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Article *in* Oceanography and Marine Biology · January 2005

3 authors:

N. Streftaris
Hellenic Centre for Marine Research

Argyro Zenetos
Hellenic Centre for Marine Research

Enangelos Papathanassiou
Hellenic Centre for Marine Research

Oceanography and Marine Biology: An Annual Review, 2005, **43**, 419-453

Taylor & Francis

GLOBALISATION IN MARINE ECOSYSTEMS: THE STORY OF NON-INDIGENOUS MARINE SPECIES ACROSS EUROPEAN SEAS

NIKOS STREFTARIS,* ARGYRO ZENETOS &
EVANGELOS PAPATHANASSIOU
Hellenic Centre for Marine Research, Anavissos 19013, Attica, Greece
*E-mail: nstrefta@ath.hcmr.gr

Abstract The introduction of non-indigenous species (NIS) across the major European seas is a dynamic non-stop process. Up to September 2004, 851 NIS (the majority being zoobenthic organisms) have been reported in European marine and brackish waters, the majority during the 1960s and 1970s. The Mediterranean is by far the major recipient of exotic species with an average of one introduction every 4 wk over the past 5 yr. Of the 25 species recorded in 2004, 23 were reported in the Mediterranean and only two in the Baltic.

The most updated patterns and trends in the rate, mode of introduction and establishment success of introductions were examined, revealing a process similar to introductions in other parts of the world, but with the uniqueness of migrants through the Suez Canal into the Mediterranean (Lessepsian or Erythrean migration). Shipping appears to be the major vector of introduction (excluding the Lessepsian migration). Aquaculture is also an important vector with target species outnumbered by those introduced unintentionally. More than half of immigrants have been established in at least one regional sea. However, for a significant part of the introductions both the establishment success and mode of introduction remain unknown.

Finally, comparing trends across taxa and seas is not as accurate as could have been wished because there are differences in the spatial and taxonomic effort in the study of NIS. These differences lead to the conclusion that the number of NIS remains an underestimate, calling for continuous updating and systematic research.

Introduction

A non-indigenous species (NIS, also known as exotic, introduced, invasive, alien or non-native species) is any species whose translocation into an environment outside its native geographical habitat, within historical times, has been either man-mediated (either intentionally or accidentally) (Olenin & Leppakoski 2002), or has been an action of active dispersal via natural pathways (e.g., Gibraltar and Dardanelle straights). As marine species know fewer and fewer boundaries, invasive species now constitute one of the four greatest threats to the world's oceans on local, regional and global scales (IMO 2000–2004), the other three being land-based sources of marine pollution, overexploitation of living marine resources and physical alteration/destruction of marine habitat.

Such transportation and release of NIS, often referred to as 'ecological roulette' or 'biological pollution' (Carlton & Geller 1993), represent a growing problem due to the unexpected and potentially harmful environmental as well as social (e.g., health) and economic impacts that such invasions cause. Aquatic ecosystems may be affected by the introduced species through predation, competition, mixing of exotic genes, habitat modification and the introduction of pathogens. Human communities may also be impacted as newly established fisheries in an area can change the existing fishing patterns, land use and resource access. There are hundreds of other examples of catastrophic introductions around the world, causing severe human health, economic and/or ecological impacts in their host environments. Worldwide, dinoflagellates and their cysts transferred in ballast waters are responsible for toxic 'red-tides', a serious threat to public health and marine fisheries (Ruiz et al. 1997). It is even suggested that outbreaks of serious diseases such as cholera might be facilitated by transportation in ballast water.

Unlike other forms of marine pollution where ameliorative action can be taken and their effects can be reversed, the impacts of invasive marine species are most often irreversible. Nevertheless, while recent attention has focused on the adverse impacts of introduced species, introductions are a valid means to improve production and economic benefit from fisheries and aquaculture.

The impacts of NIS on genetics, populations, ecosystems and economics in European seas have been discussed to some extent (Rosenthal 1980, Boudouresque & Ribera 1994, Ruiz et al. 1997, Olenin & Leppakoski 1999, Galil 2000a, Leppakoski et al. 2002a). Two cases have attracted interdisciplinary scientific interest and raised public awareness in Europe. First, in the Black Sea, the filter-feeding North American jellyfish *Mnemiopsis leidyi* (accidentally introduced in the early 1980s possibly with ballast water (Vinogradov et al. 1989)) has depleted native ichthyo- and mesozooplankton stocks to such an extent that it contributed to the collapse of entire Black Sea commercial fisheries in the late 1980s (FAO 1997, Shiganova et al. 2001). Second, in the Mediterranean, a small colony of *Caulerpa taxifolia* introduced in 1984 from a public aquarium (Oceanographic Museum of Monaco, where it was cultivated beginning in 1982) has spread to more than 6000 hectares today, out-competing native species and seriously reducing diversity in areas of the northwestern Mediterranean. Yacht anchors and fishing gear have carried it from anchorage to anchorage and from harbour to harbour, sometimes over great distances (Madl & Yip 2003).

On the other hand, beneficial aspects of introductions are well known; introduced species have significantly contributed to aquaculture production (FAO DIAS 1998), as well as fisheries (stocking) and recreational angling (Minchin & Rosenthal 2002). Even unintentionally introduced species that have exhibited invasive character have become locally of commercial importance such as the cases in the Mediterranean of the gastropod *Strombus persicus* and the blue crab *Callinectes sapidus*, reported by Mienis (1999) and EEA (1999), respectively, to mention just a few.

The significance of introduced species in marine ecosystems worldwide has been highlighted in recent years. International organisations, councils and the scientific community have addressed the impact of invasive species from scientific and economic points of view, through articles, review papers, databases and directories (Appendix 1). The most up-to-date work regarding the distribution, impact and management of invasive aquatic species in Europe can be found in a series of papers compiled in one edition by Leppakoski et al. (2002a). However, even in that work effort has been focused on individual seas or taxonomic groups and no synthetic work has been published at the European level.

The aim of the present review is to present the status of non-indigenous marine and brackish water species across the major European seas. In an effort to highlight the susceptibility of European seas to invaders and bring forward the similarities and differences observed, patterns and trends in the rate, mode of introduction and establishment success will be examined from an updated list. The objective is to raise the awareness on this important issue by presenting a holistic picture of European NIS.

Data on non-indigenous species in European seas

Data have been compiled from a wide variety of sources from existing databases and supplemented by bibliographical research. Entries range from species-specific papers to museum collections and

Web sites, dating from 1969 to 2004. The backbone of our review has been based on key review works such as those by Goulletquer et al. (2002) for the Atlantic**,** the database by Olenin & Leppakoski (2002) covering the Baltic, Alexandrov & Zaitsev (2000) for the Black Sea, Reise et al. (1999) and Minchin & Eno (2002) dealing with the North Sea, Walden (2002) dealing with the Arctic, and numerous works covering the Mediterranean such as Por (1978), Zibrowius (1992), Ribera & Boudouresque (1995), Athanasiadis (2002), Ribera Siguan (2002), Golani et al. (2002), Galil et al. (2002), Zenetos et al. (2003) and finally the work by Wallentinus (2002) covering marine algae in European aquatic environments. The Caspian Sea NIS have not been included in the present study because the Caspian is considered the largest lake of the world and furthermore all its species are regarded as NIS at some point in time (Aladin et al. 2001). The data sources used for the current compilation are shown in Table 1.

All calculations are based on species records up to and including 2003. Non-indigenous species have been grouped into six broad categories covering all relevant phyla: phytoplankton (PP), phytobenthos (PB), zooplankton (ZP), zoobenthos (ZB), fish (F), and Protozoa (P). Unfortunately almost no data are available on the non-indigenous fish species in the North Sea. Cryptogenic species (species with no definite evidence of their native or introduced status according to Carlton (1996) and species whose probable introduction has occurred prior to the year 1800, i.e., has not been witnessed) have been included in our compiled list.

The year of introduction (or first report when the former is missing), the place of origin and recipient site, and the means of transportation have been recorded where possible. In the graphs and tables that follow, each of the seas is treated separately, i.e., introduced species in more than one sea have been recorded in each of them. Non-certain recordings (reports cited followed with question marks in relevant sources) have been treated as positive. Care has been taken to ensure that the nomenclature problems encountered (e.g., the same species recorded in different regions, lists, or data banks with different names, i.e., synonyms) have not resulted in multiple separate recordings.

The account of NIS in European seas that follows is summarised below.

Non-indigenous species in European seas: where the number of NIS per category (PP, PB, ZP, ZB, F and P) and per 'regional sea' (Arctic, Atlantic, Baltic, Black, Mediterranean and North) are recorded and discussed. When species are present in more than one sea, they are recorded separately but count as a single unit for the total number of NIS in Europe. The term 'regional sea' is used in a rather unconventional way in this paper to describe also the European coastal waters of the Atlantic and Arctic oceans. Furthermore the Mediterranean Sea is treated as one entity, i.e., covering also the waters of the Asiatic as well as the North African part.

