinova, 1940	-	1984[289]	1970[163]	1984[289]	E	AT/PO	S	Hs	I
Stypopodium schimperi (Buchinger ex Kützing) Verlaque & Boudouresque, 1991	-	-	1989[273]	1991[43]	E	IP	?Su	Hs	I
Chlorophyta									
Caulerpa mexicana Sonder ex Kützing, 1849	-	-	-	2007[133]	E	RS/IP	S	Ss	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Caulerpa racemosa (Forsskål) J. Agardh var. *cylindracea* Verlaque, Huisman & Boudouresque, 1873	-	-	1993[141]	1995[89]	E	CT	Su	Hs/Ss	I,II
Caulerpa racemosa var. *lamourouxii* f. *requienii* (Montagne) Weber-van Bosse, 1898	-	-	1998[91]	1980[90]	E	IP	Su	Hs/Ss	I,II
Caulerpa scalpelliformis (R.Brown ex Turner) C. Agardh, 1817	-	-	-	1995[138]	E	IP	Su	Ss	I,II
Caulerpa taxifolia (M.Vahl) C.Agardh, 1817	-	-	-	2006[96]	E	PO	S	Hs/Ss	I,II
Codium fragile subsp. *fragile* (Suringar) Hariot, 1889	1998[49]	1998[224]	1983[289]	1998[223]	E	AT/PO	S	Hs	_
Ulva fasciata Delile, 1813	1988[50]	1984[52]	1975[164]	1989[45]	Cr	Co	Su/S	Hs	_
Phanerogame									
Halophila stipulacea (Forsskål) Ascherson, 1867	-	-	1956[290]	1967[166]	E	RS/IO	Su	Hs/Ss	II
FORAMINIFERA									
Agglutinella arenata (Said, 1949)	-	2002[171]	-	-	C	PO	?S	?	III
Amphisorus hemprichii Ehrenberg, 1839	-	-	2004[203]	2002[203]	E	CT	Su	Hs/Ss	I,II
Amphistegina lessonii d'Orbigny, 1826	-	-	2007[206]	-	E	CT	Su	?	II
Amphistegina lobifera Larsen, 1976	-	2004[210]	2001[201]	1997[36]	E	CT	Su	Hs/Ss	I,II
Articulina alticostata Cushman, 1944	-	-	2004[202]	-	C	IP	?S	?	II
Astacolus insolithus (Schwager, 1866)	-	-	2004[202]	-	C	PO	?S	?	III
Astacolus sublegumen (Parr, 1950)	-	-	2004[202]	-	C	PO	?S	?	II
Brizalina simpsoni (Heron-Allen & Earland, 1915)	-	-	2007[206]	-	C	RS	Su	?	II
Clavulina angularis d'Orbigny, 1826	-	-	-	2001[38]	E	TA/RS	Su	?	II
Clavulina cf. *multicamerata* Chapman, 1907	-	-	-	2002[203]	E	RS/PO	Su	?	II
Coscinospira arietina (Batsch, 1791)	-	-	2008[207]	2002[203]	E	RS/TA	Su	?	II
Coscinospira acicularis (Batsch, 1791)	-	-	2007[204]	-	E	IP	Su	?	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Cushmanina striatopunctata (Parker & Jones, 1865)	-	2007[211]	2008[205]	-	E	TA	?S	?	I
Cyclorbiculina compressa (d'Orbigny)	-	-	-	2002[203]	E	TA/PO	?S	?	II
Cymbaloporetta plana (Cushman, 1924)	-	-	2007[206]	2002[203]	E	IP	Su	?	II
Edentostomina cultrata (Brady, 1881)	-	-	2004[202]	2002[203]	E	PO	?S	?	II
Elphidium cf. *charlottense* (Vella, 1957)	-	-	-	2002[203]	E	PO	?S	?	II
Elphidium striatopunctatum (Fichtel & Moll, 1798)	-	-	-	1997[36]	E	RS	Su	?	II
Euthymonacha polita (Chapman, 1900)	-	-	2007[206]	-	C	PO	S	?	II
Hauerina diversa Cushman, 1946	-	-	2007[206]	1997[36]	E	RS/AT	Su	?	II
Heterocyclina tuberculata (Mobius, 1880)	-	-	-	1988[38]	E	RS	Su	?	?
Heterostegina depressa d'Orbigny, 1826	-	-	-	1988[38]	E	CT	Su	Hs/Ss	II
Miliolinella cf. *hybrida* (Terquem, 1878)	-	-	-	2002[203]	E	RS/PO	Su	?	II
Nodopthalmidium antillarum (Cushman, 1922)	-	-	2002[205]	1995[203]	E	RS/TA	Su	?	II
Planogypsina acervalis (Brady, 1884)	-	-	2002[202]	2002[203]	E	RS/TA	Su	?	II
Planogypsina squamiformis (Chapman, 1901)	-	-	2001[203]	-	E	RS/TA	Su	?	II
Pseudomassilina reticulata (Heron-All. & Earland, 1915)	-	-	-	1988[38]	E	RS/IP	Su	?	?
Pulleniatina obliquiloculata (Parker & Jones, 1865)	-	-	2004[209]	-	C	IP	?	P	?
Pyramidulina catesbyi (d'Orbigny, 1839)	-	-	2008[207]	1988[38]	E	CT	Su	?	II
Pyrgo denticulata (Brady, 1884)	-	-	-	2002[203]	C	RS/PO	Su	?	II
Quinqueloculina cf. *mosharrafai* Said, 1949	-	-	-	2002[205]	C	RS	Su	?	II
Schlumbergerina alveoliniformis (Brady, 1879)		-	-	2002[205]	E	CT	Su	?	II
Sorites orbiculus Ehrenberg, 1839	2010[208]	-	2001[201]	1988[38]	E	CT	Su	Hs/Ss	I-III
Sorites variabilis Lacroix, 1941	-	-	2007[206]	2002[205]	E	RS	Su	Hs/Ss	II
Spiroloculina angulata (Cushman, 1917)	-	-	-	1988[38]	E	IP	Su	?	I-II
Spiroloculina antillarum d'Orbigny, 1839	-	2007[205]	2004[203]	1988[38]	E	CT	Su	?	I-II

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Triloculina cf. *fichteliana* d'Orbigny, 1839	-	-	2008[207]	2004[203]	E	RS/TA	Su	?	II
CNIDARIA									
Cordylophora caspia (Pallas, 1771)	-	-	2004[113]	-	E	Co	S	Hs	I
Macrorhynchia philippina Kirchenpauer, 1872	-	-	-	2005[110]	E	CT	Su	Hs	I
Cassiopea andromeda (Forsskål, 1775)	-	-	-	2000[67]	E	RS/IP	Su	P	I
Rhopilema nomadica Galil, Spanier & Ferguson, 1990	-	-	-	1995[178]	E	RS/IP	Su	P	I
Phyllorhiza punctata von Lendenfeld, 1884	-	-	-	2010*	C	RS	Su	P	I
Oculina patagonica De Angelis, 1908	-	-	-	2005[110]	E	WA	S	Hs	I
CTENOPHORA									
Mnemiopsis leidyi (Agassiz, 1865)	1993[217]	1994[179]	1994[179]	1992[268]	E	WA	S	P	I, II
Beroë ovata Mayer 1912	1996[180]	2004[170]	-	-	E	WA	S	P	I, II
SIPUNCULA									
Apionsoma (A.) misakianum (Ikeda, 1904)	-	-	2000[13]	2008[16]	E	IP/WA	S	Ss	II-IV
Aspidosiphon (A.) mexicanus (Murina, 1967)	-	-	2000[15]	-	E	IO/WA	S	Ss	III-IV
Aspidosiphon (A.) elegans (Chamisso & Eysen., 1821)	-	-	2006[14]	2005[14]	E	RS/IP	Su	Hs	I
POLYCHAETA									
Lepidonotus carinulatus (Grube, 1870)	-	1959[246]	-	-	Q	RS/IP	S	Ss	?
Lepidonotus tenuisetosus (Gravier, 1902)	-	-	-	2005[102]	E	RS/IP	Su	Hs	I
Pisione guanche San Martín, López & Núñez, 1999	-	-	-	2005[102]	C	AT	S	Ss	I
Eurythoe complanata (Pallas, 1766)	-	-	-	1993[135]	Q	?IP	Su	Hs	I
Linopherus canariensis Langerhans, 1881	-	-	2005[102]	1993[135]	E	At	S	Hs/Ss	I
Podarkeopsis capensis (Day, 1963)	-	-	1972[134]	-	Q	IP	S	Ss	I
Sigambra constricta (Southern, 1921)	-	1959[246]	-	-	Q	RS/IP	S	Ss	?
Sigambra parva (Day, 1963)	-	-	1972[134]	-	Q	IO	S	Ss	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Synelmis rigida (Fauvel, 1919)	-	1959[246]	-	-	Q	RS/IP	S	Ss	?
Eusyllis kupfferi Langerhans, 1879	-	-	-	2005[102]	E	?AT	S	Hs	I
Exogone breviantennata Hartmann-Schröder, 1959	-	-	-	2005[102]	E	RS/IP	Su	Hs	I
Prosphaerosyllis longipapillata (Hart.-Schröder, 1979)	-	-	-	2005[102]	E	PO	S	Ss	II
Syllis pectinans Haswell, 1920	-	-	2004[113]	-	E	PO	S	Hs	I
Ceratonereis mirabilis Kinberg, 1866	-	-	-	2005[102]	E	RS/IP	Su	Hs/Ss	I-III
Leonnates decipiens Fauvel, 1929	-	-	-	2005[102]	E	RS/IP	Su	Hs	I
Leonnates indicus Kinberg, 1866	-	-	-	2005[102]	E	RS/IP	Su	Hs	I
Leonnates persicus Wesenberg-Lund, 1949	-	-	2001[108]	2000[137]	E	RS/IP	Su	Ss	II-IV
Nereis jacksoni Kinberg, 1866	-	-	-	2005[102]	E	RS/IP	Su	Ss	I,II
Nereis persica Fauvel, 1911	-	1959[246]	-	2005[102]	E	RS/IP	Su	Ss	I-III
Pseudonereis anomala Gravier, 1900	-	-	2004[105]	1973[61]	E	RS/IP	Su	Hs	I
Glycinde bonhourei Gravier, 1904	-	-	-	2005[102]	E	RS/IP	Su	Ss	I
Lumbrineris perkinsi Carrera-Parra, 2001	-	-	-	2005[102]	E	IP	?Su	Hs	I,II
Scoletoma debilis Grube, 1878	-	1959[246]	-	-	Q	IP	S	Ss	?
Eunice antennata (Savigny, 1820)	-	-	-	1993[195]	E	RS/IP	Su	Hs	I
Lysidice collaris Grube, 1870	-	-	1993[103]	1993[135]	E	RS/IP	Su	Hs/Ss	I,II
Marphysa disjuncta Hartman, 1961	-	-	-	2005[196]	C	PO	S	Ss	III
Palola valida (Gravier, 1900)	-	-	-	2005[195]	E	RS	Su	Hs	I
Onuphis eremita oculata Hartman, 1951	-	-	-	2005[102]	E	WA	S	Ss	I,II
Dorvillea similis (Crossland, 1924)	-	-	-	2005[102]	E	RS/IP	Su	Hs/Ss	I,II
Laonice norgensis Sikorski, 2003	-	-	2000[119]	-	C	AT	S	Ss	IV
Paraprionospio coora Wilson, 1990	-	2008[282]	1999[282]	-	Cr	?IP	S	Ss	II-IV
Polydora cornuta Bosc, 1802	-	2002[118]	1986[111]	-	E	WA	S	Ss	I,II

