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Alien species on the coasts of Turkey

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Abstract

The compilation of data on alien species reported from the Turkish coasts yielded a total of 263 species belonging to 11 systematic groups, of which Mollusca had the highest number of species (85 species), followed by Crustacea (51), fishes (43) and phytobenthos (39). The Black Sea is represented by a total of 20 alien species, the Sea of Marmara by 48 species, the Aegean Sea by 98 species and the Levantine Sea by 202 species. The majority of aliens found in the Black Sea and the Sea of Marmara were transported via shipping, whereas the Levantine coast is extensively subjected to Lessepsian migration. Benthic habitats (soft and hard substrata) comprise 76% of the total alien species and the pelagic environment is inhabited by thirty-nine species. Almost 50% of aliens collected from the Turkish coasts were found only at 0-10 m depth. Eight species occur at depths deeper than 100 m. The impacts of aliens on the benthic and pelagic ecosystems are presented.

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

Introduction

Species introduction is one of the major factors adversely affecting biological diversity (ELTON, 1958). The impacts of alien species on their new environment include restructuring established food webs, importing new diseases and competition with native organisms for food and space. Other significant ecological changes may occur when the invading organisms reproduce with native species, altering the gene pool (OCCHIPINTI AMBROGI, 2001). Invaders may belong to any taxonomical group, and are

capable of colonizing every ecosystem on earth, changing the ecological relations within communities, altering evolutionary processes and causing dramatic changes in native populations, including extinctions (MACK *et al.*, 2000).

The negative effects of aliens experienced world-wide have triggered the social and scientific media to take some precautions against the dispersal of aliens among regions or among localities within a particular region. Thus, compiled data regarding all aliens or a target organism (i.e. *Caulerpa taxifolia* in the Mediterranean Sea) are urgently required by scientists

and decision makers. In addition, monitoring programmes on spatio-temporal structures of communities particularly in the hot spot areas for aliens such as harbours, brackish and polluted waters should be undertaken both on local and global scales.

Turkey is surrounded by four seas with different hydrographical characteristics. The maritime traffic taking place through the Dardanel and Bosphorus straits and among commercial harbours makes the Turkish coasts more susceptible to invasions by aliens. The proximity of Turkey to the Suez Canal has resulted in dense settlements of Lessepsian migrants, especially in habitats along the Levantine coast of Turkey. Alien species and their roles in the benthic and pelagic ecosystems is increasingly becoming a subject of study in the country.

This paper reviews the alien species reported from the Turkish coasts and constitutes the first comprehensive database for future studies.

Methods

Data on alien species along the Turkish coasts

In this study, only reported data on aliens along the Turkish coasts have been taken into account. All calculations are based on species' records up to the end of 2005. Cryptogenic species have not been included in our compiled list. Some of the species in Table 1, which represent uncertainty in their real taxonomic position and distributional pattern, are classified as questionable or excluded. The questionable species will turn into aliens if their real taxonomic and distributional identities are clarified. In all calculations, including number of species per sea, only the established and questionable species have been taken into account. The importance of aliens in the total biota was estimated, based on the authors' databases.

Results and Discussion

List of alien species from the Turkish coasts

Table 1 includes all alien species reported from the Turkish coasts. The species are categorized by their origins, the mode of introduction and their habitat and depth preferences. The establishment success is assigned for each species. The first reported years of the species together with the relevant publications are also given for each sea.

The present data show that a total of 263 alien species, which belong to 11 systematic groups, occur along the Turkish coasts. Among the groups, Mollusca had the highest number of species (85 species), followed by Crustacea (51), fishes (43) and phytobenthos (39). Cnidaria is represented by only two species (*Rhopilema nomadica* and *Cassiopea andromeda*), Ctenophora by 2 species (*Mnemiopsis leidyi* and *Beroe ovata*), Pantopoda by one species (*Anoplodactylus californicus*), Bryozoa by one species (*Rhynchozoon larreyi*) and Echinodermata by 2 species (*Ophiactis savignyi* and *Synaptula reciprocans*).

Thirty-two species are considered as questionable or excluded in Table 1, mainly due to the uncertainty in their real taxonomical status and distributional patterns. The polychaetes, *Branchediosyllis exilis*, *Opisthosyllis brunnea*, *Rhodine loveni* and *Monticellina dorsobranchialis*, which were previously considered as Lessepsian migrants, indeed occur also in the western Mediterranean and the Atlantic Ocean. These species were also previously proposed to be excluded from the list of Lessepsian species (ERGEN *et al.*, 2002; ÇINAR, 2003; 2005). RULLIER (1963) found 11 polychaete species with Indo-Pacific affinity from the Sea of Marmara (Table 1). Of the species, *Nereis zonata persica* and *Timarete ancylochaeta* were also reported along the Levantine coast and considered as Lessepsian migrants (BEN-ELIAHU, 1995). The other species have not been subsequently reported from elsewhere in the Mediterranean Sea.

A total of 176 Lessepsian and 48 ship-transferred species were reported along the Turkish

Table 1.

The list of alien species and their first year of reports from the Turkish coasts. The habitat and depth preferences of aliens along the coasts together with their origins and establishment success are also given. The marked species in the list are questionable or excluded ones. BS: Black Sea, SM: Sea of Marmara, AS: Aegean Sea, LS: Levantine Sea, O: Origin (IP: Indopacific, 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) Es: Establishment success (E: Established, Q: Questionable, Ex: Excluded), MI= Mode of Introduction (L: Lessepsian, S: Shipping, G: Gibraltar, Aq: Aquaculture), H: Habitat [Hs: hard substrata (including algae, sponge), Ss: soft substrata (including phanerogams), P: pelagic, Pz: parasite], D: Depth range (I: 0-10 m, II: 11-50m, III: 51-100 m, IV: 101-200 m, V: 201-400, VI: 401-500 m).

	BS	SM	AS	LS	Es	O	MI	H	D
PHYTOPLANKTON									
<i>Alexandrium tamarense</i> (Lebour) Balech 1992	-	-	1984 ¹²⁴	-	Q	WA	S	P	I
<i>Chaetoceros coarctatus</i> Lauder 1864	-	-	1987 ¹²⁵	-	E	AT,PO	S	P	I
<i>Gymnodinium</i> cf. <i>mikimotoi</i> Miyake et Kominami ex Oda 1935	-	-	2002 ⁴⁴	-	Q	?	S	P	I
<i>Heterosigma</i> cf. <i>akashiwo</i> (Hada) Hada, 1968	-	-	2002 ⁴⁴	-	Q	?	S	P	I
<i>Rhizosolenia calcar-avis</i> M. Schultze, 1858	1999 ⁷¹	1993 ¹²³	-	-	E	AT	S	P	I
<i>Scrippsiella trochoidea</i> (Stein) Loeblich III, 1976	1999 ⁷¹	-	-	-	E	AT	S	P	I
<i>Thalassiosira nordenskiöldii</i> Cleve 1873	2002 ¹⁶⁰	-	-	-	E	AT	S	P	I
PHYTOBENTHOS									
Cyanophyta (=Cyanobacteria)									
<i>Trichodesmium erythraeum</i> Ehrenberg, 1830	-	-	1996 ⁶⁹	-	E	IP,RS	L	Hs,Ss	I
Rhodophyta									
<i>Acanthophora nayadiformis</i> (Delile) Papenfuss, 1968	-	1973 ¹⁷⁷	1970 ¹⁰³	1997 ²⁰	E	RS	L	Hs	I,II
<i>Acanthophora muscoides</i> Linnaeus, 1753	-	-	1986 ¹⁷⁸	-	E	AT	S	Hs	I,II
<i>Acrochaetium codicolum</i> Børgesen, 1927	1996 ²⁸	1986 ¹⁷⁸	1990 ⁵⁵	1997 ¹⁹	E	IP,AT	S	Hs,Ss	I
<i>Asparagopsis armata</i> Harvey, 1855	1973 ¹⁷⁶	1986 ¹⁷⁸	1973 ¹⁷⁶	1969 ¹⁷⁴	E	IP,AT	S	Hs	I
<i>Asparagopsis taxiformis</i> (Delile) Trevisan de Saint-Léon, 1845	-	-	2001 ²⁷	-	E	CT	L	Hs	I
<i>Bonnemaisonia hamifera</i> Hariot, 1891	-	1986 ¹⁷⁸	-	1997 ²⁰	E	PO,AT	?S	Hs	I
<i>Botryocladia madagascariensis</i> G.Feldmann, 1945	-	-	-	2000 ¹⁶¹	E	IO	?S	Hs	I
<i>Chondria collinsiana</i> Howe, 1920	-	1986 ¹⁷⁸	-	-	E	AT, IO	?L	Hs	II
<i>Chondrophycus papillosus</i> (C. Agardh) Garbary & Harper 1998	1973 ¹⁷⁵	1957 ¹⁴³	1969 ¹⁷⁴	1969 ¹⁷⁴	E	RS	?L	Hs	I
<i>Ganonema farinosum</i> (Lamouroux) Fan & Wang, 1974	1995 ²¹	1899 ⁹¹	1986 ²⁶	1997 ¹⁹	Q	IP,RS	?L	Hs,Ss	I