Rate of introduction: where the chronological trend of introductions is presented in 20-year intervals per group and per sea (as above).

Vectors of introduction: where the means of transportation are investigated, namely, shipping (fouling and ballast water), aquaculture (intentional and unintentional; intentional releases and stocking), via Suez Canal, via Gibraltar, and other modes (e.g., escapees, ornamental, etc.). When more than one mode is argued (as is often the case), then all modes are computed. Thus the number of vectors is higher than the number of organisms transported.

Success of introduced species: where NIS have been grouped as established (species with self maintained populations or with many records including cryptogenic species), aliens (i.e., not established, species with sporadic recordings in place and times) and unknown. Although establishment success of a given species may differ between regional seas and this is reflected in the scenario for each regional sea, at a European scale it counted positively if the species is established in at least one regional sea.

Table 1 Data sources used for compiling the comprehensive list of NIS in European marine and brackish waters

Regional sea	Data source
Arctic	Walden 2002
Atlantic	Eno et al. 2002
	Goulletquer et al. 2002
	Hoppe 2002
	Minchin & Eno 2002
	Wallentinus 2002
Baltic	Olenin & Leppakoski 2002
	Wallentinus 2002
Black	Alexandrov & Zaitsev 2000
	Wallentinus 2002
	Zaitsev & Ozturk 2001
Mediterranean	Athanasiadis 2002
	Balena et al. 2002
	Barnich & Fiege 2003
	Bello et al. 2004
	Belluscio et al. 2004
	Ben-Eliahu & Boudouresque 1995
	Ben-Eliahu & Fiege 1996
	Ben Souissi et al. 2003
	Bitar & Kouli-Bitar 2001
	Bogdanos & Fredj 1983
	Boudouresque & Verlaque 2002
	Castriota et al. 2002
	Ceviker & Albayrak 2002
	Çinar 2003
	Cormaci et al. 2004
	Galil et al. 2002
	Gofas & Zenetos 2003
	Golani 2002
	Golani & Fine 2002
	Golani et al. 2002
	Goren & Aronov 2002
	Jacques & Soyer 1977
	Laubier 1970
	Massuti et al. 2002
	Mienis 2002
	Mienis 2003a
	Mienis 2003b
	Mienis 2003c
	Mienis 2004a
	Mienis 2004b
	Moraitou-Apostolopoulou 1969
	Murina & Zavodnik 1986
	Occhipinti Ambrogi 2000
	Piazzi & Cinelli 2003
	Por 1978
	Ribera Siguan 2002

Table 1 (continued) Data sources used for compiling the comprehensive list of NIS in European marine and brackish waters

Regional sea	Data source
	Ribera & Boudouresque 1995
	Rudman 1999a
	Rudman 1999b
	Rudman 2001
	Rudman 2003
	Sartoni & Boddi 2002
	Scordella et al. 2003
	Shiganova et al. 2001
	Siokou-Frangou 1985
	Soljan 1975
	van Soest 1976
	Verlaque 2001
	Vila et al. 2001
	Wallentinus 2002
	Yokes & Galil 2004
	Zenetos et al. 2003
	Zibrowius 1992
	Zibrowius and Bitar 2003
North	Eno et al. 2002
	Hopkins 2002
	Minchin & Eno 2002
	Nehring 2002
	Reise et al. 1999
	Reise et al. 2002
	Wallentinus 2002

Impact of NIS across Europe: negative but also positive aspects are given.
Limitations and reservations of the datasets used and conclusion drawn are discussed in each section.

A preliminary list of species including 660 NIS and based on a fact sheet prepared in 2002 for the European Environment Agency is available at the Web site (http://www.eea.eu.int/). The full list of species can be found in Appendix 2.

Non-indigenous species in European 'regional seas'

The bibliographical study of the exotic species has revealed that 828 exotic marine species have been introduced in European coastal waters through shipping, aquaculture and following natural or man-made changes in the environment up to 2003. The Mediterranean Basin has received 615 such visitors, while 141, 133, 80, 42 and 13 species are known to have arrived in the North Sea, Atlantic, Baltic, Black and Arctic 'regional sea' coasts, respectively (Figure 1).

The high number of NIS in the Mediterranean Sea has been attributed to human activities, e.g., seafaring, commercial and tourism activities over centuries, to the presence of numerous habitats susceptible to invasions (lagoons, estuaries, marinas) (Galil 2000b) and to the recent expansion of aquaculture (Boudouresque 1994). The opening of the Suez Canal (nineteenth century) has led to

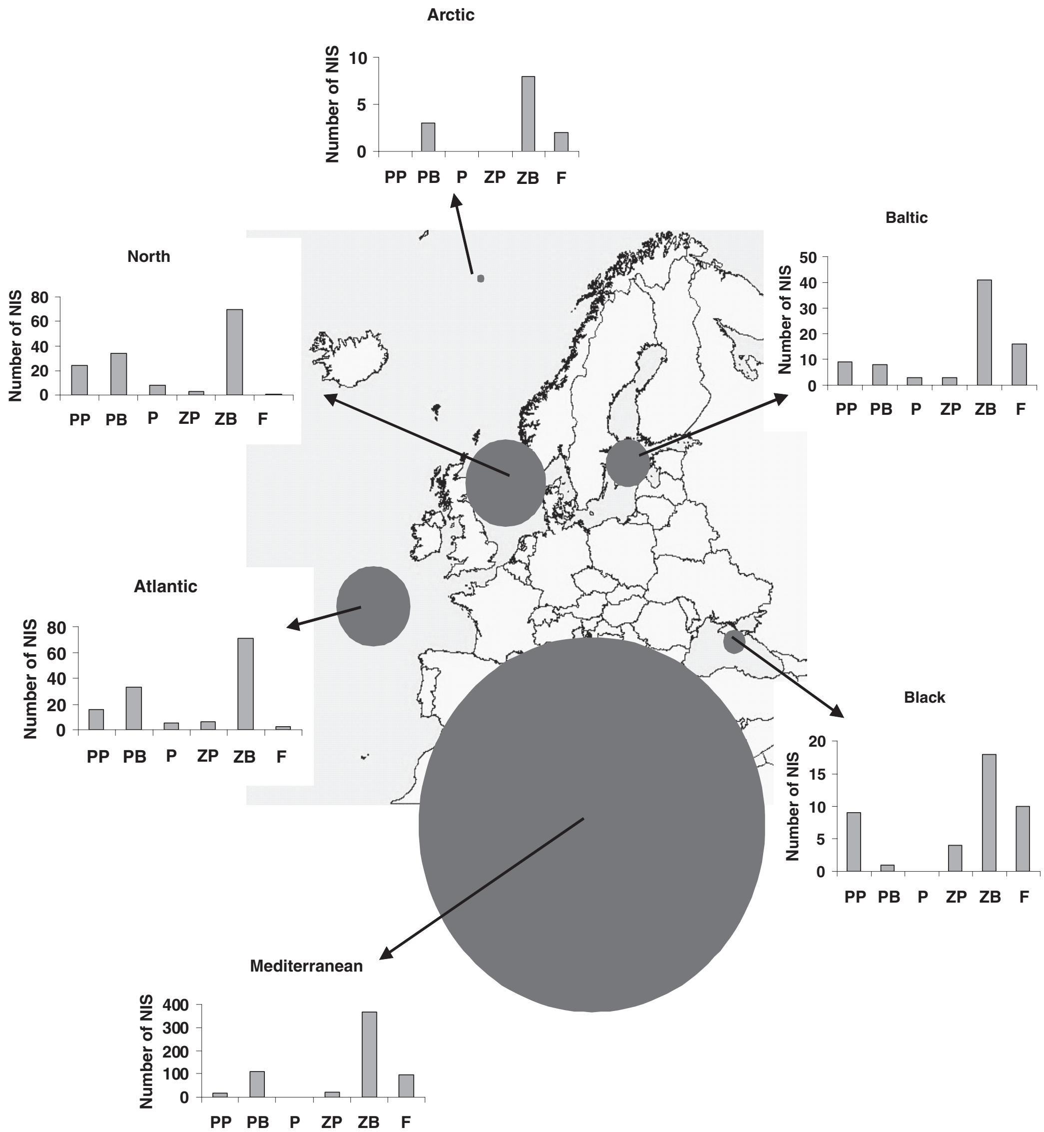

Figure 1 Non-indigenous species in European seas. *Category*: PP= phytoplankton; PB = phytobenthos; P = Protozoa; ZP = zooplankton; ZB = zoobenthos; F = fish.

the introduction of hundreds of Lessepsian immigrants (Por 1978, Zibrowius 1992, see also section on vectors of introduction). The most commonly introduced species are listed in Table 2.