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Prionospio (Aquilaspio) krusadensis Fauvel 1929	-	-	-	2005[116]	E	IP	S	Ss	I
Prionospio (A.) sexoculata Augener, 1918	-	-	-	2005[116]	E	RS/IP	S	Ss	I
Prionospio (Prionospio) depauperata Imajima, 1990	-	-	2000[19]	2005[116]	E	PO	S	Ss	I,II
Prionospio (P.) paucipinnulata Blake & Kudenov, 1978	-	-	2000[117]	2009[117]	E	PO	S	Ss	I,II
Prionospio (P.) saccifera Mackie & Hartley, 1990	-	-	2000[119]	1995[104]	E	RS/IP	Su	Ss	I-III
Prionospio (Minuspio) pulchra Imajima 1990	-	2008[107]	2000[119]	-	E	IP	S	Ss	I-II
Pseudopolydora paucibranchiata Okuda, 1937	-	2008[107]	2000[115]	2005[115]	E	IP	S	Hs/Ss	I
Spiophanes algidus Meißner, 2005	-	-	2000[119]	-	C	IO	S	Ss	IV
Streblospio gynobranchiata Rice & Levin, 1998	-	2005[112]	2000[111]	-	E	WA	S	Ss	I,II
Capitellethus dispar (Ehlers, 1907)	-	1959[246]	-	-	Q	RS/IP	S	Ss	?
Dasybranchus carneus Grube, 1870	-	1959[246]	-	-	Q	RS	S	Ss	?
Neopseudocapitella brasiliensis Rullier & Amoureux, 1979	-	-	2001[109]	-	E	RS/WA	S	Ss	II
Notomastus aberans Day, 1957	-	-	1980[228]	2000[216]	E	IP	Su	Ss	I-III
Notomastus mossambicus (Thomassin, 1970)	-	-	-	2005[102]	E	IO	Su	Ss	I-III
Chaetozone corona Berkeley & Berkeley, 1941	-	2010[107]	1980[106]	2005[102]	Cr	?PO	S	Ss	I,II
Timarete anchylochaeta (Schmarda, 1861)	-	1959[246]	-	-	Q	IP	S	Ss	?
Timarete caribous (Grube, 1859)	-	-	-	2005[102]	C	WA	S	Hs	I
Timarete dasylophius (Marenzeller, 1879)	-	1959[246]	-	-	Q	IP	S	Ss	?
Timarete punctata (Grube, 1859)	-	-	-	2005[101]	E	RS/IP	Su	Hs	I
Pherusa parmata (Grube, 1878)	-	-	-	2005[102]	E	IP	S	Hs	I
Pherusa saldanha Day, 1961	-	-	-	2005[102]	E	IO	S	Hs	I
Metasychis gotoi (Izuka, 1902)	-	2008[107]	1996[136]	2000[102]	E	RS/IP	Su	Ss	II,III
Loimia medusa (Savigny, 1818)	-	1959[246]	-	-	Q	RS	?Su	Ss	?

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Pista unibranchia Day, 1963	-	-	1998[229]	1993[135]	E	RS/IP	Su	Ss	I,II
Polycirrus twisti Potts, 1928	-	-	-	2005[102]	E	RS	Su	Hs/Ss	I
Streblosoma comatus (Grube, 1856)	-	-	-	2005[102]	E	IP	?Su	Hs	I
Branchiomma bairdi (McIntosh, 1885)	-	-	-	2005[102]	E	WA/PO	?S	Hs/Ss	I
Branchiomma luctuosum Grube, 1869	-	-	-	2005[110]	E	RS/IP	Su	Hs	I
Desdemona ornata Banse, 1957	-	2005[112]	-	-	E	IP	S	Ss	I
Laonome triangularis Hutchings & Murray, 1984	-	-	-	2005[102]	E	PO	S	Ss	I
Ficopomatus enigmaticus (Fauvel, 1923)	-	1952[123]	1972[134]	-	E	ST	S	Hs	I
Hydroides brachyacanthus Rioja, 1941	-	-	-	2005[100]	E	IP	?S	Hs	I
Hydroides dianthus (Verrill, 1873)	-	-	1865[245]	-	E	WA	S	Hs	I
Hydroides diramphus Mörch, 1863	-	1894[227]	-	2005[100]	E	CT	S	Hs	I
Hydroides elegans (Haswell, 1883)	-	-	1972[134]	1991[62]	E	CT	S	Hs	I
Hydroides heterocerus (Grube, 1868)	-	-	-	2005[100]	E	RS/IO	Su	Hs	I,II
Hydroides homoceros Pixell, 1913	-	-	-	2005[100]	E	RS/IO	Su	Hs	I
Hydroides minax (Grube, 1878)	-	-	-	2005[100]	E	IP	Su	Hs	I
Hydroides operculatus (Treadwell, 1929)	-	-	-	2005[100]	E	IO	S	Hs	I
Spirobranchus kraussi (Baird, 1865)	-	-	-	2005[100]	E	IP	Su	Hs	I
Spirobranchus tetraceros (Schmarda, 1861)	-	-	-	2005[100]	E	IP	Su	Hs	I,II
Janua (Dexiospira) steueri (Sterzinger, 1909)	-	-	-	2005[102]	E	RS/IP	Su	Ss	I,II
Spirorbis marioni Caullery & Mesnil, 1897	-	-	1987[183]	2005[102]	E	PO	S	Hs	I
PANTOPODA									
Anoplodactylus californicus Hall, 1912	-	-	-	1959[251]	E	CT	Su	Hs	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
CRUSTACEA									
Copepoda									
Centropages furcatus (Dana, 1846)	-	2000[270]	-	1999[259]	E	RS/IP	Su	P	I-III
Calanopia elliptica (Dana, 1846)	-	-	-	1999[259]	E	RS/IP	Su	P	I
Calanopia biloba Bowman, 1957	-	-	-	2002[269]	E	RS/IP	Su	P	I-III
Calanopia minor Scott, 1902	-	-	-	1998[269]	C	RS/IP	Su	P	I-III
Labidocera pavo Giesbrecht, 1889	-	-	-	1999[259]	E	RS/IP	Su	P	I
Subeucalanus subcrassus (Giesbrecht, 1888)	-	-	-	1998[269]	Q	IP	Su	P	I-III
Parvocalanus latus Andronov, 1972	-	1998[270]	-	1998[269]	E	IO	Su	P	I-III
Parvocalanus elegans Andronov, 1972	-	2000[270]	-	1998[269]	E	RS/IP	Su	P	I-III
Acartia tonsa Dana, 1848	-	1993[167]	2001[257]	-	E	WA, IP	S	P	I
Paracartia grani Sars G.O., 1904	-	-	1998[200]	-	E	AT	S	P	I
Spinocalanus terranovae Damkar, 1975	-	-	-	1987[269]	Q	?	S	P	?
Cirripedia									
Amphibalanus eburneus (Gould, 1841)	1968[244]	1939[218]	1968[244]	1968[244]	E	AT	S	Hs	I
Balanus trigonus Darwin, 1854	-	-	1993[190]	-	E	CT	S	Hs	I
Heterosaccus dollfusi Boschma, 1960	-	-	-	1994[242]	E	RS	Su	Pz	I-II
Amphipoda									
Elasmopus pectenicrus (Bate, 1862)	-	-	-	2005[250]	C	CT	Su	Hs	I
Gammaropsis togoensis (Schellenberg, 1925)	-	-	-	2005[59]	E	Co	Su	Hs	I
Hamimaera hamigera (Haswell, 1879)	-	-	1976[186]	1976[186]	E	IP	Su	Hs	I
Monocorophium sextonae (Crawford, 1937)	-	2006[87]	-	-	C	PO	S	Hs/Ss	II
Parhyale explorator Arresti,1989	-	-	-	2005[58]	C	AT	S	Hs	I
Stenothoe gallensis Walker, 1904	-	-	1977[186]	1976[186]	E	IP	Su	Hs/Ss	I-II

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Isopoda									
Paradella dianae Menzies, 1962	-	-	2004[113]	-	E	Co	?S	Hs/Ss	I
Sphaeroma walkeri (Stebbing, 1905)	-	-	1995[182]	-	E	IP	Su	Hs	I
Cumacea									
Eocuma sarsii (Kossmann, 1880)	-	-	1976[174]	-	E	IP	Su	Hs/Ss	I,II
Decapoda									
Fenneropenaeus merguiensis (De Man, 1888)	-	-	-	2006[234]	C	IP/PG	Aq	Ss	II
Farfantepenaeus aztecus (Ives, 1891)	-	-	-	2009[125]	C	WA	S	Ss	II
Marsupenaeus japonicus (Bate, 1888)	-	2001[283]	2001[283]	1930[215]	E	IP	Su	Ss	I-III
Melicertus hathor (Burkenroad, 1959)	-	-	2005[230]	2002[194]	E	IP	Su	Ss	I-II
Metapenaeopsis aegyptia Galil & Golani, 1990	-	-	-	2003[276]	E	IP	Su	Ss	I
Metapenaeopsis mogiensis consobrina (Nobili, 1904)	-	-	-	2003[276]	E	IP	Su	Ss	I
Metapenaeus affinis (H. Milne Edwards, 1837)	-	-	2008[39]	-	E	IP	Su	Ss	I-II
Metapenaeus monoceros (Fabricius, 1798)	-	-	-	1959[168]	E	IP	Su	Ss	I-II
Metapenaeus stebbingi (Nobili, 1904)	-	-	-	1966[185]	E	RS/IO	Su	Ss	I-III
Penaeus semisulcatus de Haan, 1844	-	-	-	1930[161]	E	IP	Su	Ss	I-IV
Trachysalambria palaestinensis Steinitz, 1932	-	-	-	1968[153]	E	IO	Su	Ss	I-V
Leptochela pugnax de Man, 1916	-	-	2000[33]	1966[185]	E	IP	Su	Ss	I-IV
Palaemonella rotumana (Borradaile, 1898)	-	-	-	1999[35]	E	IP	Su	Hs	I-II
Urocaridella pulchella Yokes & Galil, 2006	-	-	-	2003[279]	E	IP	Su	?	II
Alpheus audouini Coutière, 1905	-	-	-	2002[149]	E	IP	Su	Hs	I-II
Alpheus inopinatus Holthuis & Gottlieb, 1958	-	-	-	1969[151]	E	IP	Su	Hs/Ss	I-II
Alpheus migrans Lewinsohn & Holthuis, 1978	-	-	-	1993[187]	E	RS	Su	Ss	I-III
Alpheus rapacida de Man, 1908	-	-	2005[230]	1981[185]	E	IP	Su	Ss	I-III