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Gracilaria arcuata</i> Zanardini 1858	-	1986 ¹⁷⁸	-	-	E	RS,IP	L	Hs	I
<i>Griffithsia corallinoides</i> (Linnaeus) Trevisan, 1845	-	1993 ²³	-	-	E	AT, IP	G	Hs	I
<i>Hypnea spinella</i> (C. Agardh) Kützing, 1847	-	-	1987 ¹⁸	-	E	AT,IP	S	Hs	I
<i>Hypnea variabilis</i> Okamura, 1909	-	1986 ¹⁷⁸	1986 ¹⁷⁸	-	E	PO	S	Hs	I
<i>Laurencia intermedia</i> Yamada, 1931	1986 ²⁶	-	-	-	E	PO,RS	S	Hs	I,II
<i>Lophocladia lallemandii</i> (Montagne) Schmitz, 1893	-	-	1970 ¹⁰³	1986 ⁵³	E	IP	L	Hs	I,II
<i>Polysiphonia fucoides</i> (Hudson) Greville, 1824	1973 ¹⁷⁶	-	1973 ¹⁷⁶	-	E	AT, IO	S	Hs	I,II
<i>Polysiphonia paniculata</i> Montagne, 1842	1986 ²⁶	-	-	-	E	AT	S	Hs	I
<i>Polysiphonia kampsaxii</i> Boergesen, 1939	-	-	1984 ¹⁷	1997 ²⁰	E	IP	S	Hs	I
<i>Radicalingua thysanorhizans</i> (Holmes) Papenfuss, 1956	-	1986 ¹⁷⁸	1986 ²⁶	1986 ⁵³	E	AT	S	Hs	I
<i>Rhodophysema georgii</i> Batters, 1900	-	1986 ¹⁷⁸	-	-	E	AT,PO	?S	Hs	I
<i>Spyridia hypnoides</i> (Bory de Saint- Vincent) Papenfuss, 1968	-	-	1987 ¹⁸	1997 ¹⁹	E	IO	S	Hs	I
Heterokontophyta									
<i>Chorda filum</i> (Linnaeus) Stackhouse 1797	-	1986 ¹⁷⁸	-	-	?	AT,PO	?S	Hs	I,II
<i>Ectocarpus siliculosus</i> (Dillwyn) Lyngbye, 1819	1973 ¹⁷⁵	1899 ⁹¹	1899 ⁹¹	1986 ¹⁴⁶	E	AT	S	Hs	I
<i>Halothrix lumbricalis</i> (Kützing) Reinke, 1888	2004 ²⁹	1993 ²³	1986 ¹⁷⁸	1993 ¹⁴⁵	E	AT,PO	S	Hs	I
<i>Pilayella littoralis</i> (Linnaeus) Kjellman, 1872	1998 ²⁴	1993 ²³	1985 ¹⁰⁵	1985 ¹⁰⁵	E	AT	S	Hs	I
<i>Protectocarpus speciosus</i> Boergesen, 1902	-	1993 ²³	-	-	E	AT	S	Hs	I
<i>Sargassum latifolium</i> (Turner) C. Agardh, 1820	-	1986 ¹⁷⁸	1986 ¹⁷⁸	-	E	RS	?L	Hs	I,II
<i>Sphaerotrichia divaricata</i> (Agardh) Kylin, 1940	-	1986 ¹⁷⁸	1970 ¹⁰³	1986 ¹⁷⁸	E	AT	S	Hs	I
<i>Stypopodium schimperi</i> (Buchinger ex Kützing) Verlaque & Boudouresque, 1991	-	-	-	1997 ²⁰	E	RS,AT	?L	Hs	I
Chlorophyta									
<i>Bryopsis pennata</i> Lamouroux, 1809	-	1986 ²⁶	1978 ⁵²	1978 ⁵²	E	AT	S	Hs	I
<i>Caulerpa racemosa</i> (Forsskål) J. Agardh, 1873	-	-	1991 ⁵⁴	1986 ⁵³	E	CT	?L	Hs,Ss	I,II
<i>Caulerpa scalpelliformis</i> (R.Brown ex Turner) C. Agardh, 1817	-	-	-	1998 ⁸⁶	E	AT,IP	?L	Ss	I,II
<i>Cladophora boodleoides</i> Børgesen 1925	-	-	1996 ⁷⁰	-	E	AT	G	Hs	I

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Codium fragile</i> (Suringar) Hariot ssp. <i>tomentosoides</i> (Goor) P.C. Silva, 1955	-	-	1986 ¹⁷⁸	-	E	AT,PO	?S	Hs	I
<i>Ulva fasciata</i> Delile, 1813	1990 ²⁵	1986 ²⁶	1977 ¹⁰⁴	1996 ²²	E	?RS	?L	Hs	I
Phanerogame									
<i>Halophila stipulacea</i> (Forsskål) Ascherson	-	-	1985 ¹⁰⁵	1985 ¹⁰⁵	E	IO,RS	L	Hs	I
FORAMINIFERA (Benthic)									
<i>Astaculus insolitus</i> (Schwager, 1866)	-	-	2004 ¹³²	-	E	IP,RS	L	Ss	III
<i>Astaculus sublegumen</i> (Parr, 1950)	-	-	2004 ¹³²	-	E	IP,RS	L	Ss	III
<i>Planogypsina acervalis</i> (Brady, 1884)	-	-	2004 ¹³²	-	E	IP,RS	L	Ss	II
<i>Planogypsina squamiformis</i> (Chapman, 1901)	-	-	2004 ¹³²	-	E	IP,RS	L	Ss	II,III
<i>Amphistegina lobifera</i> Larsen, 1976	-	-	2004 ¹³²	2002 ¹³³	E	IP,RS	L	Ss	I,II
CNIDARIA									
<i>Cassiopea andromeda</i> (Forsskål, 1775)	-	-	-	2002 ³⁹	E	IP,RS	L	Ss	I
<i>Rhopilema nomadica</i> Galil, Spanier & Ferguson, 1990	-	-	-	1995 ¹¹³	E	IP,RS	L	P	?
CTENOPHORA									
<i>Mnemiopsis leidyi</i> (Agassiz, 1865)	1994 ¹³⁷	1994 ¹¹⁴	1994 ¹¹⁴	1993 ¹⁶⁷	E	WA	S	P	I,II
<i>Beroe ovata</i> Mayer 1912	2001 ¹¹⁵	2004 ¹⁰⁸	-	-	E	WA	S	P	I,II
POLYCHAETA									
<i>Lepidonotus carinulatus</i> (Grube, 1870)	-	1963 ¹⁴⁹	-	-	Q	IP,RS	?S	?	?
<i>Harmothoe boholensis</i> (Grube, 1878)	-	1963 ¹⁴⁹	-	-	Q	IP,RS	?S	?	?
<i>Harmothoe minuta</i> (Potts, 1910)	-	1963 ¹⁴⁹	-	-	Q	IP,RS	?S	?	?
<i>Ancistrosyllis rigida</i> Fauvel, 1919	-	1963 ¹⁴⁹	-	-	Q	IP,RS	?S	?	?
<i>Sigambra constricta</i> (Southern, 1921)	-	1963 ¹⁴⁹	-	-	Q	IP,RS	?S	?	?
<i>Opisthosyllis brunnea</i> Langerhans, 1879	-	-	2002 ⁶³	-	Ex	IP,RS	L	Hs	I
<i>Branchiosyllis exilis</i> (Gravier, 1900)	-	-	2002 ⁶³	-	Ex	IP,RS	L	Hs	I
<i>Leonnates persicus</i> Wesenberg-Lund, 1949	-	-	2002 ⁶⁵	2003 ⁸⁵	E	IP,RS	L	Ss	II-IV
<i>Nereis zonata persica</i> Fauvel, 1911	-	1963 ¹⁴⁹	-	-	Q	IP,RS	?L	?	?
<i>Pseudonereis anomala</i> Gravier, 1900	-	-	2005 ⁶⁴	1989 ³³	E	IP,RS	L	Hs	I
<i>Glycera alba adspersa</i> Fauvel, 1939	-	1963 ¹⁴⁹	-	-	Ex	IP	?S	?	?
<i>Eurythoe complanata</i> (Pallas, 1766)	-	-	-	1997 ⁸¹	Q	?IP	L	Hs	I
<i>Linopherus acarunculata</i> Monro, 1937	-	-	-	1997 ⁸¹	E	RS	L	Ss	I
<i>Lumbrineris debilis</i> Grube, 1878	-	1963 ¹⁴⁹	-	-	Q	IP	?S	?	?
<i>Lysidice collaris</i> Grube, 1870	-	-	1998 ⁶¹	1997 ⁸¹	Q	IP,RS	L	Hs,Ss	I,II
<i>Prionospio saccifera</i> Mackie & Hartley, 1990	-	-		1999 ⁶²	E	IP,RS	L	Ss	III
<i>Polydora cornuta</i> Bosc, 1802	-	-	2005 ⁶⁶	-	E	?	S	Ss	I,II
<i>Streblospio gynobranchiata</i> Rice & Levin, 1998	-	-	2005 ⁶⁶	-	E	WA	S	Ss	I,II
<i>Dasybranchus carneus</i> Grube, 1870	-	1963 ¹⁴⁹	-	-	Q	RS	?S	?	?
<i>Notomastus aberans</i> Day, 1957	-	-	1983 ¹⁴¹	-	E	IP	L	Ss	I