Zoobenthos appears to be by far the dominant group in all seas investigated comprising about 57% of the newcomers. In the Arctic, zoobenthos accounts for 62% of the NIS (the highest category, but the records in these waters must be examined with some reservation, see limitations), in the Mediterranean zoobenthos accounts for 60% (the second highest category) and in the Black Sea it accounts for 43% (the lowest category). Although it can be argued that these figures are biased because greater scientific interest and research may have led to increased records, the cases of the Mediterranean and the Baltic seas where databases have been compiled by prominent organisations

Table 2 Common introduced NIS (in alphabetical order) in European seas and first publication records

Species	Category	Origin	Vector	Arctic	Atlantic	Baltic	Black	Mediterranean	North
Acartia tonsa	ZP	WA, IP	S		1927	1925	1976	1985	1916
Alexandrium tamarense	PP	NWA	S			?		1994	?
Anguillicola crassus	ZP	IP	As		1980s	1980			1882
Antithamnionella spirographidis	PB	IP	F		?			1914	1906
Antithamnionella ternifolia	PB	SP	S		1910			1926	1926
Asparagopsis armata	PB	SP, A	S		1925			1926	1950
Balanus eburneus	ZB	NWA	S		<1940		1892	?	1900
Balanus improvisus	ZB	WA	S	?	<1872	1844	1844	1972	1850
Bonnemaisonia hamifera	PB	NP	As		1898	1902		1910	1890
Callinectes sapidus	ZB	NWA	S		1901	1951	1967	1951	1932
Codium fragile	PB	NWP	As	?	1946	1932		1950	1900
Colpomenia peregrina	PB	PO	As	?	1905	1930		1956	1905
Corambe obscura	ZB	NWA	S		1973		1980		1886
Cordylophora caspia	ZB	PC	S		<1901	1803			1884
Coscinodiscus wailesii	PP	IP	As, S		1978	1983			1977
Crassostrea gigas	ZB	NWP	Aq	?	1966	1985	1900s	1964	1964
Crepidula fornicata	ZB	NWA	As		1949	1940		1957	1887
Diadumene cincta	ZB	NP, A	S		1963			1993	1925
Dreissena polymorpha	ZB	PC	S		?	1803			?
Elminius modestus	ZB	P	S		1953			?	1943
Eriocheir sinensis	ZB	NWP	S		1930s	1926	1998	1960	1912
Ficopomatus (= *Mercierella*) *enigmaticus*	ZB	ST	S		1921	1953	?	?	1921
Fucus evanescens	PB	NP, NWA	S	?		1927			1902
Garveia franciscana	PB	NWA	S			1950		1978	1920
Gonionemus vertens	ZP	NP, A	As		Nineteenth century			1976	1913
Gyrodinium aureolum	PP	P	S		?			<1966	?
Gymnodinium catenatum	PP	P	S		?	1993		1989	?
Haliplanella lineata	ZB	NP	As and/or F		End of nineteenth century			1971	1896
Hydroides dianthus	ZB	NWA	S		1927			1865	1970

Table 2 (continued) Common introduced NIS (in alphabetical order) in European seas and first publication records

Species	Category	Origin	Vector	Arctic	Atlantic	Baltic	Black	Mediterranean	North
Marsupenaeus (= *Penaeus*) *japonicus*	ZB	IP	Aq		1980		1970s	1927	
Mercenaria mercenaria	ZB	NWA	Aq		1861			1965	1864
Molgula manhattensis	ZB	NWA	S	?	1840				?
Mya arenaria	ZB	NWA	S	?	<1800	1245	1966	1976	1250?
Myicola ostreae	ZP	NWP	A		1972			1980	1992
Mytilicola orientalis	ZP	NWP	As		1977			1979	1992
Neosiphonia (= *Polysiphonia*) *harveyi*	PB	NP	Aq		1980s	?		1967	1908
Odontella sinensis	PP	IP, NWP	S		1930	1903			1903
Oncorhynchus mykiss	F	P	A	?	?	1890	1965		1902
Petricola pholadiformis	ZB	NWA	As	?		1927		1994	1890
Potamopyrgus antipodarum	ZB	SP	S		?	1887			1883
Pseudodactylogyrus anguillae	P	NWP	As		1984	1980			1990
Rapana venosa	ZB	NWP, then MED	S		1998		1946	1974	
Rhithropanopeus harrisii	ZB	NWA	S/F		1955–56	1948	1937	1996	1870s
Ruditapes (= *Tapes*) *philippinarum*	ZB	NWP, then NEP	Aq	?	1973–74	1983		1973	1987
Sargassum muticum	PB	NWP	As		1976	1985		1980	1960s
Styela clava	ZB	NWP	S		1968	1984			1952
Teredo navalis	ZB	C	S	?	<1800	1800	<1800	<1800	<1800
Undaria pinnatifida	PB	NWP, then MED	As		1983			1971	1986
Victorella pavida	ZB	IO	S		1960s	1960			1870

Note: Category: PP = phytoplankton; PB = phytobenthos; ZP = zooplankton; ZB = zoobenthos; F = fish; P = Protozoa

Vector: S = Shipping; S/F = Shipping/Fouling; F = Fouling; A = Associated; Aq = Aquaculture

Origin: MED = Mediterranean; ST = Sub-tropical; IO = Indian Ocean; IP = Indo Pacific; P = Pacific; NP = North Pacific; SP = South Pacific; NWP = North West Pacific; NEP = North East Pacific; A = Atlantic; WA = West Atlantic; NWA = North West Atlantic; C = Cosmopolitan support the dominance of Mollusca (the dominant phylum within the zoobenthos category) as the most commonly transported group. In our work Mollusca have been found to account for 23% of all NIS in European 'regional seas'.

It is argued that NIS have increased the biodiversity of the Eastern Mediterranean. Today, 12% (68 of 569) of the benthic biota of Israeli coasts are of Erythrean origin (Fishelson 2000). According to Gofas & Zenetos (2003), in the Mediterranean Sea, 143 of 1800 species of Mollusca are exotics, with 86 forming established populations. As for the fish, 650 species have been recorded with 90 species coming from distant seas (Golani et al. 2002). Macrophytic studies (Ribera & Boudouresque 1995) suggest that in the Mediterranean 4–5% of algal species are introduced and in the waters of the Atlantic coast of Europe the percentage ranges from 2–3%.

According to Wolff (1999) about 20% (16 of 80) of North Sea estuarine biota is considered to be of exotic origin, a proportion that decreases towards the open coast (6%) (14 of 250 species) and drops even further off shore. Goulletquer et al. (2002) in their review of exotic species in part of the Atlantic coasts (French waters) remark that the "discovered 104 species are a small number compared to the number of native species (more than 3000 in Northern Brittany)".

The knowledge of the percentage of NIS in the Baltic is provisional and based on few estimates. According to the figures reported by Leppakoski et al. (2002b) NIS account for 18% of the total biota in eastern Bothnian Sea, for 17% in Curonian lagoon (Lithuania), and for 3% in the German Baltic Sea coast.

Limitations — reservations

Care must be exerted when reviewing the relevant papers and data banks as the studies of exotics and thereafter the derived records are fragmentary and sporadic, based mostly on scientific interest alone. Mollusca, decapod Crustacea (both grouped in our review in zoobenthos (ZB)), macrophytes (grouped in phytobenthos (PB)) and fish are the groups that have been thoroughly investigated but there are arguments against the accuracy and validity of registration of other groups (bryozoans, entoprocts, hydroids, sponges, polychaetes, oligochaetes, amphipods, flatworms, nematodes, nemerteans, etc.). Zibrowius (1992) criticizes the entry of many of these species in Por's list (Por 1978) and according to Carlton (personal communication) data on species from the North Sea to Portugal are very fragmentary and it can be hypothesised that scores or even hundreds of introduced species may have been missed. Taxa with well-known taxonomy and established historical distribution records have received more attention than other groups. Thus, many of the small, less-conspicuous, understudied species are overlooked, leading to a possible underestimation of the extent to which NIS may be present.

Furthermore, the limited number of species recorded in the Arctic (13 species belonging to just two categories and with no data regarding time of arrival, or mode of transportation) may suggest that the Arctic region has received relatively little attention with respect to NIS and as such any interpretation could well be biased.

Rate of introduction

The overview of the rate of introduction in the twentieth century for each of the six categories of biota examined is shown in Table 3 and summarised in Figure 2.

A common trend was present in the chronological pattern of introductions. Examining Figure 2, it is clear that the rate of introductions peaked in the 1960–1980 period, and since then has remained stable or even declined. Examining the categories of biota, it was interesting to note the increases in phytoplankton observed in the Baltic and Black seas and in Phytobenthos observed in the Atlantic and in the Mediterranean in the latest period.