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Ogyrides mjoebergi (Balss, 1921)	-	-	-	2005[232]	E	IP	Su	Ss	I
Processa macrodactyla Holthuis, 1952	-	-	1995[34]	-	E	TA	G	Ss	II
Calappa hepatica (Linnaeus, 1758)	-	-	-	1992[60]	C	IP	Su	Ss	I-III
Ixa monodi Holthuis & Gottlieb, 1956	-	-	2005[86]	1955[169]	E	RS	Su	Ss	I-II
Coleusia signata (Paulson, 1875)	-	2006[32]	-	1976[159]	E	RS	Su	Hs/Ss	I-II
Eurycarcinus integrifrons De Man, 1879	-	-	-	2009[233]	C	IO	S	Ss	II
Myra subgranulata Kossmann, 1877	-	-	-	1930[215]	E	RS/IO	Su	Ss	I-IV
Micippa thalia (Herbst, 1803)	-	-	2006[281]	1994[129]	E	IP	Su	Ss	I-IV
Callinectes sapidus Rathbun, 1896	-	2001[283]	1967[184]	1959[168]	E	WA	S	Ss	I-II
Charybdis hellerii (H. Milne Edwards, 1867)	-	-	2005[230]	1987[128]	E	IP	Su	Hs/Ss	I-II
Charybdis longicollis Leene, 1938	-	-	2002[281]	1959[168]	E	IP	Su	Ss	I-IV
Portunus segnis (Forskål, 1775)	-	-	2004[281]	1928[160]	E	IP	Su	Ss	I-IV
Thalamita poissonii (Audouin, 1826)	-	-	1981[185]	1959[168]	E	IP	Su	Ss	I-II
Carupa tenuipes Dana, 1851	-	-	2003[281]	1996[276]	E	IP	Su	Hs	I-II
Pilumnopeus vauquelini (Audouin,1826)	-	-	-	1966[185]	E	RS/PG	Su	Hs	I
Pilimnus minutus De Haan,1835	-	-	2000[188]	2003[188]	C	IP	Su	Hs	I
Atergatis roseus (Rüppell, 1830)	-	-	2004[281]	1987[128]	E	IP	Su	Hs	I-II
Daira perlata (Herbst, 1790)	-	-	-	1988[129]	C	IP	Su	Hs/Ss	I-II
Eucrate crenata de Haan, 1835	-	-	-	1987[128]	E	IP	Su	Ss	I-IV
Percnon gibbesi (H. Milne Edwards, 1853)	-	-	-	2005[278]	E	AT/TA	S	Hs	I-II
Macrophtalmus graeffei Milne Edwards, 1873	-	-	2000[33]	1994[129]	E	IP	Su	Ss	I-IV
Stomatopoda									
Clorida albolitura Ahyong & Naiyanetr, 2000	-	-	-	2009[150]	E	IP	Su	Ss	II
Erugosquilla massavensis (Kossmann, 1880)	-	2002[175]	2007[231]	1959[168]	E	IP	Su	Ss	I-IV

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
MOLLUSCA									
Gastropoda									
Diodora ruppellii (Sowerby, G.B.I, 1834)	-	-	-	1988[130]	E	RS/IP	Su	Hs	I
Nerita sanguinolenta Menke, 1829	-	-	-	2004[142]	E	RS	Su	Ss	I
Smaragdia souverbiana (Montrouzier, 1863)	-	-	-	1989[83]	E	RS/IP	Su	Ss	I
Trochus erythreus Brocchi, 1821	-	-	-	1992[126]	E	RS	Su	Hs	I
Pseudominolia nedyma (Melville, 1897)	-	-	-	1992[126]	E	RS/IO	Su	Ss	I,II
Parviturbo dibellai Buzzurro & Greppi, 2006	-	-	-	2006[82]	Cr	?	?S	Ss	I
Stomatella impertusa (Burrow, 1815)	-	-	-	1999[249]	C	RS/IP	Su	Hs	I
Cerithium scabridum Philippi, 1848	-	-	1990[9]	1986[197]	E	RS/IO	Su	Hs/Ss	I
Cerithidium diplax (Watson, 1886)	-	-	-	1986[4]	E	PG	S	Ss	I-II
Cerithidium perparvulum (Watson, 1886)	-	-	-	1995[4]	E	PO	S	Ss	I
Rhinoclavis kochi (Philippi, 1848)	-	-	-	1986[197]	E	RS/IP	Su	Ss	I
Diala varia A. Adams, 1861	-	-	-	2002[121]	E	RS/IP	Su	Ss	I
Gibborissoa virgata (Philippi, 1849)	-	-	-	1997[3]	E	IP	Su	?	?
Alvania dorbignyi (Audouin, 1826)	-	-	-	1996[84]	Cr	Co	?	Ss	I,II
Finella pupoides A. Adams, 1860	-	-	2001[237]	1958[4]	E	IP	Su	Ss	I
Cerithiopsis pulvis (Issel, 1869)	-	-	2003[235]	1990[262]	E	RS	Su	Ss	I
Cerithiopsis tenthrenois (Melvill, 1896)	-	-	-	1990[262]	E	IO	Su	Ss	I
Metaxia bacillum (Issel, 1869)	-	-	-	1992[126]	E	RS	Su	?	?
Rissoina ambigua (Gould, 1849)	-	-	-	2003[213]	C	IP	?	Ss	II
Rissoina bertholleti Issel, 1869	-	-	-	1985[130]	E	RS/IO	Su	Ss	I
Conomurex persicus (Swainson, 1821)	-	-	1991[220]	1978[219]	E	PG	?S	Hs/Ss	I,II
Purpuradusta gracilis notata (Gill, 1858)	-	-	-	1982[78]	E	RS/IO	Su	Hs	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Cycloscala hyalina (Sowerby, 1844)	-	-	-	1995[154]	E	RS/IP	Su	Ss	I
Sticteulima cf. *lentiginosa* (A. Adams, 1861)	-	-	-	1989[261]	C	IP	?Su	?	?
Ergalatax junionae Houart, 2008	-	-	2002[172]	1992[126]	E	RS	S	Hs	I
Thais lacera (Born, 1778)	-	-	-	1991[220]	E	PG/IO	S	Hs/Ss	I
Rapana venosa (Valenciennes, 1846)	1960[146]	1993[26]	1995[126]	-	E	PO	S	Ss	I
Zafra savignyi (Moazzo, 1939)	-	-	-	1986[2]	E	RS	Su	Ss	I, II
Zafra selasphora (Melvill & Standen, 1901)	-	-	-	1993[243]	E	RS/IO	Su	Ss	I
Lienardia mighelsi Iredale & Tomlin, 1917	-	-	2003[213]	-	C	IP	?Su	?	III
Murchisonella columna (Hedley, 1907)	-	-	-	1993[79]	E	IP	?Su	Hs	I
Chrysallida fischeri (Hornung & Mermod, 1925)	-	-	-	1989[212]	E	RS	?Su	Ss	I
Chrysallida maiae (Hornung & Mermod, 1924)	-	-	-	1963[1]	E	RS	Su	Hs/Ss	I
Chrysallida micronana (Öztürk & Aartsen, 2006)	-	-	2000[236]	1997[236]	C	RS	?S	Ss	I,II
Chrysallida pirinthella (Melvill, 1910)	-	-	-	1989[212]	E	RS	Su	Ss	I,II
Amathina tricarinata (Linnaeus, 1767)	-	-	-	2000[99]	E	RS	Su	Hs	I
Leucotina cf. *eva* Thiele, 1935	-	-	2000[239]	1995[154]	C	IP	?Su	Ss	I,II
Leucotina natalensis Smith, 1910	-	-	-	1986[8]	E	RS/IP	?Su	Ss	I
Monotigma fulva (A. Adams, 1853)	-	-	2008[5]	-	C	IP	Su	Ss	II
Monotigma lauta (A. Adams, 1853)	-	-	-	1989[212]	E	RS/IP	Su	Ss	I,II
Cingulina isseli (Tryon, 1886)	-	-	-	1986[11]	E	RS	Su	Ss	I
Turbonilla edgarii (Melvill, 1896)	-	-	-	1989[212]	E	IP	Su	Ss	?
Syrnola cinctella A. Adams,1860	-	-	-	1994[10]	C	RS/IP	Su	Ss	I
Syrnola fasciata Jickeli, 1882	-	-	2001[237]	1963[11]	E	IP	Su	Ss	I
Syrnola lendix (A. Adams, 1853)	-	-	-	1988[212]	E	PG	?Su	Ss	I
Odostomia lorioli (Hornung & Mermod, 1924)	-	-	-	2007[121]	C	RS	?Su	Ss	I,II

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Iolaea neofelixoides (Nomura, 1936)	-	-	-	1994[10]	C	PO	?S	Ss	I
Hinemoa cylindrica (de Folin, 1879)	-	-	-	1992[85]	C	IP	?S	?	?
Acteocina crithodes Melvill & Standen, 1907	-	-	-	2003[213]	C	IP	?S	Ss	II
Acteocina mucronata (Philippi, 1849)	-	-	-	1986[12]	E	RS	Su	Ss	?
Cylichnina girardi (Audouin, 1826)	-	-	1996[84]	1990[12]	E	IP	Su	Ss	II
Pyrunculus fourierii (Audouin, 1826)	-	-	-	1989[11]	E	RS/IP	Su	Ss	II,III
Bulla arabica Malaquias & Reid, 2008	-	-	-	2001[280]	E	IP	?Su	Ss	II
Haminoea cyanomarginata Heller & Thomson, 1983	-	-	2002[280]	2002[280]	E	RS	Su	Hs	II
Atys angustatus Smith, 1872	-	-	-	1986[7]	Cr	RS	Su	Ss	I
Chelidonura fulvipunctata Baba, 1938	-	-	-	1959[253]	E	IP	?Su	Ss	I,II
Oxynoe viridis (Pease, 1861)	-	-	-	2002[280]	E	IP	?Su	Ss	I
Elysia grandifolia Kelaart, 1858	-	-	-	2001[280]	E	IO	?Su	Hs	I
Elysia tomentosa Jensen, 1997	-	-	-	2001[280]	E	?IP	?Su	Hs	I,II
Aplysia dactylomela Rang, 1828	-	-	-	2005[110]	E	CT	?Su	Hs	I
Aplysia parvula Guilding in Mörch, 1863	-	1961[253]	2004[267]	1961[253]	Cr	CT	?	Hs	I
Bursatella leachii Blainville, 1817	-	-	1959[253]	1959[253]	E	CT	?Su	Hs	I
Syphonota geographica (Adams & Reeve, 1850)	-	-	-	1999[81]	E	IP	Su	Ss	I,II
Plocamopherus ocellatus Rüppell & Leuckart, 1830	-	-	-	1998[280]	E	RS	Su	Hs	I
Hypselodoris infucata Rueppel & Leuckart, 1828	-	-	-	1999[93]	E	RS/IP	Su	Hs	I
Chromodoris annulata Eliot, 1904	-	-	-	2008[156]	E	RS/IP	Su	Hs	I
Chromodoris quadricolor (Rüppell & Leuckart 1830)	-	-	-	2004[237]	C	RS/IO	?Su	Hs	II
Melibe viridis (Kelaart, 1858)	-	-	-	2000[280]	E	IP	?Su	Hs	I
Flabellina rubrolineata (O'Donoghue, 1929)	-	-	2003[280]	2001[280]	E	RS/IP	Su	Hs	I,II