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Monticellina dorsobranchialis</i> (Kirkegaard, 1959)	-	-	2006 ⁸⁴	-	Ex	?	L	Ss	?
<i>Timarete dasylophius</i> (Marenzeller, 1879)	-	1963 ¹⁴⁹	-	-	Q	IP	?S	?	?
<i>Timarete anchylochaeta</i> (Schmarda, 1861)	-	1963 ¹⁴⁹	-	-	Q	IP	?S	?	?
<i>Metasychis gotoi</i> (Izuka, 1902)	-	-	2002 ⁸³	-	E	IP,RS	?L	Ss	?
<i>Rhodine loveni</i> Malmgren, 1865	-	-	1992 ⁸⁰	1998 ⁸²	Ex	IP,AT	L	Ss	II
<i>Pista unibranchia</i> Day, 1963	-	-	1998 ¹⁴²	1997 ⁸¹	E	IP,RS	L	Ss	I,II
<i>Ficopomatus enigmaticus</i> (Fauvel, 1923)	-	1952 ⁶⁷	1976 ⁷⁹	-	E	ST	S	Hs	I
<i>Hydroides dianthus</i> (Verrill, 1873)	-	-	1865 ¹⁴⁸	-	E	WA	S	Hs	I
<i>Hydroides elegans</i> (Haswell, 1883)	-	-	1976 ⁷⁹	1991 ³⁴	E	A,P	S	Hs	I
<i>Spirorbis marioni</i> Caullery & Mesnil, 1897	-	-	1991 ¹¹⁷	-	E	P	S	Hs	I
PANTOPODA									
<i>Anoplodactylus californicus</i> Hall, 1912	-	-	-	1962 ¹⁵³	E	CT	L	Hs	I
CRUSTACEA									
Copepoda									
<i>Centropages furcatus</i> (Dana, 1846)	-	2000 ¹⁶⁴	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Calanopia elliptica</i> (Dana, 1846)	-	-	-	2003 ¹⁵⁷	E	IP,RS	L	P	I
<i>Calanopia biloba</i> Bowman, 1957	-	-	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Calanopia minor</i> Scott, 1902	-	-	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Labidocera pavo</i> Giesbrecht, 1889	-	-	-	2003 ¹⁵⁷	E	IP,RS	L	P	I
<i>Euchaeta concinna</i> Dana, 1846	-	-	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Eucalanus crassus</i> Giesbrecht, 1888	-	-	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Eucalanus subcrassus</i> Giesbrecht, 1888	-	-	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Parvocalanus latus</i> Andronov, 1972	-	2000 ¹⁶⁴	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Parvocalanus elegans</i> Andronov, 1972	-	2000 ¹⁶⁴	-	2002 ¹⁶⁸	E	IP,RS	L	P	I-III
<i>Acartia tonsa</i> Dana, 1848	-	2000 ¹⁶⁴	2001 ¹⁵⁵	-	E	WA	S	P	?
<i>Acartia hasanii</i> Unal, Shmeleva & Kideys, 2002	-	-	-	2002 ¹⁶³	Q	?RS	?L	P	I
<i>Paracartia ioannae</i> Unal, Shmeleva & Kideys, 2002	-	-	-	2002 ¹⁶³	Q	?RS	?L	P	I
<i>Paracartia janetae</i> Unal, Shmeleva & Kideys, 2002	-	-	-	2002 ¹⁶³	Q	?RS	?L	P	I
Cirripedia									
<i>Heterosaccus dollfusi</i> Boschma, 1960	-	-	-	1997 ¹⁴⁰	E	RS	L	Pz	I,II
Amphipoda									
<i>Maera hamigera</i> Haswell, 1879	-	-	1978 ¹²¹	1978 ¹²¹	E	IP	L	Ss	I,II
<i>Stenothoe gallensis</i> Walker, 1904	-	-	1978 ¹²¹	1978 ¹²¹	E	IP	L	Ss	I,II
Isopoda									
<i>Sphaeroma walkeri</i> (Stebbing, 1905)	-	-	1976 ¹¹⁸	-	E	IP	L	Hs	I,II

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
Tanaidacea									
<i>Apseudes intermedius</i> Hansen, 1985	-	-	1978 ¹¹⁹	-	E	AT	?S	Hs	I,II
Cumacea									
<i>Eocuma sarsii</i> (Kossmann, 1880)	-	-	1983 ¹⁰⁹	-	E	IP	L	Ss	I,II
Decapoda									
<i>Marsupenaeus japonicus</i> (Bate, 1888)	-	2001 ¹⁷³	2001 ¹⁷³	1930 ¹³⁶	E	IP	L	Ss	I-III
<i>Melicertus hathor</i> (Burkenroad, 1959)	-	-	-	2002 ¹²⁸	E	RS,IO	L	Ss	I-III
<i>Metapenaeopsis aegyptia</i> Galil & Golani, 1990	-	-	-	2004 ¹⁷⁰	E	IP,RS	L	Ss	I-III
<i>Metapenaeopsis mogiensis consobrina</i> (Nobili, 1904)	-	-	-	2004 ¹⁷⁰	E	IP,RS	L	Ss	I-III
<i>Metapenaeus monoceros</i> (Fabricius, 1798)	-	-	-	1961 ¹⁰⁶	E	IP,RS	L	Ss	I-III
<i>Penaeus semisulcatus</i> de Haan, 1844	-	-	-	1930 ¹⁰¹	E	IP,RS	L	Ss	I-IV
<i>Metapenaeus stebbingi</i> (Nobili, 1904)	-	-	-	1981 ¹²⁰	E	RS,IO	L	Ss	I-III
<i>Trachysalambria palaestinensis</i> Steinitz, 1932	-	-	-	1968 ⁹⁵	E	RS	L	Ss	II,III
<i>Leptochela pugnax</i> de Man, 1916	-	-	-	1981 ¹²⁰	E	IP,RS	L	Ss	I-IV
<i>Palaemonella rotumana</i> (Borradaile, 1898)	-	-	-	2002 ⁹²	E	IP,RS	L	Ss	I-IV
<i>Alpheus audouini</i> (Coutière, 1905)	-	-	-	2002 ⁹²	E	IP,RS	L	Hs	I,II
<i>Alpheus inopinatus</i> Holthuis & Gottlieb, 1958	-	-	-	1969 ⁹³	E	IO,RS	L	Hs,Ss	I,II
<i>Alpheus migrans</i> Lewinsohn & Holthuis, 1978	-	-	-	1994 ¹²²	E	RS	L	Ss	II,III
<i>Alpheus rapacida</i> de Man, 1908	-	-	-	1981 ¹²⁰	E	IP	L	Ss	I-III
<i>Urocaridella antonbrunii</i> (Bruce, 1967)	-	-	-	2004 ¹⁷⁰	Ex	IP	L	Ss	I,II
<i>Ixa monodi</i> Holthuis & Gottlieb, 1956	-	-	-	1956 ¹⁰⁷	E	RS	L	Ss	II,III
<i>Leucosia signata</i> Paulson, 1875	-	-	-	1982 ⁹⁹	E	IP	L	Ss	I,II
<i>Myra subgranulata</i> Kossmann, 1877	-	-	-	1930 ¹³⁶	E	IP,RS	L	Ss	I-IV
<i>Micippa thalia</i> (Herbst, 1803)	-	-	-	1995 ⁷⁴	E	IP	L	Hs,Ss	I-III
<i>Callinectes sapidus</i> Rathbun, 1896	-	-	2001 ¹⁷³	1961 ¹⁰⁶	E	WA	S	Ss	I-III
<i>Charybdis hellerii</i> (Milne Edwards, 1867)	-	-	-	1981 ¹²⁰	E	IP,RS	L	Hs	I,II
<i>Charybdis longicollis</i> Leene, 1938	-	-	-	1961 ¹⁰⁶	E	IP,RS	L	Ss	I-III
<i>Portunus pelagicus</i> (Linnaeus, 1758)	-	-	-	1928 ¹⁰⁰	E	IP,RS	L	Ss	I-III
<i>Thalamita poissonii</i> (Audouin, 1826)	-	-	-	1961 ¹⁰⁶	E	IP,RS	L	Hs,Ss	I-III
<i>Carupa tenuipes</i> Dana, 1851	-	-	-	2004 ¹⁷⁰	?	IP,RS	L	Hs	I-III
<i>Pilumnopus vauquelini</i> (Audouin, 1826)	-	-	-	1981 ¹²⁰	E	IP,RS	L	Hs	I
<i>Calappa hepatica</i> (Linnaeus, 1758)	-	-	-	2003 ³⁰	E	IP,RS	L	Ss	I-III
<i>Atergatis roseus</i> (Rüppell, 1830)	-	-	-	1990 ⁷⁶	E	IP,RS	L	Hs	I,II