Table 3 Newly introduced NIS at 20-year intervals in European regional seas

		Year					
Regional sea	Category	<1900	1901–1920	1921–1940	1941–1960	1961–1980	1981–2000
North Sea	Phytoplankton		1		1	7	4
	Phytobenthos	4	5	2	3	5	4
	Protozoa	1				3	3
	Zooplankton		3				
	Zoobenthos	17	2	10	2	10	15
	Fish		1				
Baltic Sea	Phytoplankton	1	1			1	5
	Phytobenthos	1	1	4			2
	Protozoa					3	
	Zooplankton			1		1	1
	Zoobenthos	8	2	4	10	9	8
	Fish	3		1	4	5	3
Black Sea	Phytoplankton			1			5
	Phytobenthos						1
	Protozoa						
	Zooplankton			1		2	1
	Zoobenthos	3	1	3	4	4	3
	Fish			1	1	7	1
Mediterranean Sea	Phytoplankton	1				4	4
	Phytobenthos	8	4	8	13	20	49
	Protozoa						
	Zooplankton		3	1	1	10	5
	Zoobenthos	18	9	57	32	131	89
	Fish		2	11	17	22	38
Atlantic coastal waters	Phytoplankton			1		4	3
	Phytobenthos	2	6	1	2	4	10
	Protozoa					3	2
	Zooplankton	1		1	1	2	1
	Zoobenthos	8	3	6	4	21	19
	Fish						1

This increasing rate of NIS introductions coincides with findings in the United States (Ruiz et al. 1997) and has been attributed to changes in ballast water transfer (see Vectors of introduction). In European waters, according to ICES/IOC/IMO SGBOSV (2001), over the period 1998–2000 one new species has been introduced every 3 wk.

According to our compiled list a somewhat different picture has emerged when the introduction rate was examined on a yearly basis over the past years: a decreasing pattern is apparent in the yearly rate of introduction over the past years. While one new species has been introduced every 4 wk in 1998 and 1999, the time span has increased to 6 wk in 2000.

However, the process does not appear to be slowing down so rapidly in the Mediterranean Sea where it is mostly attributed to Erythraen invaders via the Suez Canal (Table 4). It is characteristic that in the twenty-first century 63 new species appear to have been introduced in the Mediterranean. Twenty-three of these species, based on 2004 publications, are not included in Appendix 2.

These are: *Electroma vexillum* (bivalve mollusc) found in Iskenderun Bay (Çevik personal communication), *Heniochus intermedius* (fish) recorded in the Adriatic (ICES/IOC/IMO WGBOSV, 2004), *Urocaridella antonbrunii* (decapod crustacean) recorded in southwest Turkey (Yokes & Galil

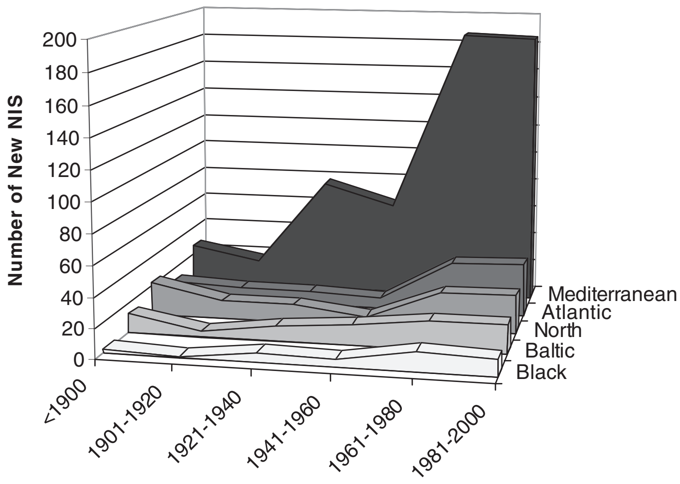

Figure 2 Rate of introduction of non-indigenous species across European seas.

Table 4 Time span (weeks) for NIS introduction in the Mediterranean

Year	1998	1999	2000	2001	2002	2003
Weeks per 1 NIS	5.2	4.3	7.4	3.3	3.7	2.9

2004), and 20 species of Mollusca (5 gastropods and 15 bivalves) recorded in Israel (Mienis 2004b), which need further confirmation.

Another two species have been reported in the Baltic. These are *Palaemon elegans* (crustacean) (ICES/IOC/IMO WGBOSV, 2004) and *Gammarus tigrinus* (crustacean) (ICES/IOC/IMO WGBOSV, 2004).

The decrease in introductions over the past two decades may well be attributed to changes in EU policies with stricter rules against possible invaders.

Legislation dealing with introduced species appears in several international treaties as well as in regional conventions, e.g., the United Nations Convention on the Law of the Sea (UNCLOS), the Convention on Biological Diversity (CBD), and the Bonn Convention on the Conservation of Migratory Species of Wild Animals. Furthermore, the International Maritime Organisation (IMO) under the auspices of the United Nations Conference on Environment and Development (UNCED) has been adopting regulations since 1992 on reducing ballast water impacts through its Marine Environment Protection Committee (resolution MECP 67(37) in 1995 and MECP 49/22 2003).

At the European level, the Berne Convention in 1979 provides that "each contracting party undertakes … to strictly control the introduction of non-native species". The EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora requires Member States to "ensure that the deliberate introduction into the wild of any species which is not native to their territory is regulated so as not to prejudice natural habitats within their natural range or the wild native fauna and flora and, if they consider necessary, prohibit such introduction" (article 22(b)).

More specifically, EU Directives legislate for the protection of the ecosystem against the adverse effects of aquaculture-related introduced organisms (Directive on the deliberate release into the environment of Genetically Modified Organisms (GMOs) (90/220/EEC) and Environmental Impact Assessment (EIA) Directive and its amendment (85/337/EEC & 97/11/EC)).

Limitations — reservations

The rate of introductions is based on publication dates of first records. However, the time span between the first finding and publication time may range from one to many years. Furthermore the peak in NIS observed in the 1961–1980 period may be partly attributed to the revival of scientific interest, whereas the current (2001 onwards) trend may be biased, as there may be a delay in new introductions being recorded and/or reported in the literature. The picture is distorted even further by the fact that authors are more aware of NIS introductions in the Mediterranean (where some data exist only in grey literature). Unfortunately no detailed data could be found regarding the Arctic region.

Vectors of introduction

Non-indigenous species in general are intentionally or accidentally transported and released by man. Some organisms, however, extend their geographical range following natural or man-made changes in the environment, e.g., construction of the Suez Canal. In many cases the introductory vector is unknown or assumed, whereas in some others the introduction has been facilitated by more than one vector.

Transportation via shipping and aquaculture (including stocking) are the major vectors of global dispersion of NIS. Vessels and aquaculture contribute the most in the translocation of species and genes. Vessels provide suitable transportation habitats in ballast waters, sediment in ballast tanks, sediment attached to anchors, and hull fouling. Aquaculture introductions may be intentional or unintentional, the latter comprising associated (free-living or parasitic) non-target species. For the last quarter of the twentieth century ballast water is perceived as the most important vector. According to the International Maritime Organisation (IMO), changes in maritime conditions, e.g., lower port residency time (resulting in less opportunity for organisms to settle on a ship), faster ship speeds (resulting in more organisms being washed away), and powerful antifouling paints (resulting in fewer organisms settling on a ship hull) have decreased the importance of hull fouling (Bartley 2000). Barnacles, hydroids, mussels, sea anemones and many other organisms have been carried around the world for many centuries on the external parts of ships and today thousands of species (bacteria, small invertebrates and the eggs, cysts and larvae of various species) are carried in ships' ballasts. The older estimate of 3000–4000 species (on average) that may be transported each day (Carlton & Geller 1993, Gollasch 1996) has now been raised to more than 10,000 species (Carlton 1999).

Other modes of introduction include escapees from scientific research and aquaria; fishing bait or packing material for bait, e.g., *Fucus spiralis* from Brittany, France, introduced into Gruissan lagoon in Mediterranean France (Ribera & Boudouresque, 1995); colonised fishing gear (Wallentinus, 1999); ornamental trade and release of pet species; and opening of canals supporting natural migration (Jansson 1994, Ruiz et al. 1997, Gollasch & Leppakoski 1999, Minchin & Gollasch 2002). It has been assumed that exotic species will not be able to survive and propagate in different environments, but the examples of *Caulerpa taxifolia* and *Sargassum muticum* have proved the fallacy of this argument (Ribera Siguan 2002).