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Siphonaria crenata de Blainville 1827	-	-	-	1999[28]	E	RS/PG	Su	Hs	I
Bivalvia									
Anadara transversa (Say, 1822)	-	-	1977[124]	-	E	WA	S	Ss	I,II
Anadara inflata (Reeve, 1844)	-	-	-	1998[98]	C	IO	S	Ss	?
Anadara kagoshimensis (Tokunaga, 1906)	2003[23]	1993[25]	1995[126]	-	E	IP	S	Ss	I,II
Anadara natalensis (Krauss, 1848)	-	-	-	1985[220]	E	RS/IO	Su	Ss	I,II
Brachidontes pharaonis (Fischer, P., 1870)	-	-	1990[9]	1978[181]	E	RS/IO	Su	Hs	I
Septifer bilocularis (Linnaeus, 1758)	-	-	-	2006[27]	C	RS	S	Hs	II
Septifer forskali Dunker, 1855	-	-	-	2001[28]	E	RS	S	Hs	I
Crassostrea gigas (Thunberg, 1793)	-	2004[30]	-	1998[94]	E	PO	Aq	Hs	I
Saccostrea cucullata (Born, 1778)	-	-	-	1998[94]	E	RS/IP	S	Hs	I,II
Dendrostrea frons (Linnaeus, 1758)	-	-	-	1998[97]	E	IP	?S	Hs	I
Pinctada radiata (Leach, 1814)	-	-	1990[262]	1982[181]	E	RS/IP	Su	Hs	I
Electroma vexillum (Reeve, 1857)	-	-	-	2002[95]	E	RS/IP	Su	Hs	I
Malvufundus regulus (Forsskål, 1775)	-	-	-	1973[143]	E	RS/IP	Su	Hs	I
Spondylus cf. *multisetosus* Reeve, 1856	-	-	-	1992[97]	Q	IP	?Su	Hs	I,II
Spondylus spinosus Schreibers, 1793	-	-	-	1991[97]	E	RS/IP	Su	Hs	I,II
Cardites akabana (Sturany, 1899)	-	-	-	2005[99]	C	RS	Su	Ss	I
Chama aspersa Reeve, 1846	-	1990[Ps]	2006[214]	1993[122]	E	RS/IP	?S	Hs	I
Chama pacifica Broderip, 1834	-	-	-	2000[97]	E	RS/IP	Su	Hs	I,II
Fulvia fragilis (Forrskål, 1775)	-	-	2001[238]	1986[197]	E	RS/IO	Su	Ss	I
Afrocardium richardi (Audouin, 1826)	-	-	-	2000[6]	E	RS	Su	Ss	?
Tellina valtonis Hanley, 1844	-	-	-	1995[154]	C	RS/IO	Su	Ss	I
Teredo navalis Linnaeus, 1758	2007[254]	1966[221]	2007[254]	2007[254]	Cr	CT	S	Hs	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Psammotreta praerupta (Salisbury, 1934)	-	-	-	1992[127]	C	WA	S	Ss	IV
Gafrarium pectinatum (Linnaeus, 1758)	-	-	-	1986[197]	E	RS/IP	Su	Ss	I
Petricola hemprichi Issel, 1869	-	-	-	1999[99]	Q	RS	Su	Hs	I
Clementia papyracea (Gmelin, 1791)	-	-	-	1985[130]	E	RS/IP	Su	Ss	III
Paphia textile (Gmelin, 1791)	-	-	-	1985[130]	E	RS/IP	Su	Ss	I,II
Ruditapes philippinarum (Adams & Reeve, 1850)	-	2004[24]	2000[29]	-	E	PO	Aq	Ss	I
Antigona lamellaris Schumacher, 1817	-	-	-	1988[127]	C	RS/IP	Su	Ss	I
Mya arenaria Linnaeus, 1758	-	1993[25]	2008[Ps]	-	E	WA	S	Ss	II
Sphenia rueppelli A. Adams, 1850	-	-	-	1998[284]	E	IO	?Su	Hs	I
Gastrochaena cymbium Spengler, 1783	-	-	-	1990[220]	E	RS/IP	Su	Ss	I-III
Laternula anatina (Linnaeus, 1758)	-	-	-	1992[126]	E	RS/IP	Su	Ss	I-III
Cephalopoda									
Octopus aegina Gray, 1849	-	-	-	1992[248]	E	IP	Su	Ss	III
Sepioteuthis lessoniana Lesson, 1830	-	-	-	2002[247]	E	IP	Su	P	I-III
BRYOZOA									
Celleporaria brunnea (Hincks, 1884)	-	-	2004[189]	-	E	AT	S	Ss	I
Rhynchozoon larreyi (Audouin, 1826)	-	-	1962[271]	-	E	RS/IP	Su	Ss	I
ECHINODERMATA									
Amphiodia (Amphispina) obtecta Mortensen, 1940	-	-	-	2005[252]	E	IP	S	Ss	I-III
Asterias rubens Linnaeus, 1758	2003[173]	1990[22]	-	-	E	AT	S	Hs	I,II
Diadema setosum (Leske, 1778)	-	-	-	2006[277]	C	RS/IP	Su	Hs	I
Ophiactis macrolepidota Marktanner-Turneretscher, 1887	-	-	-	2005[252]	C	AT/PO	Su	Ss	I
Ophiactis savignyi (Müller & Troschel, 1842)	-	-	1993[103]	2005[252]	E	RS/IP	Su	Hs	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Synaptula reciprocans (Forrskål, 1775)	-	-	2001[283]	2005[110]	E	RS/IP	Su	Hs	I,II
CHAETOGNATHA									
Ferosagitta galerita (Dallot, 1971)	-	-	-	2003[258]	E	IO	S	P	I,II
TUNICATA									
Phallusia nigra Savigny, 1816	-	-	-	2005[110]	E	WA	?S	Hs	I,II
Pyura (=Herdmania) momus (Savigny, 1816)	-	-	-	2001[110]	E	RS	Su	Hs	I,II
Symplegma brakenhielmi (Michaelsen, 1904)	-	-	-	2005[110]	E	RS/IO	Su	Hs	I,II
PISCES									
Elasmobranchii									
Carcharhinus altimus (Springer, 1950)	-	-	-	1994[56]	C	TA	G	Ss	I-VI
Himantura uarnak (Forsskål, 1775)	-	-	-	1966[65]	E	RS/IP	Su	Ss	I,II
Actinopterygii									
Chirocentrus dorab (Forsskål, 1775)	-	-	-	1999[17]	Q	RS/IP	Su	P	I-III
Dussumieria elopsoides Bleeker, 1849	-	-	-	1952[64]	E	RS/IP	Su	P	I,II
Etrumeus teres (DeKay, 1848)	-	-	2002[225]	1994[57]	E	RS/IP	Su	P	I,II
Herklotsichthys punctatus (Rüppell, 1837)	-	-	-	1984[274]	E	RS	Su	P	I,II
Enchelycore anatina (Lowe, 1839)	-	-	2002[225]	1998[31]	E	TA	G	Hs	I,II
Pisodonophis semicinctus (Richardson, 1848)	-	-	-	2009[74]	C	TA	G	Ss	I
Bregmaceros atlanticus Goode & Bean, 1886	-	-	2005[144]	2002[275]	E	CT	Su/S	Ss	I, II
Saurida undosquamis (Richardson, 1848)	-	-	1973[66]	1951[192]	E	RS/IP	Su	Ss	I-III
Parexocoetus mento (Valenciennes, 1846)	-	-	1966[65]	1966[65]	E	RS/IP	Su	P	I
Hemiramphus far (Forsskål, 1775)	-	-	1942[260]	1942[191]	E	RS/IP	Su	P	I
Fistularia commersonii (Rüppell, 1835)	-	-	2002[77]	2001[75]	E	IP/IO	Su	Hs/Ss	I,II
Hippocampus fuscus Rüppell 1838	-	-	-	2003[158]	E	RS/IO	Su	Ss	I

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Syngnathus rostellatus Nilsson, 1855	-	-	-	2003[158]	Q	BA	G	Hs/Ss	I
Atherinomorus forskalii (Rüppell, 1838)	-	-	1966[152]	1949[191]	E	RS/IP	Su	P	I
Sargocentron rubrum (Forsskål, 1775)	-	-	1949[191]	1949[191]	E	RS/IP	Su	Hs	I-III
Pelates quadrilineatus (Bloch, 1790)	-	-	-	1984[199]	E	RS/IP	Su	Ss	I,II
Pomadasys stridens (Forsskål, 1775)	-	-	-	2009[74]	C	RS/IO	Su	Ss	I
Apogon pharaonis Bellotti, 1874	-	-	2002[225]	1984[199]	E	RS/IP	Su	Hs/Ss	I,II
Apogon fasciatus (White, 1790)	-	-	-	2009[265]	E	RS/IP	Su	Ss	I-II
Apogon queketti Gilchrist, 1903	-	-	2009[145]	2004[139]	E	RS/IO	Su	Ss	I-III
Apogon smithi (Kotthaus, 1970)	-	-	-	2008[155]	E	RS/IP	Su	Ss	I,II
Sillago sihama (Forsskål, 1775)	-	-	2004[69]	1983[162]	E	RS/IP	Su	Ss	I,II
Monotaxis grandoculis (Forsskål, 1775)	-	-	-	2007[70]	C	RS/IP	Su	Ss	I,II
Alepes djedaba (Forsskål, 1775)	-	-	1966[152]	1955[21]	E	RS/IP	Su	P	I-III
Nemipterus randalli Russell, 1986	-	-	-	2007[72]	E	RS/IO	Su	Ss	I-II
Equulites klunzingeri (Steindachner, 1898)	-	-	1966[65]	1942[131]	E	RS	Su	Ss	I-III
Decapterus russelli (Rüppell, 1830	-	-	-	2009[19]	E	RS/IP	Su	P	I-II
Trachurus indicus Nekrasov, 1966	-	-	-	2004[120]	C	IO	Su	P	I-III
Parupeneus forskalli (Fourmanoir & Guézé, 1976)	-	-	-	2000[110]	C	RS/IP	Su	Ss	I
Upeneus moluccensis (Bleeker, 1855)	-	-	1956[193]	1942[191]	E	IP	Su	Ss	I-IV
Upeneus pori Ben-Tuvia & Golani, 1989	-	-	2000[222]	1942[191]	E	RS/IP	Su	Ss	I,II
Pempheris vanicolensis Cuvier, 1831	-	-	1994[198]	1983[162]	E	RS/IP	Su	Hs	I,II
Heniochus intermedius Steindachner, 1893	-	-	-	2002[157]	C	RS/IP	Su	Hs/Ss	I
Liza carinata (Valenciennes, 1836)	-	-	-	1955[193]	E	RS/IO	Su	P	I
Liza haematocheila (Temminck & Schlegel, 1845)	1992[272]	1995[177]	1995[177]	-	E	PO	Aq	P	I
Sphyraena chrysotaenia Klunzinger, 1884	-	-	1966[152]	1955[21]	E	RS/IP	Su	P	I,II

(Continued)

Table 1 (Continued)