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Daira perlata</i> (Herbst, 1790)	-	-	-	1995 ⁷⁴	?	IP	L	Hs,Ss	I
<i>Eucrate crenata</i> de Haan, 1835	-	-	-	1992 ⁷⁵	E	IP,RS	L	Ss	I-III
<i>Macrophthalmus graeffei</i> Milne Edwards, 1873	-	-	-	1995 ⁷⁴	?	IP,RS	L	Ss	I-III
Stomatopoda									
<i>Erugosquilla massavensis</i> (Kossmann, 1880)	-	2004 ¹¹⁰	-	1961 ¹⁰⁶	E	IP,RS	L	Ss	I-III
MOLLUSCA									
Gastropoda									
<i>Diodora ruppellii</i> (Sowerby, 1834)	-	-	-	1995 ⁷²	E	IP,RS	L	Hs	I
<i>Smaragdia souverbiana</i> (Montrouzier, 1863)	-	-	-	1994 ⁴⁸	E	IP,RS	?	Ss	I
<i>Trochus erythreus</i> Brocchi, 1821	-	-	-	1995 ⁷²	E	RS	L	Hs	I
<i>Pseudominolia nedyma</i> (Melville, 1897)	-	-	-	1995 ⁷²	E	RS,IO	L	Ss	I,II
<i>Stomatella impertusa</i> (Burrow, 1815)	-	-	-	2000 ¹⁵²	?	IP,RS	?	Hs	I
<i>Cerithium scabridum</i> Philippi, 1848	-	-	1990 ³	1987 ¹²⁹	E	RS,IO	L	Hs,Ss	I
<i>Rhinoclavis kochi</i> (Philippi, 1848)	-	-	-	1987 ¹²⁹	E	IP,RS	?L	Ss	I
<i>Gibborissoa virgata</i> (Philippi, 1849)	-	-	-	2002 ¹	E	IP	L	?	?
<i>Finella pupoides</i> Adams, 1860	-	-	-	1990 ¹⁵⁹	E	IP	L	Ss	I
<i>Clathrofenella ferruginea</i> (Adams, 1860)	-	-	-	1995 ⁷²	E	IP,RS	L	Ss	I,II
<i>Cerithiopsis pulvis</i> (Issel, 1869)	-	-	-	1990 ¹⁵⁹	E	RS	?L	Ss	I
<i>Cerithiopsis tenthrenois</i> (Melvill, 1896)	-	-	-	1990 ¹⁵⁹	E	IO	?L	Ss	I
<i>Metaxia bacillum</i> (Issel, 1869)	-	-	-	1995 ⁷²	E	RS	?L	?	?
<i>Rissoina ambigua</i> (Gould, 1849)	-	-	-	2004 ¹³⁵	?	IP	?	?	II
<i>Rissoina bertholleti</i> Issel, 1869	-	-	-	1991 ¹³⁹	E	RS,IO	?L	Ss	I
<i>Strombus persicus</i> (Swainson, 1821)	-	-	1991 ¹³⁹	1983 ¹³⁸	E	PG	?	Hs,Ss	I,II
<i>Purpuradusta gracilis notata</i> (Gill, 1858)	-	-	-	1983 ⁴⁵	E	RS,IO	?L	Hs	I
<i>Cycloscala hyalina</i> (Sowerby, 1844)	-	-	-	1999 ⁹⁶	E	IP,RS	?	?	?
<i>Sticteulima cf. lentiginosa</i> (Adams, 1861)	-	-	-	1994 ¹⁵⁸	?	IP	?	?	?
<i>Ergalatax obscura</i> Houart, 1996	-	-	-	1995 ⁵⁰	E	RS	?	Hs	I
<i>Thais lacera</i> (Born, 1778)	-	-	-	1991 ¹³⁹	E	PG,IO	S	Hs,Ss	I
<i>Rapana venosa</i> (Valenciennes, 1846)	1960 ⁹⁰	1996 ¹²	1995 ⁷²	-	E	PO	S	Ss	I
<i>Zafra savignyi</i> (Moazzo, 1939)	-	-	-	1991 ¹³⁹	E	RS	?L	Ss	I,II
<i>Zafra selasphora</i> (Melvill & Standen, 1901)	-	-	-	1993 ¹⁴⁷	E	RS,IO	?L	?	?
<i>Lienardia mighelsi</i> Iredale & Tomlin, 1917	-	-	2003 ¹³⁵	-	?	IP	?	?	III
<i>Murchisonella columna</i> (Hedley, 1907)	-	-	-	1995 ⁴⁶	?	IP	?	Hs	I
<i>Chrysallida fischeri</i> (Hornung & Mermod, 1925)	-	-	-	1992 ¹³⁴	E	RS	?L	?	I

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Chrysallida maiae</i> (Hornung & Mermod, 1924)	-	-	-	1990 ¹⁵⁹	E	RS	L	Hs,Ss	I
<i>Chrysallida pirinthella</i> (Melvill, 1910)	-	-	-	1992 ¹³⁴	E	RS	?L	Ss	I
<i>Adelactaeon amoenus</i> (Adams, 1851)	-	-	-	1992 ¹³⁴	E	IP	?L	Ss	I
<i>Adelacteon fulvus</i> (Adams, A., 1851)	-	-	-	1992 ¹³⁴	E	IP	?L	Ss	I,II
<i>Styloptygma beatrix</i> Melvill, 1896	-	-	-	1992 ¹³⁴	E	PG	?L	?	I
<i>Cingulina isseli</i> (Tryon, 1886)	-	-	-	1989 ⁵	E	RS	?L	?	?
<i>Turbonilla edgarii</i> (Melvill, 1896)	-	-	-	1992 ¹³⁴	E	IP	?L	?	?
<i>Syrnola cinctella</i> Adams, A., 1860	-	-	-	1998 ⁴	?	IP,RS	?	?	I
<i>Syrnola fasciata</i> Jickeli, 1882	-	-	-	1989 ⁵	E	IP	?L	Ss	I
<i>Iolaea neofelixoides</i> (Nomura, 1936)	-	-	-	1998 ⁴	?	PO	?	Ss	I
<i>Hinemoa cylindrica</i> (de Folin, 1879)	-	-	-	2001 ⁵¹	?	IP	?	?	?
<i>Leucotina</i> cf. <i>eva</i> Thiele, 1925	-	-	-	2001 ⁹⁶	?	IP	?	?	?
<i>Acteocina crithodes</i> Melvill & Standen, 1907	-	-	-	2004 ¹³⁵	?	IP	?	Ss	II
<i>Acteocina mucronata</i> (Philippi, 1849)	-	-	1990 ⁶	1990 ⁶	E	RS	?L	Ss	?
<i>Cylichnina girardi</i> (Audouin, 1826)	-	-	1996 ⁴⁹	1990 ¹⁵⁹	E	IP	L	Ss	I
<i>Pyrunculus fourierii</i> (Audouin, 1826)	-	-	-	1989 ⁵	E	IP,RS	L	Ss	II,III
<i>Bulla ampulla</i> Linnaeus, 1758	-	-	-	2004 ¹⁷¹	E	IP	?L	Ss	II
<i>Haminoea cyanomarginata</i> Heller & Thomson, 1983	-	-	2004 ¹⁷¹	2004 ¹⁷¹	?	RS	?L	Hs	II
<i>Chelidonura fulvipunctata</i> Baba, 1938	-	-	-	1961 ¹⁵⁴	E	IP	?L	Ss	I,II
<i>Oxynoe viridis</i> (Pease, 1861)	-	-	-	2004 ¹⁷¹	?	IP	?L	Ss	I
<i>Elysia grandifolia</i> Kelaart, 1858	-	-	-	2004 ¹⁷¹	Q	?IO	?L	Hs	I
<i>Elysia tomentosa</i> Jensen, 1997	-	-	-	2004 ¹⁷¹	?	?IP	?	Ss	I,II
<i>Bursatella leachii</i> Blainville, 1817	-	-	1961 ¹⁵⁴	1961 ¹⁵⁴	E	CT	?L	Ss	I
<i>Syphonota geographica</i> (Adams & Reeve, 1850)	-	-	-	2004 ¹⁷¹	?	IP	L	Ss	I,II
<i>Plocamopherus ocellatus</i> Rüppell & Leuckart, 1830	-	-	-	2004 ¹⁷¹	E	RS	L	Hs	I
<i>Hypselodoris infucata</i> Rüppell & Leuckart, 1828	-	-	-	2001 ⁵⁶	E	IP,RS	?L	Hs	I
<i>Melibe viridis</i> Kelaart, 1858	-	-	-	2004 ¹⁷¹	?	IP	?	Ss	I
<i>Flabellina rubrolineata</i> (O'Donoghue, 1929)	-	-	2004 ¹⁷¹	2004 ¹⁷¹	E	IP,RS	?L	Hs	I,II
<i>Siphonaria belcheri</i> Hanley, 1858	-	-	-	2001 ¹³	E	IP,RS	L	Hs	I
Bivalvia									
<i>Anadara demiri</i> (Piani, 1981)	-	-	1977 ⁶⁸	-	E	IO	?S	Ss	I,II
<i>Anadara inflata</i> (Reeve, 1846)	-	-	-	2002 ⁶⁰	?	IO	?S	Ss	?
<i>Anadara inaequalvis</i> (Bruguière, 1789)	2003 ¹⁰	1996 ¹¹	1995 ⁷²	-	E	IP	?S	Ss	I,II
<i>Anadara natalensis</i> (Krauss, 1848)	-	-	-	1991 ¹³⁹	E	IO,RS	L	Ss	I,II
<i>Brachidontes pharaonis</i> (Fischer, 1870)	-	-	1990 ³	1985 ¹¹⁶	E	IO,RS	L	Hs	I
<i>Septifer forskali</i> Dunker, 1855	-	-	-	2001 ¹³	?	RS	?	Hs	II