The significance of shipping in facilitating and mediating the transfer and establishment of NIS is evident when examining the vectors of such introductions (Table 5 and Figure 3). This large overall contribution of shipping as a vector is mainly due to the situation in the North Sea where the shipping vector for NIS exceeds that of aquaculture and to a lesser extent this pattern is seen in the Mediterranean and the Black seas. In the Baltic, shipping and aquaculture appear to contribute equally whereas in the Atlantic coasts aquaculture appears to be more important than shipping as a vector of introduction. More than 44% of NIS introductions can be attributed to shipping in the

Table 5 Vectors of NIS introduction per European regional sea

	Vectors facilitating the introduction of NIS											
	Shipping		Aquaculture		Via Suez Canal		Via Gibraltar		Unknown		Other	
Regional sea	%	Species	%	Species	%	Species	%	Species	%	Species	%	Species
Baltic	49	40	47	38					2	2	1	1
North	44	66	29	43					21	31	7	10
Black	40	17	33	14					24	10	2	1
Atlantic coastal	37	53	45	64					18	26	0	
Mediterranean	20	135	11	74	52	343	6	40	10	70	1	8
Totals		311		233		343		40		139		20

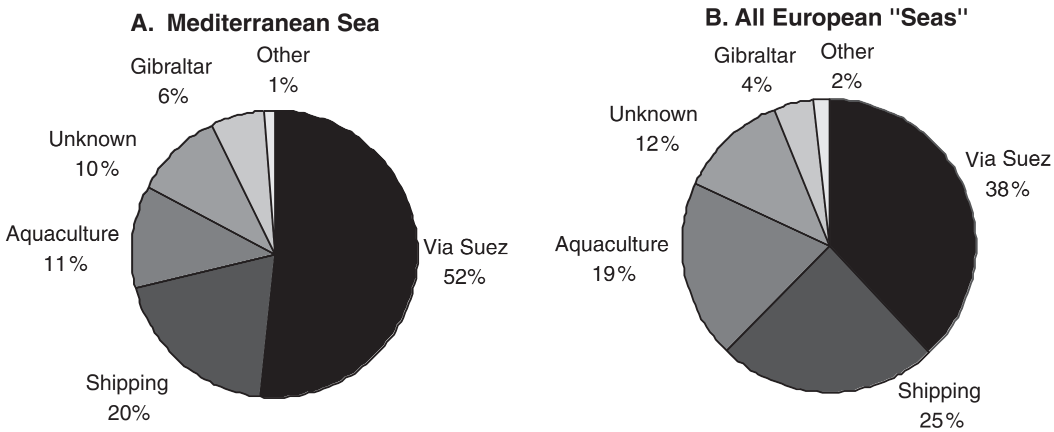

Figure 3 Vectors of introduction of non-indigenous species.

North and Baltic seas, whereas in the Atlantic and the Black seas the contribution of shipping falls to 35–40%. In the Mediterranean, shipping, although it contributed more than the aquaculture as a vector, appears to have had a less significant role (20%) overall as it is surpassed by the introduction of species via the Suez Canal (52%).

A different picture can be drawn when the importance of aquaculture is examined. In the Baltic, aquaculture accounts for 47% of the introductions, and in Atlantic for 45%. In the Black and North seas this percentage falls to 33% and 29%, respectively. Again the Mediterranean comes last in the relative list (Table 5).

These findings do not fully agree with findings by Wolff & Reise (2002) that in Europe, aquaculture-related transfers (particularly of species associated with oyster transfer) equal those mediated by shipping (ballast waters).

In the Mediterranean, introductions via the Suez Canal and via Gibraltar constitute a significant part of the NIS introduced. There is an increase of Indo-Pacific benthic immigrant species, compared with benthos from the 1970s, in the Levantine Basin (Eastern Mediterranean). According to Gofas & Zenetos (2003), 115 of 143 non-indigenous molluscs in the Mediterranean are of Indo-Pacific origin and are most likely to have spread by their own means through the Suez Canal (Lessepsian immigrants). Examining all taxa in our work, 383 transfer records have been attributed to spreading by their own means via the Suez Canal and Gibraltar (343 and 40, respectively) with the former constituting the major route of NIS introductions (52%) (Figure 3A). It is interesting to notice that 80% of the species entering the Mediterranean via Gibraltar are fish, followed by phytobenthos

(10%), Crustacea (7%) and Mollusca (3%) (phyla belonging to zoobenthos) whereas in introductions via Suez 70% are zoobenthic organisms (Mollusca 33%, Crustacea 15%, Polychaeta 14%, others: 8%), followed by fish (17%), phytobenthos (9%), zooplankton (3%) and phytoplankton (1%).

According to our compiled species list, in European waters the vector of introduction has been reported in 907 cases, which is higher than the number of transported species (828) because some species have been transported by different means in the same and/or different seas. Of the 907 cases, the majority of documented introductions has been via Suez migration and shipping (343 and 224 cases, respectively), followed by aquaculture (deliberate and unintentional) (174 cases) and those where the mode remains undetermined (113) whereas dispersal via Gibraltar and by other means plays only a minor part (40 and 14 cases, respectively) (Figure 3B).

Another interesting point arises when the effects of aquaculture are examined. According to FAO figures, in 1994 approximately 17% of the world's finfish production was due to alien species and 9.7% of aquaculture production came from introduced species: 97.1% of crustacean production in Europe, 96.2% of fish production in South America and 84.7% in Oceania (FAO, DIAS 1998). Examples of exotic species cultivated or used for restocking in Europe can be found in Minchin & Rosenthal (2002).

Aquaculture has also led to the introduction of species associated with those deliberately introduced, e.g., parasites, epibenthic algae and animals, particularly in the case of shellfish aquaculture. Schodduyn (1931) found 74 species of microflora, macroflora and fauna associated with *Ostrea edulis* transferred from the British Isles to France. According to Wolff & Reise (2002) the introduction of *Crassostrea gigas* has led to the unintentional introduction of more than 20 species of animal, five or six of which have become established.

Accidentally introduced (associated) species are more numerous compared with those intentionally introduced for aquaculture purposes. According to our compiled list, 114 species have been accidentally introduced along with 52 species imported for aquaculture (including stocking). Examining the balance of aquaculture to associated species per sea (Figure 4), the Black Sea is the least vulnerable to the introduction of associated aliens and Mediterranean Sea the most. The North Sea appears to have received the least number of intentionally introduced aquaculture species and the Baltic Sea the most.

Aquaculture production (in marine and brackish waters) has been steadily increasing since the 1970s. Nevertheless, our review shows that the increased pressure on the environment has not led to an increase of introduced species in the marine environment despite a peak in accidental

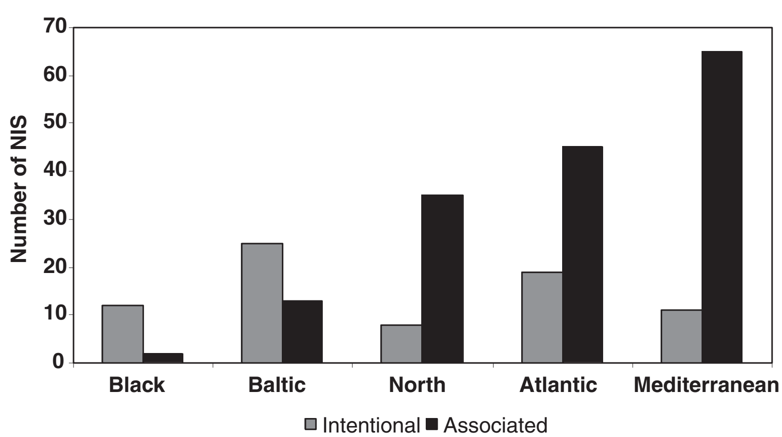

Figure 4 Intentionally and accidentally (associated) introduced species via aquaculture.

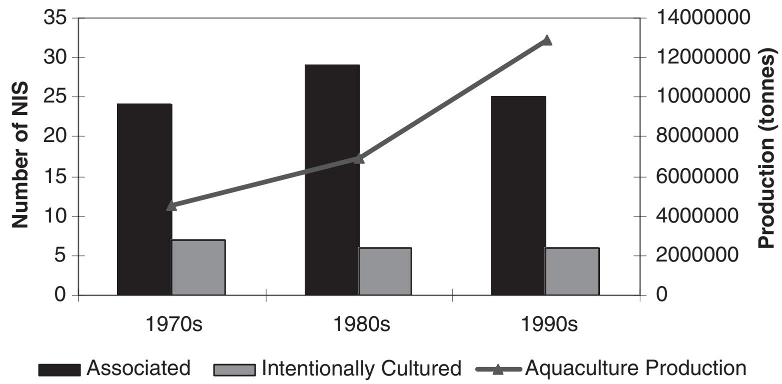

Figure 5 Aquaculture production and associated non-indigenous species.

introductions observed in the 1980s (Figure 5). Species intentionally introduced for aquaculture follow a decreasing pattern in number of species throughout the whole timespan. This fact and, more importantly, the decrease in numbers of the accidentally introduced species suggest the success of EU policies in regulating and safeguarding possible adverse effects of aquaculture-related environmental hazards. The Rio Convention (CBD 1992), The Code of Practice of the International Council of the Exploration of the Sea (ICES 1995) and additional codes enforced by many European countries (licence systems and legal measures) as well as imposed quarantines have been important in this respect.

Limitations — reservations

In many cases the mode of introduction is unknown or assumed. Furthermore, a number of species appear to have been introduced by more than one vector, e.g., aquaculture and shipping. The computation of assumed introductions and of all modes of introduction may lead to a degree of uncertainty. Finally, very limited data could be found regarding the mode of transportation in Arctic waters (the exception being the introduction of *Paralithodes camtschaticus* as a fisheries resource).

It must be emphasized that our knowledge of accidentally introduced species lags behind that of the number of species introduced for aquaculture. It has to be argued that the lack of legislation enforcing the monitoring of aquaculture-related introductions (and in general the lack of legislation concerning the monitoring the introduction of NIS in Europe) has led to an underestimation of the pressure exerted on the environment by aquaculture-associated species. Our knowledge of their existence is thus limited to scientific research and local monitoring programmes focusing mainly on places of specific interest such as lagoons.