	BS	SM	AS	LS	ES	O	MI	H	D
Sphyraena flavicauda Rüppell, 1838	-	-	-	2001[75]	E	RS/IP	Su	P	I,II
Platax teira (Forsskål, 1775)	-	-	-	2006[71]	C	RS/IP	Su	Hs	I
Pteragogus pelycus Randall, 1981	-	-	2002[77]	1998[255]	E	RS/IP	Su	Hs/Ss	I,II
Champsodon nudivittis (Ogilby, 1895)	-	-	-	2008[114]	C	IP/IO	Su/S	Ss	I,II
Petroscirtes ancylodon Rüppell, 1838	-	-	2005[226]	1997[255]	E	RS/IP	Su	Hs/Ss	I
Callionymus filamentosus Valenciennes, 1837	-	-	-	1983[162]	E	RS/IP	Su	Ss	I-III
Oxyurichthys petersi (Klunzinger, 1871)	-	-	1991[63]	1991[176]	E	RS	Su	Ss	I-III
Trypauchen vagina (Bloch & Schneider, 1801)	-	-	-	2010[18]	C	IP/IO	Su	Ss	II
Vanderhorstia mertensi Klausewitz, 1974	-	-	2010[Ps]	2008[76]	E	RS/IP	Su	Ss	I-III
Siganus luridus (Rüppell, 1829)	-	-	1973[66]	1973[147]	E	RS/IP	Su	Hs	I,II
Siganus rivulatus Forsskål, 1775	-	-	1943[260]	1942[191]	E	RS/IP	Su	Hs	I,II
Scomberomorus commerson Lacepède, 1800	-	-	1994[80]	1981[162]	E	RS/IP	Su	P	I,II
Cynoglossus sinusarabici (Chabanaud, 1913)	-	-	-	1955[21]	E	RS	Su	Hs	I,II
Stephanolepis diaspros Fraser-Brunner, 1940	-	-	1943[260]	1949[191]	E	RS/IP	Su	Hs/Ss	I,II
Lagocephalus sceleratus (Gmelin, 1789)	-	-	2003[20]	2004[73]	E	RS/IP	Su	Ss	I,II
Lagocephalus spadiceus (Richardson, 1844)	-	2007[263]	1966[65]	1949[191]	E	RS/IP	Su	Ss	I,II
Lagocephalus suezensis Clark & Gohar, 1953	-	-	2001[75]	1998[37]	E	RS	Su	Ss	I,II
Sphoeroides pachygaster (Müller & Troschel, 1848)	-	-	1999[140]	1999[198]	E	TA	G	Hs/Ss	I-V
Torquigener flavimaculosus Hardy & Randall, 1983	-	-	-	2002[68]	E	RS/IP	Su	Ss	I,II
Tylerius spinosissimus (Regan, 1908)	-	-	-	2010[264]	C	IP	Su	Ss	II,III

However, GÓMEZ (2006; 2008, pers comm.) did not accept the alien status of these species in the Mediterranean Sea. He postulated that these species had been known for many years under different names or were very rare in the region. Therefore, we did not put these species in Table 1.

The algae species, *Polysiphonia kampsaxii, Acanthophora muscoides* and *Sargassum latifolium,* which were excluded from the alien list of the Mediterranean by ZENETOS *et al.* (2010b), are given here as questionable. General morphological features of these species match with their original and subsequent descriptions, but more material is needed to clarify their real taxonomic positions. ZENETOS *et al.* (2010b) cited the report of *Caulerpa taxifolia* from Iskenderun Bay by ÇEVIK *et al.* (2007) as *Caulerpa distichophylla* Sonder. However, we prefer to keep the previous name until new evidence for its taxomic position has been presented.

In the review by ZENETOS *et al.* (2010b), some foraminiferan species were cited as casual but we have changed their established success to established here, based on personal observations and communications. For example, MERIÇ *et al.* (2010a) reported a single specimen of *Euthymonacha polita* collected near a submarine spring in Kusadası, Turkey. However, this species was later observed in different locations in the Aegean Sea (Ilıca, NW Karaburun Peninsula and Kusadasi), again around submarine springs (E. MERIÇ, pers. comm.), indicating that it has become established in the area. Again, only two specimens of *Cushmanina striatopunctata* were reported from the Dardanelles (MERIÇ *et al.,* 2009) and the Aegean Sea (MERIÇ *et al.,* 2008b). However, another specimen was also collected in the North Aegean Sea (Ayvalık, YOKES, unpublished data), suggesting that it may be a rare species with a wide range of distribution along the Turkish coastline.

Five unidentified alien foraminiferan species, namely *Entosigmomorphina* sp., *Euuvigerina* sp., *Haddonia* sp, *Quinqueloculina* sp.C and *Triloculina* sp.A, were reported along the Turkish coasts (MERIÇ *et al.,* 2008a; 2010a; 2010b). These species are not included in Table 1. *Haddonia* sp., *Quinqueloculina* sp.C and *Triloculina* sp.A were also reported from the Gulf of Aqaba (HOTTINGER *et al.,* 1993). *Haddonia* sp. was abundantly observed on the Turkish Mediterranean coast (MERIÇ *et al.,* 2008a), and the latter two on the Aegean coast (MERIÇ *et al.,* 2010a; 2010b). *Entosigmomorphina* sp. seems to have originated from the Pacific and was rarely observed on the SW coast of Turkey (MERIÇ *et al.,* 2008a). *Euuvigerina* sp. seems to be a cryptogenic species, which was only reported from the North Aegean Sea. The species *Acervulina inhaerens, Iridia diaphana, Cymbaloporetta squammosa, Pyramidulina perversa* and *Triloculina affinis* were given as alien by ZENETOS *et al.* (2008). These species have seldom been recorded or poorly preserved in the sediment or known as fossils in the Mediterranean area, thus they were excluded from the alien list of the Mediterranean Sea by ZENETOS *et al.* (2010b).

A debate is still continuing on the validity of two foraminiferan species, *Coscinospira hemprichii* and *Peneroplis arietina.* HOTTINGER *et al.* (1993) considered *Peneroplis arietina* as a junior synonym of *Coscinospira hemprichii.* Their explanation was based on the aberrant morphologies observed in the populations of peneroplids found in extreme environments with high salinity. They have compared specimens from the Gulf of Aqaba with those from the Persian Gulf and decided to include peneropliform and spiroliniform specimens with similar ornamentation and proportions of the early growth stages within the same species. However, they mentioned that the generic separation of *Coscinospira* and *Peneroplis* could be justified only in the framework of a revision of the history of peneroplids during Tertiary times. *Coscinospira hemprichii* is also distributed in the Atlantic and Mediterranean areas. However, in the eastern Mediterranean, the two distinct morphologies were found together in high abundances. The test morphologies were very prominent in terms of many characteristics. Hybrid morphologies have not been observed. Besides, the specimens which fit the description of *Peneroplis arietina* well were observed in the Levantine Basin, but not in the western Mediterranean. Thus, the two distinct morphologies cannot be related to environmental factors, but this suggests the presence of two distinct species in the eastern Mediterranean. In accordance with GROSS (2010), *Coscinospira arietina* is used as the valid name in the present study. It is also suggested that the native *Coscinospira hemprichii* is a distinct species.

Distribution of alien species in the seas.

The highest number of alien species (330 species) was encountered on the Levantine coast of Turkey, followed by the Aegean Sea (165 species), the Sea of Marmara (69 species) and the Black Sea (20 species) (Fig. 1). A total of 124 new alien species were reported on the coasts of Turkey within five years (2005-2010) (increment: ca. 44%). Increase in the number of species varies among the seas. For example, the number of alien species was stable in the Black Sea, increased from 48 to 69 in the Sea of Marmara (increment: ca. 44%), from 98 to 165 in the Aegean Sea (increment: ca. 69%) and from 216 to 330 in the Levantine Sea (increment: ca. 52%). The reasons for the high increase in the number of alien species within five years are mainly based on the increase in scientific efforts to determine the presence of alien species on the coasts and the reports of some species here that were not previously considered as aliens in the 2005 paper.

The increase in the number of alien species after the previous list also varies among groups. For example, the number of alien species rise from 26 to 75 in Polychaeta (increment: 189%), from 5 to 37 in Foraminifera (increment: 660%), from 51 to 64 in Crustacea (increment: 25%), from 90 to 105 in Mollusca (increment: 17%) and from 45 to 58 in Fishes (increment: 29%).

Phytobenthos (algae and phanerogame) rank first in terms of the number of alien species in the Black Sea (11 species, 55% of total number of alien species reported in the area) and the Sea of Marmara (22 species, 32%), whereas the group Pisces (31 species, 19%) and Mollusca (98 species, 30%) have the highest number of species in the Aegean and Levantine Seas, respectively (Fig. 1).

Probable vectors of Introduction

The main vector for the species introductions to the Turkish coasts is the Suez Canal, followed by shipping and Gibraltar (Fig. 2). Almost 66% of the total number of alien species used the Suez Canal as a gateway for entering the area. However, the importance of this vector is more distinct in the Levantine Sea, where the introduction of the majority of species (74% of total species) has been attributed to the Suez Canal. The importance of the Suez Canal as a vector of species introductions gradually diminishes from the Levantine Sea to the Black Sea. A total of 4 species (*Fenneropenaeus merguiensis, Crassostrea gigas, Ruditapes philippinarum* and *Liza haematocheila*) were introduced to the Mediterranean and Black Seas for aquaculture pur-

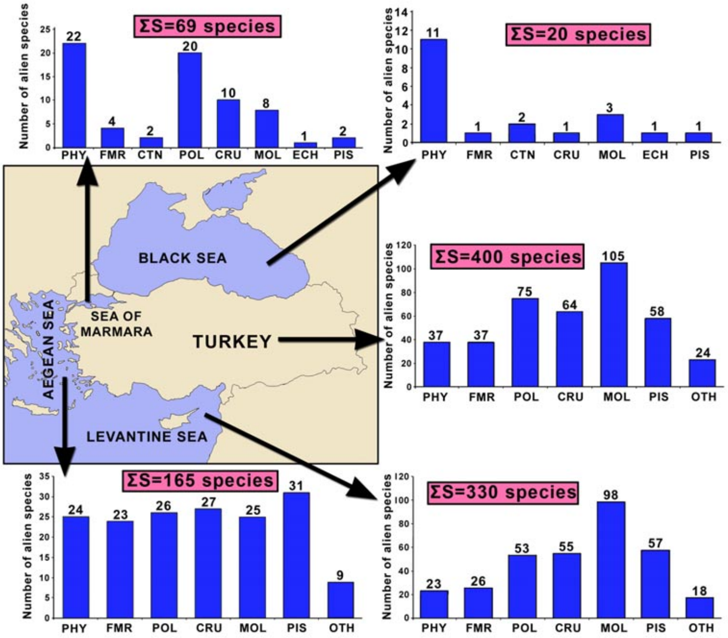

Fig. 1: The number of alien species along the coasts of Turkey. PHY: Phytobenthos, FMR: Foraminifera, CTN: Ctenophora, POL: Polychaeta, CRU: Crustacea, MOL: Mollusca, BRY: Bryozoa, ECH: Echinodermata, PIS: Pisces, OTH: Others. ΣS indicates the total number of species.