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Crassostrea gigas</i> (Thunberg, 1793)	-	2004 ¹⁵	-	2001 ⁵⁷	E	PO	Aq	Hs	I
<i>Saccostrea cucullata</i> (Born, 1778)	-	-	-	2001 ⁵⁷	E	IP,RS	?S	Hs	I,II
<i>Dendroostrea frons</i> (Linnaeus, 1758)	-	-	-	2001 ⁵⁹	E	IP	?	Hs	?
<i>Pinctada radiata</i> (Leach, 1814)	-	-	1990 ¹⁵⁹	1985 ¹¹⁶	E	IP,RS	?L	Hs	I
<i>Electroma vexillum</i> (Reeve, 1857)	-	-	-	2005 ⁵⁸	?	IP,RS	?L	Hs	I
<i>Malvufundus regulus</i> (Forsskål, 1775)	-	-	-	1974 ⁸⁸	E	IP,RS	L	Hs	I
<i>Spondylus</i> cf. <i>multisetosus</i> Reeve, 1856	-	-	-	2001 ⁵⁹	Q	IP	?	Hs	?
<i>Spondylus spinosus</i> Schreibers, 1793	-	-	-	1999 ⁷³	E	IP,RS	L	Hs	I,II
<i>Chama pacifica</i> Broderip, 1834	-	-	-	2001 ⁵⁹	E	IP,RS	L	Hs	I,II
<i>Fulvia fragilis</i> (Forsskål, 1775)	-	-	2005 ¹⁴⁴	1987 ¹²⁹	E	IO,RS	?L	Ss	I
<i>Afrocardium richardi</i> (Audouin, 1826)	-	-	-	2000 ²	E	RS	L	Ss	?
<i>Tellina valtonis</i> Hanley, 1844	-	-	-	2001 ⁹⁶	E	IO,RS	L	Ss	I
<i>Psammotreta praerupta</i> (Salisbury, 1934)	-	-	-	1999 ⁷³	?	WA	?	Ss	IV
<i>Gafrarium pectinatum</i> (Linnaeus, 1758)	-	-	-	1987 ¹²⁹	E	IP,RS	L	Ss	I
<i>Clementia papyracea</i> (Gray, 1825)	-	-	-	1995 ⁷²	E	IP,RS	L	Ss	III
<i>Paphia textile</i> (Gmelin, 1791)	-	-	-	1991 ¹³⁹	E	IP,RS	L	Ss	?
<i>Ruditapes philippinarum</i> (Adams & Reeve, 1850)	-	-	2001 ¹⁴	-	E	PO	Aq	Ss	I
<i>Antigona lamellaris</i> Schumacher, 1817	-	-	-	1999 ⁷³	?	IP,RS	?	Ss	?
<i>Mya arenaria</i> Linnaeus, 1758	-	1996 ¹¹	-	-	E	WA	?S	Ss	II
<i>Gastrochaena cymbium</i> Spengler, 1783	-	-	-	1991 ¹³⁹	E	IP,RS	L	Ss	I-III
<i>Laternula anatina</i> (Linnaeus, 1758)	-	-	-	1995 ⁷²	E	IP,RS	L	Ss	I-III
Cephalopoda									
<i>Octopus aegina</i> Gray, 1849	-	-	-	1999 ¹⁵¹	E	IP	?L	Ss	III
<i>Sepioteuthis lessoniana</i> Lesson, 1830	-	-	-	2002 ¹⁵⁰	E	IP	L	P	I-III
BRYOZOA									
<i>Rhynchozoon larreyi</i> (Audouin, 1826)	-	-	1979 ¹⁶⁵	-	E	IP, RS	L	Ss	I
ECHINODERMATA									
<i>Ophiactis savignyi</i> (Müller & Troschel, 1842)	-	-	1998 ⁶¹	-	E	IP,RS	L	Hs	I
<i>Synaptula reciprocans</i> (Forsskål, 1775)	-	-	2001 ¹⁷³	-	E	IP,RS	L	Hs,Ss	?
PISCES						IP,RS			
Chondrichthyes									
<i>Carcharhinus altimus</i> (Springer, 1950)	-	-	-	2000 ³¹	Q	TA	G	Ss	I-VI
<i>Himantura uarnak</i> (Forsskål, 1775)	-	-	-	1966 ³⁷	C	IP,RS	L	Ss	I,II
Osteichthyes									
<i>Dussumieria elopsoides</i> Bleeker, 1849	-	-	-	1953 ³⁶	E	IP,RS	L	P	I,II
<i>Etrumeus teres</i> (DeKay, 1848)	-	-	-	1997 ³²	E	IP,RS	L	P	I,II
<i>Herklotsichthys punctatus</i> (Rüppell, 1837)	-	-	-	1984 ¹⁶⁹	E	RS	L	P	I,II
<i>Enchelycore anatina</i> (Lowe, 1839)	-	-	-	2002 ¹⁷²	E	TA	G	Hs	I,II