In addition, modern science may reveal a different mode of introduction than initially assumed, as in the case of the bivalve mollusc *Brachidontes pharaonis* where molecular studies suggest that the mode of transport in Italy is shipping rather than Lessepsian migration (Galil & Zenetos, 2002).

Success of introduced species

It is not clear what makes a successful invader. Various factors that influence the invasion process have been considered by many authors. These factors include ability to survive the introducing process (conditions and duration), ability to form resting stages, life-history strategy with pelagic larval dispersal or direct development, high rate of reproduction, capacity to overcome abiotic factors and adapt to a new trophic niche and ability of the recipient environment to prevent or

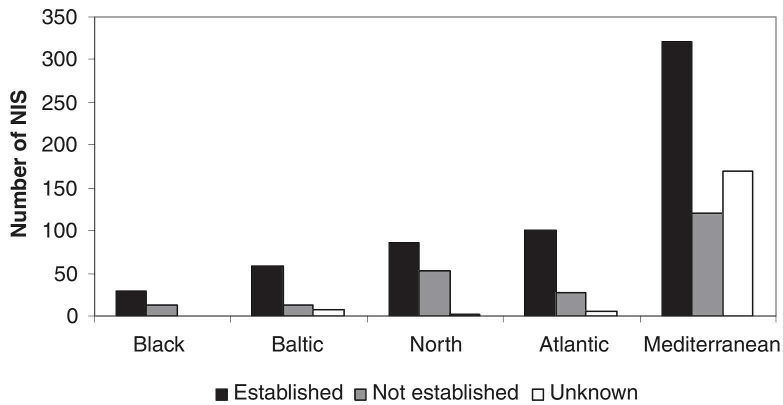

Figure 6 Success on non-indigenous species in European seas.

facilitate survival and establishment of new species: however, a clear picture has not emerged (Grosholz & Ruiz 1996, Vermeij 1996, Ruiz et al. 1997, Golani 1998, Gollasch & Leppakoski 1999, Ruiz et al. 2000, Gollasch 2002, Gofas & Zenetos, 2003). This uncertainty concerning establishment of invaders and their possible impact on the recipient ecosystem was the main reason for the term 'ecological roulette' adopted by Carlton & Geller (1993). *Mya arenaria*, due to high fecundity, planktonic dispersal, broad spectrum of habitat and food preferences, tolerance of wide range of environmental conditions, longevity and large size has become a successful invader by natural migration, aquaculture (intentional) and aquaculture-associated (non-intentional) transportation, and as a species transported in ballast water (Strasser 1999).

There is a general rule that 10% of the introduced species will settle and 1% will eventually become invasive, although it is not clear if that rule can apply to aquatic ecosystems (Williamson & Fitter 1996).

According to our compiled list, in European waters (apart from the Arctic where no data were available) of the 828 species, 456 species (55%) appear to have been established in one or more regional seas (see Appendix 2) and 195 species have been registered as aliens (24%). However, no data exist for 173 species (21%). In absolute terms, the Mediterranean harbours the majority of the established and alien species because it is the major recipient of NIS in European waters (Figure 6).

However, it appears that the Mediterranean is the least 'hospitable' environment for new invaders and the Baltic the most. The percentage of established and alien species is shown in Table 6.

Table 6 Establishment success of NIS in major European regional seas

	Percentage of NIS	
Regional sea	Established	Aliens
Atlantic	75.19	21.05
Baltic	73.75	16.25
Black	69.05	30.95
North	61.43	37.86
Mediterranean	52.46	19.84

This contrast should not come as a surprise. Investigating the invaders in estuaries in the Netherlands, Wolff (1999) proposed three hypotheses to explain high numbers of brackish water species: they stand a better chance of being transported because most ports are situated in brackish regions; they are more tolerant of conditions in ballast water tanks, hence have better chance of being transported alive; and because brackish waters have few species, it is easier for an introduced species to get established.

Limitations — reservations

The story of establishment success requires further scientific research. A major hindrance lies in the fact that no data could be found on the establishment success in the North Sea and the Arctic. Furthermore, in many cases the establishment success remains unknown, particularly among the more recent introductions. Further research will inevitably lead to revision of our figures.

Impact of NIS: negative but also positive aspects

The extent and/or our knowledge of the impacts of NIS are not the same in all European seas. In the Baltic, the ecological and economic impacts of NIS are not yet sufficiently investigated (Leppakoski et al. 2002b). In the Atlantic, only a few species have been responsible for negative impacts. The protist *Bonamia ostreae* is highly pathogenic to bivalves and since its introduction in 1979 has spread to all parts of Northern Europe drastically affecting both natural and cultured oyster populations. The slipper limpet *Crepidula fornicata*, by out-competing other molluscs and changing the physical environment, had detrimental effects on oyster beds and great scallop habitats (Goulletquer et al. 2002).

In the Mediterranean, many sudden changes in community diversity and structure may be attributed to competition between indigenous species and NIS. First indications of the impacts of *Caulerpa racemosa* suggest alarming changes in macrophytic as well as zoobenthic community structure and cover decrease of indigenous species (Ribera Siguan 2002). Examining the impact on the zoobenthos in Cyprus, Argyrou et al. (1999) discovered that while the abundance of gastropods and crustaceans has decreased, that of polychaetes, bivalves and echinoderms has increased. The enormous proliferation of *Anadara inaequivalvis* in the North Adriatic (Rinaldi 1985) is a typical example of such changes. Rapid decreases in the Israeli coast populations of some species support the aforementioned argument; thus, populations of the seastar *Asterina gibbosa*, the prawn *Melicertus kerathurus*, and the jellyfish *Rhizostoma pulmo* decreased, as those of *Asterina burtoni*, *Marsupenaeus* (=*Penaeus*) *japonicus* and *Rhopilema pulmo* increased in numbers, and fish populations of red mullet (*Mullus barbatus*) and hake (*Merluccius merluccius*) have been forced to migrate to deeper waters by the exotics *Upeneus moluccensis* and *Saurida undosquamis*, respectively (Galil & Zenetos 2002).

Similarly, NIS are known to have irreversibly modified all aspects of the North Sea ecosystem. According to Reise et al. (2002) their combined effects "exceeds the more often considered effects of eutrophication and toxic substances, and may rival those of the fishery in the North Sea and of habitat loss along its coastline".

In the Black Sea dramatic changes in the coastal benthic communities have been caused by the introduction of three alien species. The *Mnemiopsis leidyi*–*Beroë ovata* prey-predator interactions in the pelagic zone and the heavy predation by *Rapana venosa* have resulted in a decrease of coastal benthos biodiversity along the north Caucasian coast (Chikina & Kucheruk 2003).

A short review of the most infamous impacts documented, in addition to aforementioned cases of *Mnemiopsis leidyi* and *Caulerpa taxifolia*, is presented below.

Imported oysters are among the best known cases of negative impact on the European seas. Pacific oysters, *Crassostrea gigas*, have not only changed the ecological conditions in the North Sea (Dutch Oosterschelde estuary and in Wadden Sea) but also have caused economic losses as they interfered with the recreational use of the Oosterschelde estuary (Wolff & Reise 2002). In the Mediterranean the same species (and *Ruditapes philippinarum*), in addition to out-competing native species, have impacted the physical environment because their collection has led to increased loads of suspended material (Occhipinti Ambrogi 2002).

The alien macrophyte *Sargassum muticum* is known to have direct impacts on the native floral communities (reduction of kelp *Laminaria digitata* in northern France) (Cosson 1999) and secondary inhibition of the growth of other algae by modifying the physical environment by reduction of the water movements and light penetration in the North Sea (Scandinavia) (Karlsson & Loo 1999, Hopkins 2002) and in the Mediterranean (Ribera Siguan 2002). Furthermore, reports exist on adverse effects on other parts of the ecosystem such as growth inhibition of cultured oysters (Verlaque 2001). There are also adverse socio-economic impacts caused by clogging and fouling (Hopkins 2002).

Many cases of economic impacts in European waters have been documented. The red king crab *Paralithodes camtschaticus*, despite the fact that it has become an important fishery commodity in the Barents Sea (TAC has increased by almost 4-fold from 1994–2000), has also become such a by-catch nuisance for the Norwegian gillnet fishery that its eradication has been called for (Petryashov et al. 2002). Economic hardships have been caused by phytoplanktonic invaders responsible for blooms. In Norwegian waters the diatom *Coscinodiscus wailesii*, by producing copious mucilage, has caused serious clogging to nets and aquaculture cages. Similarly the dinoflagellate *Gyrodinium aureolum* has demonstrated massive blooms since 1966, resulting in economic losses to fish farmers (Hopkins 2002). Wild stocks of Atlantic salmon have been seriously depleted since 1975 by the introduced parasite *Gyrodactylus salaris* that has the ability to survive in brackish waters (Hopkins 2002). In the Marmara Sea the gastropod *Rapana venosa* has caused the decimation of the once-important fisheries for oysters and mussels but constitutes an important fisheries asset (Ozturk 2002). Similarly, economic benefits have ensued from the introduction of *Mya arenaria* along the Romanian coast in the Black Sea (Gomoiu et al. 2002).