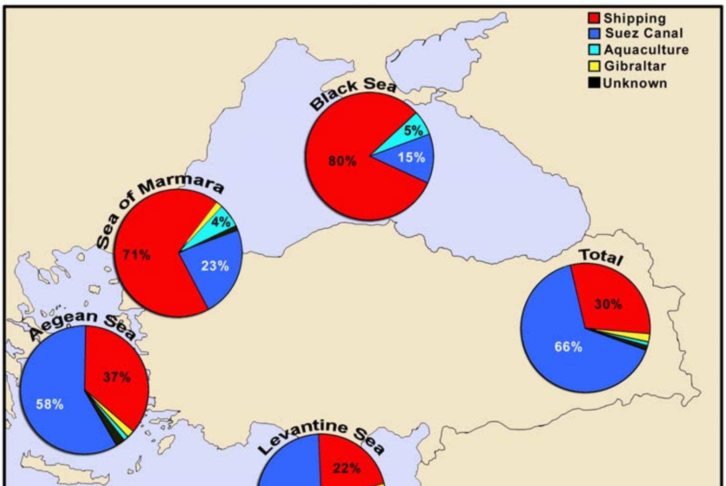

Fig. 2: The modes of introduction for alien species on the coasts of Turkey.

poses. The most successful species among them is *L. haematochelia,* which was first released into the Azov Sea from the Molochny Lagoon in 1985 and then largely expanded its distribution range to the Aegean Sea (Homa Lagoon) within 10 years (KAYA *et al.,* 1992). Ballast water and hull fouling are known to be main vectors for species translocations (CARLTON, 1985; GODWIN *et al.,* 2004). The number of introduced species has greatly increased worldwide since transoceanic shipping times became shorter than the larval life of most marine invertebrates (JENSEN & KNUDSEN, 2005). Huge volumes of ballast water (ca. 12 billion t annually) are discharged into or near ports (NETWIG, 2007), leading to establishment of some alien species that have remained alive in ballast tanks during voyage. GOLLASCH (2007) postulated that almost 33% and 27% of total marine alien species worldwide have been introduced from one area to another by hull fouling and ballast water, respectively. Almost 122 alien species have been introduced to the coasts of Turkey via shipping. This type of vector is more apparent in the Sea of Marmara and the Black Sea. Ship-mediated alien species account for 71% and 80% of total alien species in the Sea of Marmara and the Black Sea, respectively. Some sessile species such as *Hydroides* spp., *Ficopomatus enigmaticus* and barnacles, which play important roles in biofouling, could have been transferred to the area by hull fouling. The invasive spionid polychaetes such as *Polydora cornuta, Streblospio gynobranchiata* and *Pseudopolydora paucibranchiata* were reported to have been introduced to Izmir Bay via ballast water from ships (ÇINAR *et al.,* 2005b).

The importance of type of vector for species introductions in each systematic group is depicted in Figure 3. Shipping is responsible for more than 50% of the species introductions in 6 systematic groups, whereas the Suez Canal is the main vector for species introductions in Foraminifera (71% of total foraminifer species), Crustacea (78%), Mollusca (74%), Echinodermata (67%), Tunicata (67%) and Pisces (86%). Two alien bryozoan species, *Celleporaria brunnea* and *Rhynchozoon larreyi* seem to

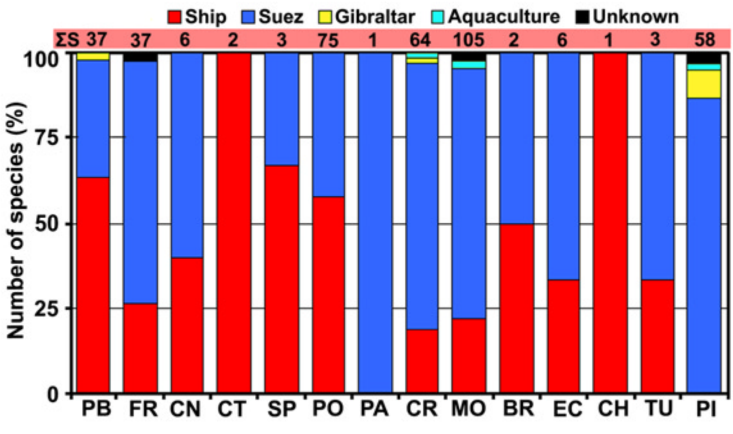

Fig. 3: The modes of introduction for alien species in each systematic group. PB: Phytobenthos, FR: Foraminifera, CN: Cnidaria, CT: Ctenophora, SP: Sipuncula, PO: Polychaeta, PA: Pantopoda, CR: Crustacea, MO: Mollusca, BR: Bryozoa, EC: Echinodermata: CH: Chaetognatha, TU: Tunicata, PI: Pisces.

have been introduced to the coasts of Turkey via ships and the Suez Canal, respectively (KOÇAK, 2007; ÜNSAL & d'HONDT, 1979). All ctenophore and chaetognath species were transferred to the area via ships. No fish species was recorded as having been introduced into Turkish waters via ships. However, only a single tropical Atlantic originated species, *Pinguipes brasilianus,* was mentioned in the CIESM atlas as having probably been introduced by ballast waters (GOLANI *et al.,* 2002). Other alien fish suspected to have arrived via shipping activities include *Omobranchus punctatus, Bregmaceros atlanticus, Champsodon nudivittis, Tridentiger trigonocephalus* and *Opleognathus fasciatus* (GOLANI, 2004; ÇIÇEK & BILECENOGLU, 2009; GOREN *et al.,* 2009; SCHEMBRI *et al.,* 2010), since they are encountered far distant from their source populations and have never been found in the Red Sea. However, a possible penetration of these species from the Suez Canal cannot be neglected by the authors, i.e. cases of *B. atlanticus* (GOREN & GALIL, 2006) and *C. nudivittis* (ÇIÇEK & BILECENOGLU, 2009) are good examples on the matter. Suspicion about the vector of origin of a definite species may only change with further studies and additional records from other localities. For example *Platax teira,* which was previously assumed to be an aquarium escape without excluding the possibility of Lessepsian migration by BILECENOGLU & KAYA (2006), has recently been found off Israeli shores, indicating the Suez Canal as a mode of entry (GOLANI *et al.,* 2011). Similarly, the recent occurrence of the spiny blaasop, *Tylerius spinosissimus,* at Iskenderun Bay could not be clearly linked to any vectors by TURAN & YAGLIOGLU (2011). However, after it was found off Israeli coasts, GOLANI *et al.* (2011) stated that we should consider the species as a Lessepsian migrant, without neglecting the possible distribution of the species in Red Sea.

Establishment Success

Of the 400 alien species reported from the coasts of Turkey, 305 species (76% of total number of species) can be classified as established, 59 species as casual (15%), 23 species as questionable (6%) and 13 species as cryptogenic (3%) (Fig. 4). As only eggs and yolk-sac larvae of *Chirocentrus dorab* were reported from the Levantine coast of Turkey (AK-ÖREK & UYSAL, 2008), its establishment success was considered as questionable. The status of casual species could be turned into established ones if further evidence of their presence in other areas is provided. Of three groups (Thallophyta, Polychaeta and Mollusca) that have cryptogenic species, Thallophyta possess the highest number of species (6 species), followed by Mollusca (5 species) and Polychaeta (2 species). The percentages of established species in total number of alien species reported from the Turkish coasts vary from 63% (Sea of Marmara) to 83% (Aegean Sea). The highest percentage of cryptogenic species (25%) was encountered in the Black Sea. The Sea of Marmara was characterized by the highest percentage of questionable species (12 species, 17% of total number of species), the majority of which (9 species) belong to Polychaeta. These species were given by RULLIER (1963), but their presences in the area are still in debate, due to poor descriptions (no figures) of the species. All alien species belonging to the groups Ctenophora, Sipuncula, Pantapoda, Bryozoa, Chaetognatha and Tunicata seem to have become established on the coasts of Turkey (Fig. 5). Mollusca (79 species) and Polychaeta (56 species) have the highest number of established

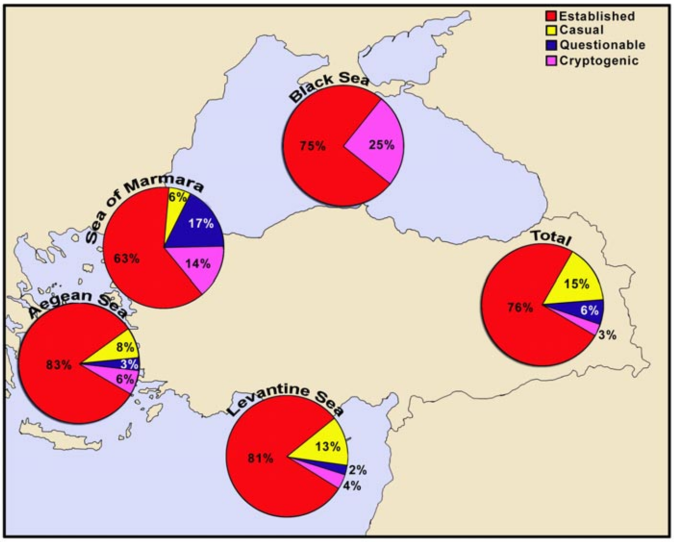

Fig. 4: The establishment successes of alien species reported on the coasts of Turkey.

species. The high number of casual species was reported within the groups Mollusca (19 species) and Pisces (11 species). Polychaeta (12 species) and Phytobenthos (5 species) have high numbers of questionable species.

Rate of Invasion

The new additions to the number of alien species on the coasts of Turkey greatly increased after 1990. A total of 154 alien species were known from the area before 1990 and 247 alien species were added to the list after 1990 (increment: 160%) (Fig. 6). A decreasing pattern is apparent in the yearly rate of introduction over the past years (Table 2). While one new alien species was introduced every 22 weeks from 1951 to 1970 on the coast of Turkey, the time span decreased to 4 weeks between 1991 and 2010. Increase in the invasion rate is most probably due to the acceleration in species introduction to the region, the range extensions of some species that were previously reported from the south-west of the Levantine Sea and the increase in the number of papers regarding alien species. The correlation analysis showed that a significant relationship ($R^2=0.98$, $p<0.05$) exists between the number of new records of alien species and the number of papers on them over the years. In the last 5 years (2005-2010), a total of 100 papers regarding alien species on the Turkish coasts have been published, reporting a total of 124 new alien species belonging to different groups, mostly Foraminifera and Polychaeta.

Depth and habitat preferences of alien species

The distributions of the total number of alien species by depth and habitat are depicted in Figure 7. The majority of aliens reported from the Turkish coasts were found on soft substrata (198 species) in shallow waters (319 species). A total of 34 species, mostly fishes, live in pelagic environment (Fig. 8). Some species such as *Dorvillea similis, Stenothoe gallensis, Charybdis hellerii,*

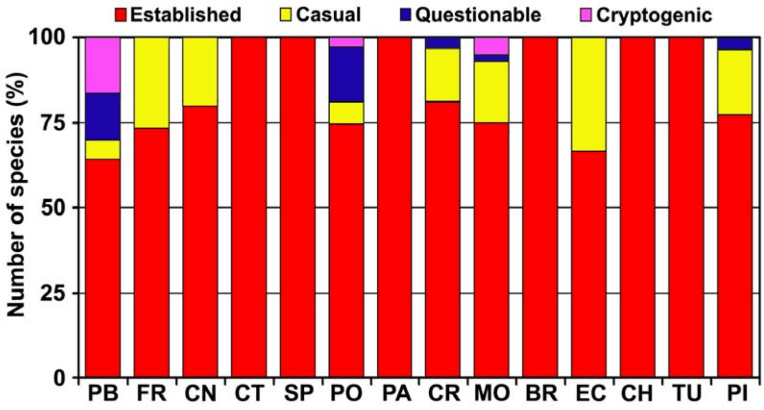

Fig. 5: The establishment successes of alien species in each systematic group. For abbreviations, see Figure 3.