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Saurida undosquamis</i> (Richardson, 1848)	-	-	1973 ³⁸	1966 ³⁷	E	IP,RS	L	Ss	I-III
<i>Parexocoetus mento</i> (Valenciennes, 1846)	-	-	1966 ³⁷	1966 ³⁷	E	IP,RS	L	P	I
<i>Hemiramphus far</i> (Forsskål, 1775)	-	-	1950 ¹²⁶	1950 ¹²⁶	E	IP,RS	L	P	I
<i>Hyporhamphus affinis</i> (Günther, 1866)	-	-	-	1954 ⁷	Q	IP,RS	L	P	I
<i>Fistularia commersonii</i> (Rüppell, 1835)	-	-	2002 ⁴³	2002 ⁴²	E	IP,IO	L	Hs,Ss	I,II
<i>Hippocampus fuscus</i> Rüppell 1838	-	-	-	2004 ⁹⁸	?	IO,RS	L	Ss	I
<i>Syngnathus rostellatus</i> Nilsson, 1855	-	-	-	2004 ⁹⁸	Q	BA	G	Hs,Ss	I
<i>Atherinomorus lacunosus</i> (Forster, 1801)	-	-	1969 ⁹⁴	1950 ¹²⁶	E	IP,RS	L	P	I
<i>Sargocentron rubrum</i> (Forsskål, 1775)	-	-	1950 ¹²⁶	1950 ¹²⁶	E	IP,RS	L	Hs	I-III
<i>Pelates quadrilineatus</i> (Bloch, 1790)	-	-	-	1987 ¹³¹	E	IP,RS	L	Ss	I,II
<i>Apogon pharaonis</i> Bellotti, 1874	-	-	-	1987 ¹³¹	E	IP,RS	L	Hs,Ss	I,II
<i>Sillago sihama</i> (Forsskål, 1775)	-	-	2004 ⁴¹	1994 ¹⁰²	E	IP,RS	L	Ss	I,II
<i>Alepes djedaba</i> (Forsskål, 1775)	-	-	1969 ⁹⁴	1957 ⁹	E	IP,RS	L	P	I-III
<i>Leiognathus klunzingeri</i> (Steindachner, 1898)	-	-	1966 ³⁷	1943 ⁷⁸	E	RS	L	Ss	I-III
<i>Upeneus moluccensis</i> (Bleeker, 1855)	-	-	1956 ¹²⁷	1950 ¹²⁶	E	IP	L	Ss	I-IV
<i>Upeneus pori</i> Ben-Tuvia & Golani, 1989	-	-	-	1950 ¹²⁶	E	IP,RS	L	Ss	I,II
<i>Pempheris vanicolensis</i> Cuvier, 1831	-	-	1999 ¹³⁰	1994 ¹⁰²	E	IP,RS	L	Hs	I,II
<i>Heniochus intermedius</i> Steindachner, 1893	-	-	-	2003 ⁹⁷	Q	IP,RS	L	Hs,Ss	I
<i>Chelon carinata</i> (Valenciennes, 1836) [= <i>Liza carinata</i>]	-	-	-	1956 ¹²⁷	E	RS,IO	L	P	I
<i>Liza haematocheila</i> (Temminck & Schlegel, 1845) [= <i>Mugil soiuy</i> Basilevsky, 1855]	1992 ¹⁶⁶	1998 ¹¹²	1998 ¹¹²	-	E	PO	Aq	P	I
<i>Sphyræna pinguis</i> Doiuchi & Nakabo, 2005 [= <i>S. chrysotaenia</i> Klunzinger, 1884]	-	-	1969 ⁹⁴	1957 ⁹	E	IP,RS	L	P	I,II
<i>Sphyræna obtusata</i> Cuvier, 1829 [= <i>S. flavicauda</i> Rüppell, 1838]	-	-	-	2002 ⁴²	E	IP,RS	L	P	I,II
<i>Pteragogus pelycus</i> Randall, 1981	-	-	-	2000 ¹⁵⁶	E	IP,RS	L	Hs,Ss	I,II
<i>Petroscirtes ancylodon</i> Rüppell, 1838	-	-	-	2000 ¹⁵⁶	E	IP,RS	L	Hs,Ss	I
<i>Oxyurichthys petersi</i> (Klunzinger, 1871)	-	-	1999 ³⁵	1992 ¹¹¹	E	RS	L	Ss	I-III
<i>Callionymus filamentosus</i> Valenciennes, 1837	-	-	-	1994 ¹⁰²	E	IP,RS	L	Ss	I-III
<i>Siganus luridus</i> (Rüppell, 1829)	-	-	1973 ³⁸	1973 ³⁸	E	IP,RS	L	Hs	I,II
<i>Siganus rivulatus</i> Forsskål, 1775	-	-	1950 ¹²⁶	1950 ¹²⁶	E	IP,RS	L	Hs	I,II
<i>Scomberomorus commerson</i> Lacepède, 1800	-	-	1997 ⁴⁷	1987 ⁸⁹	E	IP,RS	L	P	I,II
<i>Solea senegalensis</i> Kaup, 1858	-	1942 ⁷⁷	1942 ⁷⁷	1942 ⁷⁷	Q	TA	G	Hs	I-III
<i>Cynoglossus sinusarabici</i> (Chabanaud, 1931)	-	-	-	1957 ⁹	E	RS	L	Hs	I,II

(continued)

Table 1 (continued)

	BS	SM	AS	LS	Es	O	MI	H	D
<i>Stephanolepis diaspros</i> Fraser-Brunner, 1940	-	-	1950 ¹²⁶	1950 ¹²⁶	E	IP,RS	L	Hs,Ss	I,II
<i>Lagocephalus sceleratus</i> (Gmelin, 1789)	-	-	2005 ⁸	-	E	IP,RS	L	Ss	I,II
<i>Lagocephalus spadiceus</i> (Richardson, 1844)	-	-	1966 ³⁷	1950 ¹²⁶	E	IP,RS	L	Ss	I,II
<i>Lagocephalus suezensis</i> Clark & Gohar, 1953	-	-	2002 ⁴²	1999 ¹⁶	E	RS	L	Ss	I,II
<i>Sphoeroides pachygaster</i> (Müller & Troschel, 1848)	-	-	2003 ⁸⁷	1999 ¹³⁰	E	TA	G	Hs,Ss	I-V
<i>Torquigener flavimaculosus</i> Hardy & Randall, 1983	-	-	-	2003 ⁴⁰	E	IP,RS	L	Ss	I,II

coast. Forty-eight alien Crustaceans (94% of the total aliens) belong to Lessepsian migrants. Most of the plants (29 species) were introduced via ships. The other modes of introduction of species were migration through the Gibraltar straits and Aquaculture.

Distribution of alien species on the Turkish coasts

The number of alien species found along the Turkish coasts and their modes of introduction are presented in Figure 1. The Turkish Black Sea coast possessed the lowest number of species (20 species), whereas the Turkish Levantine coast had the highest (202 species). The importance of shipping as a vector of introduction of species gradually diminishes from the Black Sea to the Levantine Sea. Lessepsian migrants exclusively dominate benthic habitats of the Levantine Sea. The Aegean Sea appears to be more influenced by Lessepsian migration than ship transportation.

The majority (70% of the species) of the marine animals introduced by ships in the Aegean Sea were reported from Izmir Bay; *Polydora cornuta*, *Streblospio gynobranchiata*, *Ficopomatus enigmaticus*, *Hydroides dianthus*, *H. elegans*, *Spirorbis marioni*, *Anadara demiri* and *A. inequalvis*. This is mainly attributed to two facts; 1) Alsancak Harbour, which is one of the most important commercial harbours in Turkey, is located in the polluted part of Izmir Bay, 2) This bay has been relatively well studied and

continuously monitored since the 1970's. Species-poor communities such as polluted or physically degraded environments are known to be more vulnerable to invasion than are other communities (ZIBROWIUS, 1992). Izmir Bay has been subjected to various pollution discharges, intense marine transportation and increasing human populations. Ocean-going ships approaching Alsancak Harbour for loading or unloading processes empty their ballast tanks just before entering the harbour and the weakening in the ecosystem due to pollution greatly facilitates the settlement of alien species in the area.

Rate of invasion

The new additions to the inventory of the marine alien species on the Turkish coasts greatly increased after 1980 and the last five years alone a total of 92 new species were recorded (Fig. 2). A decreasing pattern is obvious in the yearly rate of introduction over the past years (Table 2). While one new alien species was introduced every 15.3 weeks over the period 1981-2000 in the Aegean Sea, the time span has decreased to 8.7 between 2001 and 2005. The special interest in aliens by Turkish and foreign scientists in the last decade has increased and thereby, the real diversity of aliens within the groups of phyto-benthos, fishes and crustaceans inhabiting the Turkish coasts seems to be well documented. Nowadays, a number of projects regarding the actual status of aliens along the Turkish coasts

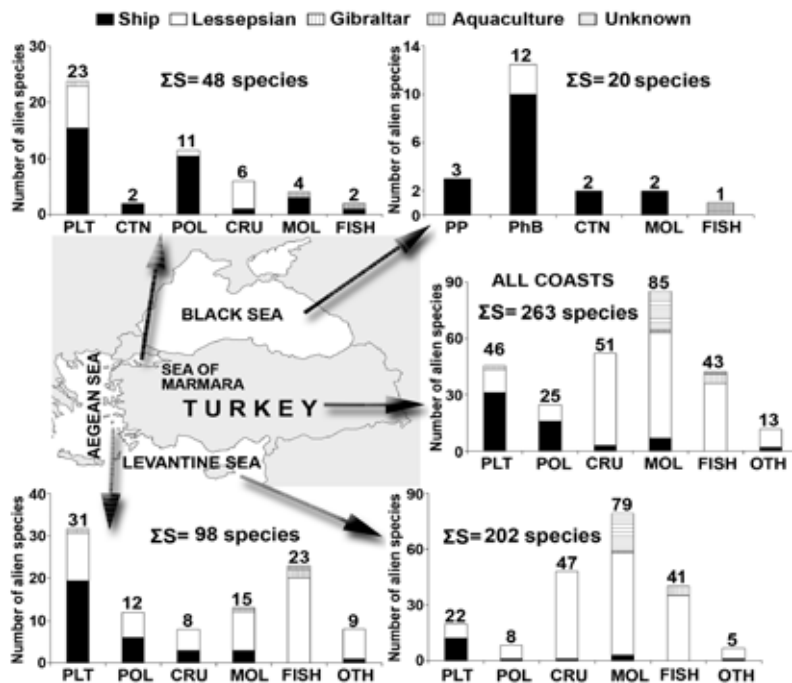


Fig. 1: The number of alien species along the Turkish coasts and their mode of introduction. PLT: All plants, PP: Phytoplankton, PhB: Phytobenthos, CTN: Ctenophora, POL: Polychaeta, CRU: Crustacea, MOL: Mollusca, OTH: Others. ΣS indicates the total number of species reported from the sea.