Limitations — reservations

The alterations of marine ecosystems caused by NIS have been poorly studied in most regional seas. There are few well-documented cases. Biodiversity changes such as the dominance of certain species exhibiting invasive character at the expense of others have been often reported but are rarely quantified. Heightened public awareness and increasing political interest across Europe on the effects of introduced microorganisms in aquatic ecosystems and on human health have stimulated a number of research projects (Globally: GloBallast Programme, IOC/PICES; EU funded: ALIENS, DAISY, HAB, MARTOB, STRATEGY, and National Risk assessments in many countries, e.g., Italy, Norway, Slovenia and Trilateral IT-SLO-HR) that are currently in progress.

Conclusions

The introduction of NIS is a dynamic non-stop process with new species reported each day. Our research has tried to catalogue NIS as accurately as possible up to 2003; meanwhile, new species have been brought to our attention as invaders in 2004. In European waters 25 new invasive species were recorded in 2004 (23 species in the Mediterranean and two in the Baltic), revealing the difficulties in keeping records up to date as well as calling for continuous research on this issue.

The story of marine NIS across the major European seas is similar to marine invasions in other parts of the world with the added dimension of Lessepsian migrants into the Mediterranean.

The following general trends are apparent. Currently, 828 NIS have been introduced to European seas, the majority during the period 1961–1980, with the Mediterranean being by far the major recipient of exotic species. Almost 55% of these have become established in European seas (however, for approximately 20% of the total the establishment success remains unknown) with the Baltic appearing to be the most hospitable sea. Examining the taxa of the introduced species, the dominance of zoobenthic organisms and particularly Mollusca was apparent across all seas (57%).

Transportation via the Suez Canal and shipping appear to be the major vectors of introduction (accounting for 38% and 25%, respectively); however, a significant part remains unaccounted for (10%). The role of shipping should be regarded as higher than currently indicated because the significance of the Suez Canal is restricted to only one European sea — the Mediterranean. Aquaculture is the third most important means of introduction (19%) with unintentionally introduced species being more numerous (65%) compared with those introduced intentionally.

Comparing trends across taxa and seas is not as accurate as one would have wished because there are differences in the spatial and taxonomic efforts in the study of NIS. In our view, the European scientific community should focus on creating a uniform database covering all aspects of NIS introduced to its seas.

Because the issue of NIS also encompasses many socio-economic as well as scientific (environmental, biological and biodiversity) aspects, a legislative framework must come into force and be rigorously applied to safeguard European seas from invasion by harmful species.

Acknowledgements

This work has been carried out under the finance of the European Environment Agency (EEA) through the European Topic Centre for Water (ETC/WRc).

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APPENDIX 1

Directories, databases and scientific workgroups focusing on non-indigenous species

Coverage	Directories, databases and workgroups	Web site
Global	The IMO Ballast Water Treatment R&D Directory	http://globallast.imo.org/research
	The Aquatic Invasions Research Directory (AIRD)	http://invasions.si.edu/aird.htm
	The Global Invasive Species Database	http://www.issg.org/database/
	The FAO Database on Introductions of Aquatic Species (DIAS)	http://www.fao.org/waicent/faoinfo/fishery /statist/fisoft/dias/index.htm
Regional	The Baltic Sea Alien Species Database	http://www.ku.lt/nemo/read_first.htm
	The CIESM Atlas — New Exotic Species in the Mediterranean Sea	http://www.ciesm.org/atlas/index.html
	ICES Study Group on Ballast and Other Ship Vectors	http://www.ices.dk/iceswork/wgdetailacme.asp?wg=SGBOSV
	ICES Working Group on Introduction and Transfers of Marine Organisms	http://www.ices.dk/iceswork/wgdetailacme.asp?wg=WGITMO
National	U.K. — Directory of non-native marine species in British waters	http://www.jncc.gov.uk/marine/dns/default.htm
	U.S. — National Ballast Water Information Clearing House	http://invasions.si.edu/ballast.htm
	U.S. —National Marine and Estuarine Invasions Database	http://invasions.si.edu/nis.htm

APPENDIX 2

List of NIS in European seas. Note: Capital letters next to species names denote the seas where species are present. Ar = Arctic; At = Atlantic; B = Baltic; Bl = Black; M = Mediterranean; N = North. An asterisk denotes phytobenthos species whose occurrence is questionable in the Mediterranean according to the latest review by Cormaci et al. (2004).

PHYTOPLANKTON

Alexandrium andersoni — M
Alexandrium catenella — M
Alexandrium leei — At, N
Alexandrium minutum — At
Alexandrium monilatum — Bl
Alexandrium pseudogonyaulax — M
Alexandrium tamarense — At, B, M, N
Asterionella japonica — Bl
Chaetoceros coarctatus — M
Chatonella antiqua — N
Chatonella marina — N
Chatonella sp. — N
Chatonella verruculosa — N
Coolia monotis — M
Corethron criophilum — N
Coscinodiscus wailesii — At, B, N
Fibrocapsa japonica — At, N
Gesnerium mochimaensis — Bl
Gonaulax grindley — M
Gymnodinium breve — M
Gymnodinium catenatum — At, B, M, N
Gymnodinium cf. *nagasakiense* — At
Gymnodinium mikimotoi — B, N
Gymnodinium uberrimum — Bl
Gymnophycus hapsiphorus — At
Gyrodinium aureolum — At, M, N
Heterosigma akashiwo — At, N
Mantoniella squamata — Bl
Odontella sinensis — At, B, N
Olisthodiscus luteus — N
Ostreopsis lenticularis — M
Ostreopsis ovata — M
Pfiesteria piscida — N
Phaeocystis pouchettii — Bl
Platysiphonia caribaea — At
Pleurosigma planctonicum — At
Pleurosigma simonsenii — B, N
Pleurosira leavis cf. *polymorpha* — B
Prorocentrum mexicanum — M
Prorocentrum minimum — B, N
Prorocentrum redfieldii — N
Pseliodinium vaubanii — M
Pyrodinium bahamense — At
Rhizosolenia (= Pseudosolenia) calcar-avis — Bl
Rhizosolenia indica — M, N
Scageliopsis patens — At
Scrippsiella trochoidea — Bl
Stephanopyxis palmeriana — N
Symphyocladia marchantioides — At
Thalassiosira hendeyi — N
Thalassiosira nordenskioeldii — Bl
Thalassiosira punctigera — B, N
Thalassiosira tealata — N

PROTOZOA

Anguillicola crassus — At, B, N
Bonamia ostreae — At, N
Gyrodactylus salaris — N
Haplosporidium armoricanum — N
Haplosporidium nelsoni — At
Marteilia refrigens — N
Pseudodactylogyrus anguillae — At, B, N
Pseudodactylogyrus bini — B, N
Pseudostylochus ostreophagus — At

ZOOPLANKTON

Acartia centrura — M
Acartia grani — M
Acartia tonsa — At, B, Bl, M, N
Ameira divagans — B
Beroë ovata — Bl
Blackfordia virginica — At, Bl
Calanopia elliptica — M
Calanopia media — M
Cassiopeia andromeda — M
Centropagus furcatus — M

Coleoplana sp. — M
Eucheilota paradoxica — M
Eurytemora pacifica — At
Gonionemus vertens (=murbachi) — At, M, N
Maeotias inexspectata — At, B
Mnemiopsis leidyi — Bl, M
Muggiaea atlantica — M
Nemopsis bachei — At, N
Paramphiascella sibronica — M
Phyllorhiza punctata — M
Pseudocalanus elongata — M
Pseudodiaptomus salinus — M
Rhopilema nomadica — M
Sagitta neglecta — M
Scottolana bulbosa — M
Scottolana longipes — M
Stenhelia inopinata — M
Stenhelnia minuta — M