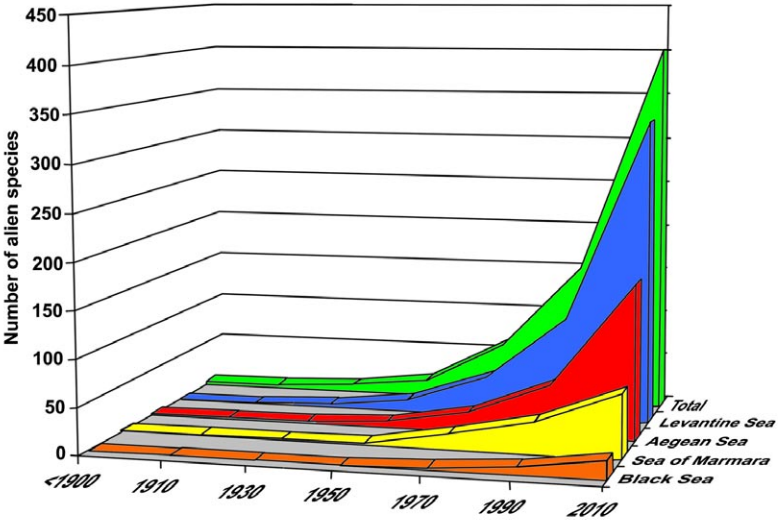

Fig. 6: Rate of introduction of alien species along the coasts of Turkey.

Thais lacera and *Chrysallida maiae* were reported both from the hard and soft substrata. The habitat types of many alien foraminifer species are unknown as species descriptions were based on their dead tests (i.e. MERIÇ *et al.,* 2004a; 2010a) that had accumulated in the benthic area. Only *Heterosaccus dollfusi,* which was found on the Lessepsian crab *Charybdis longicollis* (ØKSNEBJERG *et al.,* 1997), was reported as a parasite. All alien species of Pantopoda, Bryozoa and Tunicata, and more than 50% of a number of species of Phytobenthos and Echinodermata were report-

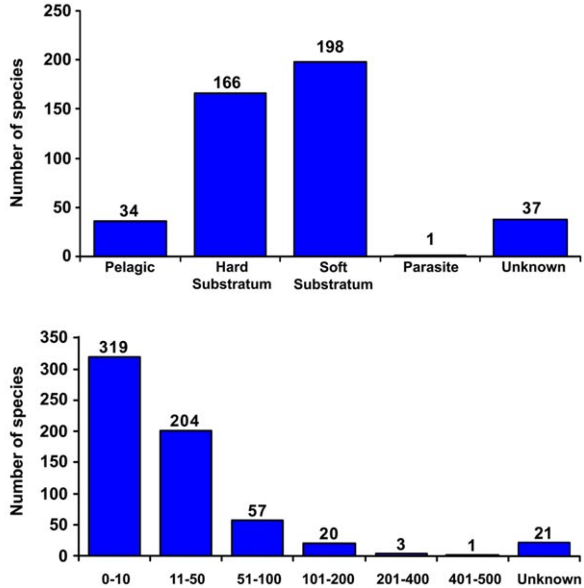

Fig. 7: The habitat (upper graphic) and depth (lower graphic) preferences of alien species along the coasts of Turkey.

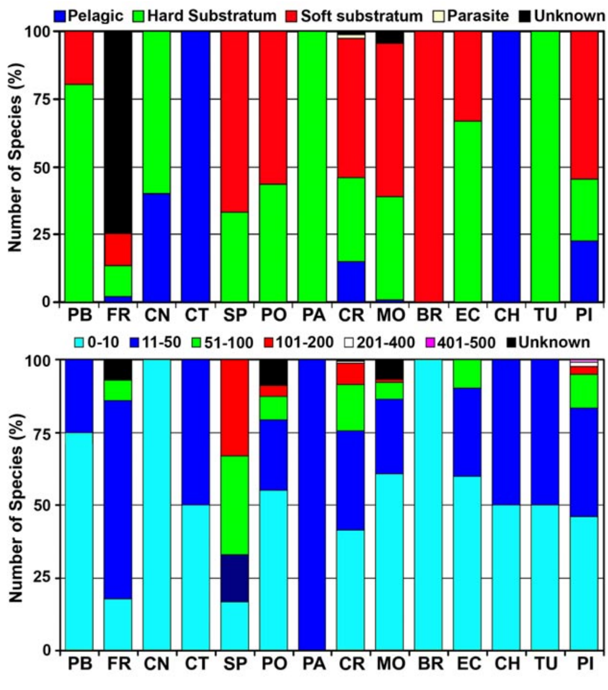

Fig. 8: The habitat (upper graphic) and depth (lower graphic) preferences of alien species in each systematic group. For abbreviations, see Figure 3.

Table 4
Time span (weeks) for alien species' introduction along the Turkish coasts.

	1951-1970	1971-1990	1991-2010
	Weeks per 1 alien species		
Black Sea	494	164.6	82.3
Sea of Marmara	70.6	54.9	29.1
Aegean Sea	65.9	29.1	8.8
Levantine Sea	34.1	14.3	4.5
Total	22	10.9	4

ed on hard substrata. The majority of species belonging to the groups Sipuncula, Polychaeta, Crustacea, Mollusca and Pisces were reported from soft substrata.

The number of alien species decreases with increasing depths. A sharp decrease occurs from 11 m downwards. Alien species greatly dominate the shallow water (0-10 m) habitats (319 species, 80% of total number of species). The alien species that were reported in deep waters are *Trachysalambria palaestinensis, Carcharhinus altimus* and *Sphoeroides pachygaster.* All species of Cnidaria and Bryozoa, and more than 50% of the species of Phytobenthos, Polychaeta, Mollusca, Echinodermata and Pisces were reported between 0 and 10 m depths. Alien sipunculans species were reported between 11and 200 m depths.

Impacts of Alien species

It is generally accepted that alien species may have ecological, economic or health related influences, especially after they succeed in establishing dense populations, or presenting invasive characters. Although a wide range of scientific literature has tended towards the negative impacts of alien species-giving rise to the axiomatic 'native good, aliens bad' philosophy, facilitative alien-native interactions also occur frequently as an indication of the positive alien impact (GOODENOUGH, 2010). The review by ÇINAR *et al.* (2005a) presented concise data on the impact of alien species on Turkey (for example *Caulerpa racemosa, Mnemiopsis leidyi, Beroe ovata, Rapana venosa* etc.), while some new and updated information is given below.

Alien species have become very important components of benthic and pelagic communities in Iskenderun Bay. A bottom trawl haul in August 2009 (30 m depth) near Yumurtalık revealed that 92% of the number of specimens and 89% of total biomass belonged to Lessepsian species (unpublished data). *Rhopilema nomadica* (58% of total biomass), *Charybdis longicollis* (17%), *Penaeus semisulcatus* (5%) and *Equulites klunzingeri* (4%) comprised the majority of biomass (84%) in the area. The most abundant species in the catch were *C. longicollis* (63% of total specimens) and *E. klunzingeri* (20%).

The genus *Caulerpa* was represented by two alien species on the coasts of Turkey, i.e. *C. racemosa* and *C. scalpelliformis* (ÇINAR *et al.,* 2005a), while CEVIK *et al.* (2007) later added *C. taxifolia* to the list based on the material collected off Yumurtalik coasts (Iskenderun Bay) during 2006. The DNA sequences revealed that the Turkish population was different from that inhabiting the Western Mediterranean Sea. Shipping (most probably) or aquarium dumping was suspected as a possible vector of the introduction of the Turkish population. Its origin was thought to be the Australian coast. However, there is a debate on its taxonomic position. ZENETOS *et al.* (2010b) regarded the report of *C. taxifolia* from Iskenderun Bay as *C. distichophylla.* However, we use the previous name as evidence for *C. distichophylla* has not been presented till now. Although *C. taxifolia* seems to be established in Iskenderun Bay, there is not enough data at the moment to indicate any possible negative impacts on the biota. A recent observation (July 2009) by M.E. ÇINAR and M. BILECENOĞLU revealed that the population of *C. taxifolia* was very scarce in the area. However, a monitoring programme specific to this species is urgently needed.

Halophila stipulacea is a locally abundant species, forming meadows generally at depths below 25 m. A competition between native seagrasses and *H. stipulacea* has not been observed yet. This alien seagrass seems to support a diverse local biota including epiphytes and benthic invertebrates, which constitute food sources for organisms at higher trophic levels (AKCALI & CIRIK, 2007).

It has been suggested that the majority of the alien foraminifer species observed on the coasts of Turkey were introduced from the Red Sea. The most abundant species are *Amphistegina lobifera, Amphisorus hemprichii, Sorites orbiculus, Heterostegina depressa* and *Coscinospira arietina.* The alien foraminifer species are found to coexist with other native benthic foraminifers. However, *A. lobifera* and *A. hemprichii* were found to be exceptionally common on the southwestern coasts of Turkey. They fully cover benthic habitats in shallow waters and even colonize biota such as the alien phanerogame *Halophila stipulacea* (Fig. 9). Holes among crusts formed by overlapped tests of *A. hemprichii* can also serve as hiding places for some species, such as small individuals of *Octopus vulgaris* (Fig. 9).

Amphistegina lobifera shows a wide distribution range in the Indo-Pacific and Atlantic Oceans (LANGER & HOTTINGER, 2000), and it is the most abundant alien foraminifer species in the Mediterranean Sea. It was recorded in Israel (LANGER & HOTTINGER, 2000), Lebanon (MONCHARMONT ZEI, 1968), Greece (KOUKOUSIOURA *et al.,* 2010), Turkey (AVŞAR, 1997), Libya (BLANC-VERNET *et al.,* 1979), Tunisia (GLACON, 1962) and Malta (YOKEŞ *et al.,* 2007a). According to LANGER & HOTTINGER (2000), the occurrences of living amphisteginids are delimited by the 14°C winter isotherms. However, *A. lobifera* is observed almost everywhere on the Aegean and Mediterranean coasts of Turkey, and even in the Sea of Marmara. Dense populations of *A. lobifera* observed around the submarine springs on the Aegean coast of Turkey suggest that the environmental conditions created by the warm springs help the thermophilic aliens to form dense local colonies and find the chance to spread the larval forms (MERIÇ *et al.,* 2010a).

Amphisorus hemprichii is also widely distributed in the Indo-Pacific and abundantly found in the Gulf of Aqaba, Red Sea (REISS & HOTTINGER, 1984; HAUNOLD *et al.,* 1998). Populations of *A. hemprichii* were first determined in June 2002 in sediment samples from a few coves around Kalkan, Kas, and Kekova (Antalya–SW Turkey). However, within two years, it had covered more than 100 km coastline and is still spreading towards the

Fig. 9: Dense settlements of *Amphisorus hemprichii* on leaves of *Halophila stipulacea* (upper figure) and on hard substrates, serving as a hiding place for a young individual of *Octopus vulgaris* (lower figure) (Photograph: Baki Yokeş).

Aegean Sea. Both *Amphistegina lobifera* and *A. hemprichii* form uncountable dense populations on the benthos along the coasts of Antalya (SW Turkey) (MERIÇ *et al.*, 2008a). The density of living *A. lobifera* individuals on rocks can reach 230000-310000 ind. m^{-2}. The high ratio of tests in the sediment (>350 ind./g; 0.75 g tests/g) results in large amounts of sand formation at an extreme rate. Certain stations off Kaş (Antalya) were monitored for six years and the deposition of the test belonging to these two species was found to be 2-4.5 cm/year. The extensive accumulation of sand is creating an immense ecological problem by changing the whole habitat type and coastal structure, while definitely altering the species composition of the coastal ecosystem (YOKEŞ & MERIÇ, 2004).