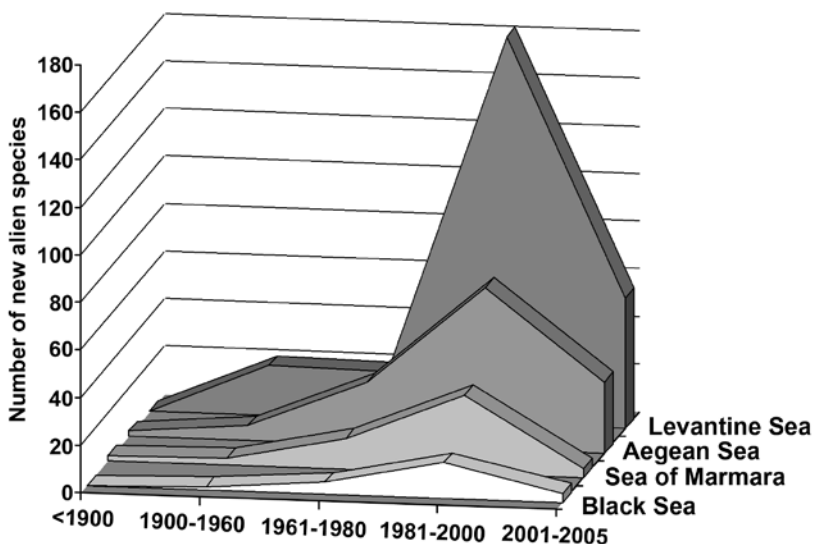


Fig. 2: Rate of introduction of alien species along the Turkish coasts.

Table 2.
Time span (weeks) for alien species introduction along the Turkish coasts.

	1961-1980	1981-2000	2001-2005
Weeks per 1 alien species			
Black Sea	208	69.3	65
Sea of Marmara	80	31.5	65
Aegean Sea	40	15.3	8.7
Levantine Sea	52	6.4	4.7
Total	16.3	3.7	2.8

and their probable impacts on the native biota are undertaken.

Depth and habitat preferences of alien species

The distribution of alien species by depth and habitat is indicated in Figure 3. The majority of aliens collected from the Turkish coasts were found in shallow waters. A total of 106 species (41% of the total number of aliens) solely occurred at depths ranging from 0 to 10 m, and 180 species (68%) at the depth interval 0-50 m. Species with a wide distributional range in the area are *Leonnates persicus* (10-200 m), *Penaeus semisulcatus* (0-200 m), *Leptochela pugnax* (0-200 m), *Palaemonella rotumana* (0-200 m), *Myra subgranulata* (0-200 m), *Carcharhinus altimus* (0-500 m), *Upeneus moluccensis* (0-200 m) and *Sphoeroides pachygaster* (0-400 m).

Benthic habitats (soft and hard substrata) harboured 76% of the total number of alien species (Figure 3). Thirty-nine species inhabited the pelagic environment. In soft substrata, all major groups, except for algae, are represented by a higher number of species. The majority of hard bottom organisms were reported among algae.

The echinoderm *Ophiactis savignyi* was only reported in canals of the sponge *Sarcotragus muscarum* from the southern part of the Aegean Sea [ÇINAR & ERGEN, 1998 (as *Ophiactis virens* (M. Sars, 1857)); ÇINAR *et al.*, 2002). The sweeper, *Pempheris vanicolensis*, prefers cavern habitats (BILECENOĞLU & TASKAVAK, 1999). The shrimp scad, *Alepes djedaba*, is generally associated with the venomous jellyfish *Rhopilema nomadica* (KIDEYS & GÜCÜ, 1995). ØKSNEBJERG *et al.* (1997)

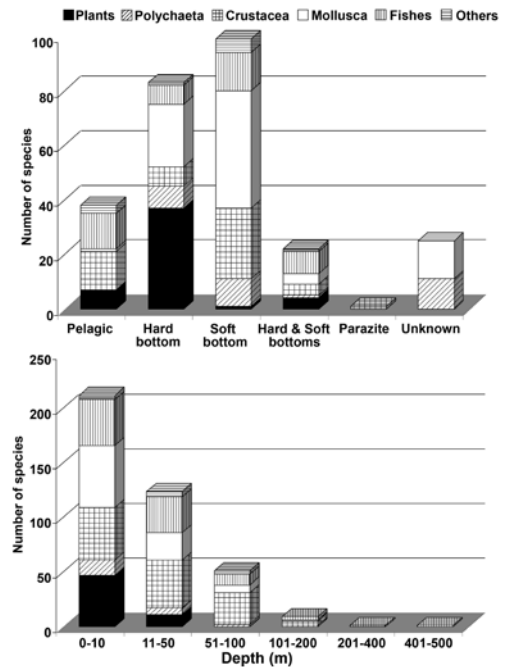


Fig. 3: The habitat (upper graphic) and depth (lower graphic) preferences of alien species along the Turkish coasts.

reported the parasitic cirriped *Heterosaccus dollfusi* on the Lessepsian crab *Charybdis longicollis*. The nudibranch *Flabellina rubrolineata* was found on hydroids (YOKES & RUDMAN, 2004). ALBAYRAK & ÇEVİKER (2001) reported *Septifer forskali* on the bivalve *Spondylus spinosus*. *Electroma vexillum* was encountered in discharge canals of the Iskenderun Iron and Steel Factory, where hot water is discharged into the sea (ÇEVİK *et al.*, 2005).

Impacts of alien species

The phytoplankton species, *Alexandrium tamarense*, *Gymnodinium* cf. *mikimotoi* and *Heterosigma* cf. *akashii*, which were reported from Izmir Bay and classified as questionable in Table 1, have a potential to cause a toxic and/or harmful bloom along the Turkish coasts (KORAY, 1984; BIZSEL & BIZSEL, 2002).

The green alga *Caulerpa racemosa* invaded soft and hard bottom habitats of the Levantine and Aegean coasts but its impact on the native biota has not yet been documented in the area. However, its occurrence off the Dardanel (salinity: 27 psu) indicates its highly adaptive and invasive character (OKUDAN *et al.*, 2002).

The negative effect of *Mnemiopsis leidyi* on the Black Sea ecosystem was summarized by KIDEYS (2002). This zooplanktonic predator reached enormous biomass levels in the summer of 1989, devastating the food chain of the entire Black Sea basin, and subsequently led to a sharp decrease in the anchovy production along the Turkish coast. The other ship-mediated ctenophore, *Beroë ovata*, which largely feeds on ctenophores, appeared in 1997 in the Black Sea and has resulted in the decrease in the population of *M. leidyi*.

The outburst of the population of *Rhopilema nomadica* off the Levantine coast of Turkey was reported to have negative consequences on human health, tourism and fisheries (KIDEYS & GÜCÜ, 1995). Many swimmers were stung and sought medical treatment. The blockage of nets of fishermen by individuals of *R. nomadica* also created major economical losses.

Rapana venosa, which feeds exclusively on bivalves, is responsible for the decrease in stocks of the bivalves *Ostrea edulis* Linné, 1758 and *Mytilus galloprovincialis* (Lamarck, 1819) in the Black Sea (BILECIK, 1990). The fishery of *R. venosa* was intense along the Turkish Black Sea coast, reaching up to 1166 tons in 1986, yielding 3.415.884 US \$ (BILECIK, 1990).

Low faunal diversity found on sponge samples collected from the southern Aegean Sea was due to the invasion of the Lessepsian species *Ophiactis savignyi* (ÇINAR *et al.*, 2002).

The species number and density of other groups within the sponge samples were sharply declined as compared to those collected from the northern sites where this echinoderm was not present. A negative correlation was estimated between number of specimens of the ophiuroid and the total number of specimens of other taxa.

The soft bottom near Alsancak Harbour in Izmir Bay was exclusively dominated by the spionid polychaete *Streblospio gynobranchiata*, which originated from the western Atlantic (ÇINAR *et al.*, 2005). Its density reached almost 34 300 ind.m⁻² in the area and accounted for almost 100% of faunal populations at some stations. The soft bottom benthic community around Alsancak Harbour seems to be restructured by this species.

KOÇAK *et al.* (1999) found dense populations of two alien serpulid species, *Hydroides elegans* and *H. dianthus*, on panels submerged in a polluted marina in Izmir Bay. The species density of *H. elegans* reached up to 98000 ind.m⁻² and that of *H. dianthus* up to 2 000 ind.m⁻². The above authors also reported that an alien serpulid species of eastern Pacific origin, *Spirorbis marioni*, inhabited port environments subjected to relatively less pollution.

The density of *Anadara demiri* was found to be 300 ind.m⁻² on grey mud and 30 ind.m⁻² on black mud in Izmir Bay (DEMİR, 1977).