Massive swarms of the stinging nomadic jellyfish *Rhopilema nomadica* have been considered a threat to human health, tourism and fisheries since their first occurrence on the Mersin coasts during August 1995 (KIDEYS & GÜCÜ, 1995). In summer 2009, several blooms were observed along the coastline between Antalya and Adana, where 815 hospitalized cases were recorded (ÖZTÜRK & ISINIBILIR, 2010). Some injuries were quite serious, leaving whip-like marks on the body (Fig. 10). The other alien jellyfish, *Cassiopea andromeda,* not currently as widespread as *R. nomadica,* form only locally abundant populations.

A recent study in Ölüdeniz Lagoon (Fethiye) indicated that *C. andromeda* reached a maximum density of 14 individuals per 100 m^2, but no injury has been reported to date, despite its potential threat to human health (ÖZGÜR & ÖZTÜRK, 2008). Recently, a single specimen of the Lessepsian jellyfish, *Phyllorhiza punctata,* was captured in Iskenderun Bay (ÇEVİK *et al.,* 2011). If it forms a proliferating population in the area, it would become a pest for tourism activities and fisheries.

The other alien invertebrates that pose risks to human health are *Macrorhynchia philippina* (Hydrozoa), *Eurythoe complanata* (Polychaeta) and *Diadema setosum* (Echinoidea). The first two species, which have nematocysts and venomous chaetae, respectively, have built up dense populations on the Levantine coast of Turkey and may cause continuous itching and painful stinging when touched (ÇINAR *et al.,* 2006a, pers. obs.). The long spines of *D. setosum* with barbed tips can penetrate human skin and release venom from their tissue and lumen. The venom may cause redness, swelling and acute pain, which subsides after a few hours; however, spine fragments are difficult to remove, and healing may take several weeks (YOKEŞ & GALIL, 2006a).

The sipunculan species, Aspidosiphon (*A.*) *elegans,* which is a bio-eroder species, has an impact on shapings of limestone in shallow waters, together with other boring species such as *Lithophaga lithophaga* (LINNAEUS, 1758) [AÇIK, 2008a, pers. obs. (MEÇ)]. The eunicid worms, *Eunice antennata* and *Palola valida,* also play important roles in the erosion of calcareous structures in the area. The former species is locally abundant (KURT SAHIN & ÇINAR, 2009a).

The ballast water-mediated polychaete species such as *Polydora cornuta, Streblospio gynobranchiata* and *Pseudopolydora paucibranchiata* dominate the polluted soft-bottom benthic environments in Izmir Bay (ÇINAR *et al.,* 2006b) and the Golden Horn

Fig. 10: A swimmer stung by *Rhopilema nomadica* at Yumurtalik (Adana) during fall 2009 (Photograph: Tahir Özcan).

Estuary (ÇINAR *et al.,* 2009) and seem to have replaced some other opportunistic polychaete species such as *Capitella* spp. and *Malacoceros fuliginosus* (CLAPARÈDE, 1869). These alien species account for almost 90% of total zoobenthic populations in Alsancak Harbour and its vicinity (ÇINAR *et al.,* 2006b; DAĞLI & ÇINAR, 2008).

The natural and artificial hard substrates in Iskenderun and Mersin Bays (south-east of Turkey) were densely colonized by alien serpulid polychaetes such as *Hydroides operculatus* and *Pomatoleios kraussii,* comprising 95% of the total serpulid specimens in the area. The Lessepsian species, *P. kraussii,* formed a densely populated belt in shallow-water areas in Mersin Bay, providing a suitable habitat for small vagile fauna (ÇINAR, 2006). In the area, the population density and biomass values of *H. operculatus* reached up to 384000 ind.m^{-2} and 246 g.m^{-2}, respectively. *Hydroides elegans* and *H. dianthus* form dense populations in Alsancak Harbour (Izmir Bay) and their population densities may attain 110700 ind.m^{-2} and 33050 ind.m^{-2}, respectively (ÇINAR *et al.,* 2008). *Hydroides elegans* is one of main pests for aquaculturists in the Aegean Sea [pers. obs. (MEÇ)]. This species together with other fouling organisms can block the net mesh and greatly reduce water circulation. The reef builder species, *Ficopomatus enigmaticus,* was considered an ecosystem engineer by providing a suitable habitat for other species and also by changing the physical factors of the invaded environment (SCHWINDT *et al.,* 2001). This species was reported from the Sea of Marmara (DEMIR, 1952-1954) and the Aegean Sea (ERGEN, 1976), and forms dense aggregates on artificial substrates like wood or concrete piles. These species, with their calcareous tubes, may become a nuisance to humans when they attach themselves to hard underwater structures such as quays, mariculture equipment and ship hulls.

The invasive crab, *Percnon gibbesi,* was first recorded along the coast of Turkey in the Kaş-Kekova Marine Protected Area in 2006 (YOKEŞ & GALIL, 2006b). Only two individuals were found at two locations in 2006, whereas 112 individuals at 27 locations were observed in 2010 (KATSANEVAKIS *et al.,* 2011). This species is omnivorous, primarily feeding on algae. Its impact on the prevailing ecosystem is unpredictable at the moment but because of its invasive character, *P. gibbesi* is a a pest species candidate.

The sea-star *Asterias rubens* has intensively invaded the shallow-water benthic habitats of the Sea of Marmara and expanded its distributional range to the Black Sea (ALBAYRAK, 1996; KARHAN *et al.,* 2007). This species consumes large quantities of the native mussel *Mytilus galloprovincialis* (LAMARCK, 1819) and competes with the large sea-star *Marthasterias glacialis* (LINNAEUS, 1758) for food and space (KARHAN *et al.,* 2007). The dimension of its impact on the prevailing ecosystem is still unknown and requires further investigation.

The newly discovered alien bristle star in the Mersin and Iskenderun Bays, *Amphiodia obtecta,* was reported to be of invasive character, reaching a maximum density of 420 ind.m^{-2} in summer (STÖHR *et al.,* 2010). Bristle stars are known to feed on small invertebrates such as polychaetes and crustaceans (KISSELEVA, 1981). It was shown that the density and biomass of *A. obtecta* were negatively correlated with those of sipunculan and other echinoderm species (STÖHR *et al.,* 2010). However, the impact of *A. obtecta* on the prevailing ecosystem is still little understood and requires further investigation.

Lagocephalus sceleratus, which poses a great risk to human health due to tetradotoxin in its flesh and is also a major nuisance to small-scale fisheries (BILECENOGLU, 2010), is probably the worst invasive alien fish species throughout the entire Levant basin. Cases of poisonings in Turkey have become quite frequent over the last few years. However, there has been no report of a death until now. The fishing, landing and marketing of *L. sceleratus* were totally banned by the Turkish government in November 2008, but human consumption of this highly toxic pufferfish still continues, especially in the vicinity of Antalya, increasing the potential lethal risks. The species have powerful jaws that easily cut bottom longlines, thus also resulting in a financial loss for small scale fisheries.

Siganus spp. present complicated impacts on the eastern Mediterranean ecosystem. Their grazing pressure on the intertidal rocky algae have likely resulted in the eradication of some local vegetation and enhanced settlement of the alien mussel, *Brachiodontes pharaonis* (GALIL, 2007). Although we also suspect a similar negative impact on the Turkish coasts, further research is required. The venomous spines of *Siganus* spp. have a potential risk to humans, but envenomations are generally rapidly recovered from due to the relatively weak toxin of the species. It is worth noting that siganids are frequently marketed (sometimes at a high price during the summer season) and commercially support local fisheries.

The red-eye round herring (*Etrumeus teres*), which expanded its range to the Aegean Sea, has regularly been caught off the Turkish Levant coast since the 1990's (BILECENOGLU, 2010) and a commercially fishable population was reported from the Rhodes area (CORSINI *et al.,* 2005). Considering the southern Aegean coasts of Turkey, local purse seiners frequently capture the species in small quantities (100-200 kg/day), but a larger scale fishery was recently observed (ca. 20 tonnes within 2 days) on the Marmaris coast on 8th February 2011 and appeared in many Turkish newspapers, erroneously called *'Japon Hamsisi'* (Japanese anchovy). The fish was transported to Izmir to be sold at a price of ca. 2.5 euros/kg. Although the reasons for this unexpectedly dense population of *E. teres* cannot be easily explained at the moment, it seems to have the potential to support local fisheries. The species was recently observed in the Northern Aegean Sea (YARMAZ *et al.*, 2010) without any clues to indicate an established population. However, we should not discount a population increase in the area.

The recent invasion of shrimp-goby, *Vanderhorstia mertensi,* was documented from Turkey by BILECENOGLU *et al.* (2008). After its first occurrence in Fethiye Bay, *V. mertensi* has rapidly increased its population especially in soft substrates of shallow coasts and spread to southern Turkey (YOKES *et al.,* 2009). The species is known to live in symbiosis with *Alpheus* spp., but more specifically with the Lessepsian migrant *A. rapacida.* According to a recent study conducted in Gökova Bay, a small population of *V. mertensi* was observed at a depth of 15 m, which represents the first record of this species in the Aegean Sea. The existence of the shrimp-goby along the Turkish coasts currently seems to have no negative impact on the local fauna, while some indirect positive influences may be suspected. The biodiversity of the Kas-Kekova Specially Protected Area has long been monitored by one of us (MBY), where the alien alpheid *A. rapacida* appeared in remarkable quantities only after the shrimp-goby introduction. Since alpheids constitute a common prey item of several Mediterranean demersal fish species , we may suspect a facilitative impact of the increased alien alpheid population as a potential food resource. Another alien burrowing goby, *Trypauchen vagina,* has recently been reported from Iskenderun Bay (AKAMCA *et al.,* 2011) shortly after its first Mediterranean occurrence on the Israeli coast (SALAMEH *et al.,* 2010), but it is not clear at the moment if the species has the potential to impact on the food web structure in the future.

Conclusions

The present review elucidates that the coasts of Turkey, especially the Levantine coast, are under heavy invasion by alien species, mostly coming from the Red Sea and Indo-Pacific areas. Scientific and public interest in the species introductions and their impacts have resulted in the productions of new papers and synthesis on them, and made great contributions to our understanding of the dimensions of this phenomenon. Therefore, this up-to-date inventory of the alien species on the coasts of Turkey, apart from its scientific merits, can fulfil the needs of the regulatory requirements and environmental management options for decision makers. Unfortunatelly, strict precautions and regulations to limit the spread of invasive species have not been implemented in Turkey. To date, no regulation concerning the control of ballast water discharge (except for polluted ballast waters) has been put into effect . However, some developments relating to this are said to be taking place in the near feature.

Monitoring studies to be held along the coasts of Turkey are crucial to determine the new entry of alien species to the area. Such studies might also provide extensive information about prompt action for their control and eradications. Therefore, bio-ecological studies in hot spot areas for alien species such as the Iskenderun and Mersin Bays, large international harbors, estuarine areas and deltas should be performed and monitored.

Acknowledegments

We are greatly indebted to Dr. Argyro ZENETOS (Greece) and three referees for their constructive comments on the ms. We would also like to thank Drs. Christiane DELONGUEVILLE (Belgium), Roland SCAILLET (Belgium) and Panayotis OVALIS (Greece) for providing us with collection dates for some molluscan species.

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