Aliens might bring their own parasites with them. ØKSNEBJERG *et al.* (1997) reported that 90% of the specimens of *Charybdis longicollis* collected between Karatas and Fener Burnu (Levantine coast of Turkey) were infected by the rhizocephalan *Heterosaccus dollfusi*. They also stated that the prevalence of this parasite was estimated at 50-60% in the east of Karatas, with its prevalence gradually declining towards the east into Iskenderun Bay. GALİL & LÜTZEN (1995) found that 55% of the males and 43% of the females of *C. longicollis* were visibly infected by this parasite along the Israeli coast in May 1994.

From a large number of aliens inhabiting the Turkish coasts, only a few possess commercial value, mostly belonging to fishes and crustaceans. Little is known concerning the impact of

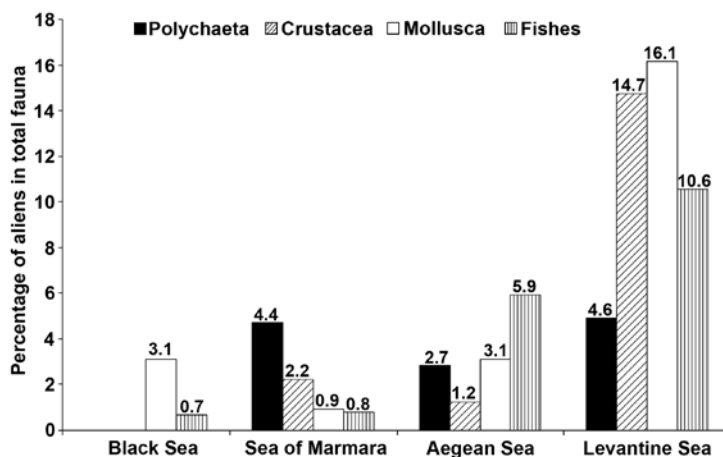


Fig. 4: Percentages of alien species in total fauna along the Turkish coasts.

commercially important alien species on local fisheries, since there is no available catch statistic that distinguishes native and alien species' landings. Due to the great number of species caught during various fisheries activities, governmental statistics tend to present relevant data on a family basis. For example, the "mullids" category includes four species (native *Mullus spp.* and Lessepsian *Upeneus spp.*); a similar situation is valid for sphyraenids (two native species vs. two Lessepsian species). Lessepsian clupeids, especially *Etrumeus teres*, form a remarkable proportion of the pelagic catch along the Levantine coast. The siganids are generally sold together with the native *Sarpa salpa* due to their similar morphologies (BILECENOĞLU & KAYA, 2002). At least seven fish species (*Upeneus moluccensis*, *Saurida undosquamis*, *Scomberomorus commerson*, *E. teres*, *Sphyraena pinguis*, *Siganus spp.*) are captured in large amounts (mainly by bottom trawls), and consumed throughout the Levantine and southern Aegean Sea coasts. In terms of biomass, *S. undosquamis* is the most prominent species in the bottom trawl catch composition (31.9% of total CPUE in Iskenderun Bay), followed by *U. moluccensis* and *Siganus rivulatus* (GÜCÜ *et al.*, 1994).

Some species have relatively smaller catches and thus mostly consumed locally, i.e.

Alepes djedaba, *Sillago sihama*, *Dussumieria elopsoidea*, *Atherinomorus lacunosus*. Among alien crustaceans, the highest annual production belongs to *Callinectes sapidus* (ca. 200 tonnes/year), which is captured especially in lagoons in amounts as much as 2 tonnes/day during summer periods (ÖZCAN *et al.*, 2003). *Marsupenaeus japonicus* is one of the most valuable shrimp species along the Levantine coast, which is also imported to various cities in Turkey. Since they are not captured in large quantities, other commercial shrimps (*Metapenaeus spp.*, *Penaeus semisulcatus*) and brachyurans (*Portunus pelagicus*) are, in general, consumed locally.

Importance of alien species in total fauna

The relative percentages of aliens in total fauna are shown in Figure 4. Mollusca had the highest score in the Black (3.1%) and Levantine (16.1%) Seas, Polychaeta in the Sea of Marmara (4.4%) and fishes in the Aegean Sea (5.9%). The score for Polychaeta in the Sea of Marmara does not reflect its true number as 11 of 12 aliens are questionable. The score seems to be accurate for the better-studied group, fishes, which has more aliens on the southern coasts than the northern coasts due to the influence of Lessepsian migrants. The highest alien percentages for all groups examined were found on the Levantine

coast. This partly shows the impact of Lessepsian migration on the Levantine fauna and partly the lack of detailed works on some groups on the coast. The total number of species given for Mollusca and Polychaeta from the Levantine coast of Turkey is highly underestimated and undoubtedly would increase as further studies are carried out. It is a common assumption that Lessepsian migrants account for at least 10% of the species inventory of the Levantine Sea (POR, 1978). BEN-ELIAHU (1995) estimated that the proportion of migrant polychaetes is almost 9%; for fishes 13% (GOLANI, 1998) and for decapod crustaceans 20% (GALIL, 1986).

Similarity among seas in terms of alien species

The dendrogram and MDS configuration in Figure 5 show that there are two groups in terms of the presence and absence of alien species in the Turkish seas. The Black Sea and the Sea of Marmara constitute one group, in which 16 species (mainly algae) are common. The other group with a similarity of 40% is composed from the Aegean and Levantine Seas, where 63 species (mainly lessepsian fishes) are common. There is a very weak similarity (20%) between the groups, which are placed at different corners of the MDS plot. As pointed out earlier, the southern seas seem to be more affected by Lessepsian migrants than ship-borne species, whereas shipping is the main vector in the transportation of aliens to the northern seas. The difference in the way of introduction seems to be the main reason for similarity or dissimilarity among the seas.

Conclusions

The compiled data show that a total of 263 established or questionable alien species inhabit the coast of Turkey, with the Levantine Sea having the majority of them (202 species). Detecting new aliens depends totally on accurate taxonomic identifications and the knowledge of local biodiversity. This requires the availability of systematic experts on biotal components in the area and a close cooperation among scientists both on local and global scales. The wealth

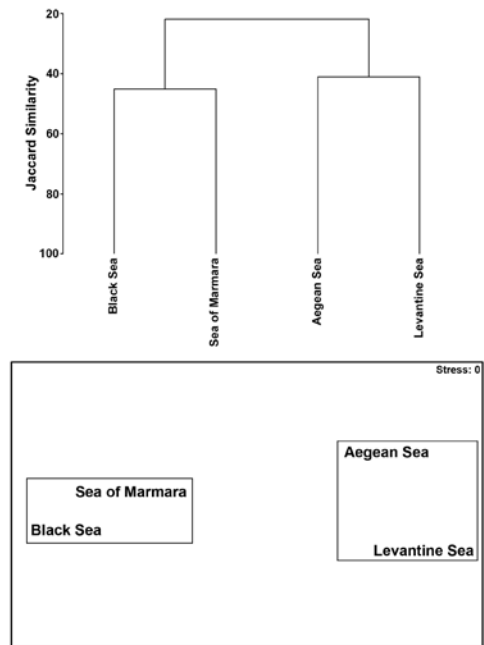


Fig. 5: Dendrogram and MDS plot showing affinities of the seas in terms of alien species they included.

of data accumulated on aliens depicts the importance of monitoring studies on the understanding of ecological and functional roles of aliens in the ecosystems. Finally, results of studies and projects should not be concealed among pages of reports and papers. They should be presented to governmental establishments and politicians to force them to take immediate precautions on the dispersal of aliens, particularly via ballast water discharges.

Addendum

Before the publication of this contribution, a total of 14 new alien species were reported from the Levantine (13 species) and Aegean [1 species (*Platax teira*)] coasts of Turkey (BILECENOĞLU & KAYA, 2006; ÇEVİKER & ALBAYRAK, 2006; ÇINAR *et al.*, 2006; ÖZTÜRK & CAN, 2006). These species belong to Hydrozoa (*Macrorhynchia philippina* (Kirchenpauer, 1872), Anthozoa (*Oculina patagonica*

De Angelis, 1908), Polychaeta (*Branchiommata luctuosum* Grube, 1869), Gastropoda (*Amathina tricarinata* (Linnaeus, 1767), *Aplysia dactylomela* Rang, 1828, *Chromodoris quadricolor* (Rüppell & Leuckart 1830)], Bivalvia [*Cardites akabana* (Sturany, 1899) and *Petricola hemp-richi* Issel, 1869], Echinodermata [*Synaptula reciprocans* (Forsskål, 1775)], Tunicata [*Phallusia nigra* Savignyi, 1816, *Pyura* (= *Herdmania*) *momus* (Savignyi, 1816) and *Symplegma brakenhielmi* (Michaelsen, 1904)] and Osteichthyes [*Parupeneus forsskali* (Fourmanoir and Guézé, 1976) and *Platax teira* (Forsskål, 1775)]. These findings increased the number of alien species known from the coast of Turkey from 263 to 277, and from 202 to 216 on the Levantine coast of Turkey.

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