PHYTOBENTHOS

Acanthophora nayadiformis — M*
Acetabularia calyculus — M
Acrochaetium balticum — N
Acrochaetium cf. *codicolum (=Rhodothamnionella)* — M
Acrothamnion preissii — M
Acrothrix gracilis — M
Agardhiella subulata — M, N
Aglaothamnion feldmanniae — M
Ahnfeltiopsis flabelliformis — M
Alaria esculenta — N
Anotrichium furcellatum — At, N
Antithamnion amphigeneum (=algeriense) — M
Antithamnion densum — At, N
Antithamnion diminuatum — At
Antithamnion pectinatum (=nipponicum) — At, M
Antithamnionella elegans — M
Antithamnionella spirographidis — At, M, N
Antithamnionella sublittoralis — M
Antithamnionella ternifolia — At, M, N
Apoglossum gregarium — M
Asparagopsis armata — At, M, N
Asparagopsis taxiformis — M*
Asperococcus scaber — N
Audouinella sargassicola — M
Audouinella spathoglossi — M*
Audouinella subseriata — M
Batophora sp. — M
Bonnemaisonia hamifera — At, B, M, N
Botryocladia madagascariensis — M
Caulacanthus ustulatus — At
Caulerpa mexicana — M
Caulerpa racemosa — M
Caulerpa scalpelliformis — M
Caulerpa taxifolia — M
Ceramium bisporum — M*
Ceramium strobiliforme — M
Chondria coerulescens — M
Chondria curvilineata — M
Chondria polyrhiza — M
Chondria pygmaea — M
Chondrus giganteus — M
Chorda filum — M
Chrysonephos lewisi — M
Chrysymenia wrightii — M
Cladophora cf. *patentiramea* — M*
Cladophoropsis zollingeri — M
Cladosiphon zosterae — M
Codium fragile — Ar, B
Codium fragile atlanticum — At, N
Codium fragile scadinavicum — N
Codium fragile tomentosoides — At, M, N
Codium taylori — M
Colpomenia peregrina — Ar, At, B, M, N
Corynophlaea umbellata — N
Cryptonemia hibernica — At
Dasya baillouviana — B, N
Dasya sessilis — M
Dasysiphonia sp. — At, N
Derbesia boergesenii — M
Derbesia rhizophora — M
Desmarestia viridis — Bl, M*
Devaleraea ramentheca — N
Dipterosiphonia dendritica — M
Ectocarpus siliculosus — M
Elodea canadensis — B
Endarachne binghamiae — At
Fucus evanescens — Ar, B, N
Fucus spiralis — M
Galaxaura rugosa — M*
Ganonema farinosum — M*
Goniotrichiopsis sublittoralis — M*
Gracilaria arcuata — M*
Gracilaria disticha — M*
Gracilaria gracilis — N

Grallatoria reptans — At
Grateloupia cf. *turuturu*— M
Grateloupia doryphora — At, N
Grateloupia filicina luxurians — At, M, N
Grateloupia lanceolata — M
Grateloupia sp. — M
Griffithsia corallinoides — M
Halophila stipulacea — M
Halothrix lumbricalis — M
Herposiphonia parca — M
Heterosiphonia japonica — M
Hypnea cornuta — M
Hypnea esperi — M*
Hypnea muciformis — At
Hypnea nidifica — M*
Hypnea spicifera (= *harveyi*) — M
Hypnea spinella (=cervicornis) — M
Hypnea valentiae — M
Laminaria japonica — M
Laminaria ochotensis — N
Laurencia brogniartii — At
Laurencia okamurae — M
Leathesia difformis — M
Leathesia verruculiformis — N
Lithophyllum yessoense — M
Lomentaria hakodatensis — At, M
Lophocladia lallemandii — M
Macrocystis pyrifera — At
Mastocarpus stellatus — N
Monostroma obscurum — M
Neosiphonia (=Polysiphonia) harveyi — At, B, M, N
Neosiphonia sphaerocarpa — M
Padina boergesenii — M
Padina boryana — M
Pikea californica — At
Pilayella littorallis — M
Pleonosporium caribaeum — At, M
Plocamium secundatum — M
Polysiphonia atlantica — M
Polysiphonia fucoides (= nigrescens) — M*
Polysiphonia morrowii — M
Polysiphonia paniculata — M
Polysiphonia senticulosa — N
Porphyra yezoensis — M
Predaea huismanii — At
Prionitis patens — M
Pterosiphonia pinnulata — At
Pterosiphonia tanakae — M
Punctaria tenuissima — M
Radicilingua thysanorhizans — M
Rhodophysena georgii — M
Rhodymenia erythraea — M
Sarconema filiforme — M
Sarconema scinaioides — M
Sargassum muticum — At, B, M, N
Scyptosiphon dotyi — M, N
Solieria chordalis — N
Solieria dura — M
Solieria filiformis — M
Sorocarpus sp — M
Spartina alterniflora — At, N
Spartina anglica — At, N
Spartina versicolor — At
Spartina X *townsendii* — At
Spathoglossum variabile — M*
Sphaerococcus coronopifolius — N
Sphaerotrichia divaricata — M
Stypopodium schimperi — M
Symphyocladia marchantiodes — M
Ulva fasciata — M
Ulva pertusa — M
Ulva scandinavica — M
Undaria pinnatifida — At, M, N
Womersleyella setacea — M

ZOOBENTHOS

CRUSTACEA

Alpheus audouini — M
Alpheus inopinatus — M
Alpheus migrans — M
Alpheus rapacida — M
Apantura sandalensis — M
Apseudes intermedius — M
Arietelus pavoninus — M
Ashtoret lunaris — M
Atergatis roseus — M
Balanus albicostatus — At
Balanus amphitrite amphitrite — At, N
Balanus eburneus — At, Bl, M, N
Balanus improvisus — Ar, At, B, Bl, M, N
Balanus reticulatus — M
Balanus trigonus — M
Brachynotus sexdentatus — At, N
Calappa pelii — M
Callinectes danae — M

Callinectes sapidus — At, B, Bl, M, N
Canuellina insignis — M
Caprella macho — N
Caprella mutica — N
Caprella scaura — M
Carupa tenuipes — M
Cercopagis pengoi — B, N
Chaetogammarus ischnus — B
Chaetogammarus warpachowskyi — B
Charybdis helleri — M
Charybdis longicollis — M
Corophium curvispinum — B, N
Corophium sextonae — At, N
Cryptosoma cristatum — M
Diamysis bahirensis — At
Daira perlata — M
Dromia spinirostris — M
Dyspanopeus sayi — M
Echinogammarus pungentoides — M
Elasmopus pectenicrus — M
Elminius modestus — At, M, N
Enhydrosoma vicinum — M
Eocuma sarsii — M
Eriocheir sinensis — At, B, Bl, M, N
Erugosquilla massavensis — M
Eucrate crenata — M
Eusarsiella zostericola — N
Gammarus tigrinus — B, N
Gmelinoides fasciatus — B
Halimede tyche — M
Hemigrapsus penicillatus — At, N
Hemigrapsus sanguineus — At, M
Hemimysis anomala — B, N
Herbstia nitida — M
Herrmannella duggani — At
Heteropanope laevis — M
Homarus americanus — N
Hyastenus hilgendorfi — M
Iphinoes crassipes haifae — M
Ixa monodi — M
Kalliapseudes omercooperi — M
Lepas anatifera — N
Leptochela aculeocaudata — M
Leptochela pugnax — M
Leptochelia dubia — M
Leucosia signata — M
Libinia dubia — M
Limnomysis benedeni — B
Limnoria tripunctata — At, N
Loxothylacus texanus — M
Lucifer hanseni — M
Macromedaeus voeltzkowi — At
Macrophthalmus graeffei — M
Marsupenaeus (=Penaeus) japonicus — At, Bl, M
Megabalanus tintinnabulum — At, M
Melicertus hathor — M
Menaethius monoceros — M
Merhippolyte ancistrota — M
Metapenaeopsis aegyptia — M
Metapenaeopsis mogiensis consobrina — M
Metapenaeus monoceros — M
Metapenaeus stebbingi — M
Micippa thalia — M
Myicola ostreae — At, M, N
Myra subgranulata — M
Mytilicola intestinalis — At
Mytilicola orientalis — At, M, N
Notopus dorsipes — M
Obesogammarus crassus — B
Ogyrides mjoebergi — M
Orconectes limosus — B
Orconectes virilis — B
Pacifastacus leniusculus — B
Palaemonella rotumana — M
Pandalus kessleri — Bl
Panulirus ornatus — M
Paracerceia sculpta — M
Paradella dianae — M
Paralithodes camtschaticus — Ar, N
Paramysis lacustris — B
Parapilumnus malardi — At
Penaeus semisulcatus — M
Percnon gibbesi — M
Periclimenes calmani — M
Pilumnopeus vauquelini — M
Pilumnus hirsutus — M
Pilumnus perlatus — N
Plagusia tuberculata — M
Platorchestia platensis — N
Pomatocypris humilis — B
Porcellidium ovatum — At
Portunus (=Neptunus) pelagicus — M
Proasellus coxalis — N
Processa macrodactyla — M
Pseudomyicola spinosus — At
Ptericartia josephinae — M
Rhithropanopeus harrisii — At, B, Bl, M, N

Robertonia salsa — M
Scyllarus caparti — M
Scyllarus posteli — M
Sirpus zariqieyi — Bl
Solenocera crassicornis — M
Solidobalanus fallax — At
Sphaeroma walkeri — M
Sphaerozius nitidus — M
Stenothoe gallensis — M
Synidotea laevidorsalis — At
Thalamita gloriensis — M
Thalamita poissonii — M
Trachysalambria palaestinensis — M

MOLLUSCA

Acar plicata — M
Acteocina mucronata — M
Adelactaeon amoenus — M
Adelactaeon fulvus — M
Aeolidiella indica — M
Afrocardium richardi — M
Alvania dorbignyi — M
Amathina tricarinata — M
Anadara (=Scapharca) inaequivalvis — Bl, M
Anadara (=Scapharca) inflata — M
Anadara demiri — M
Anadara natalensis — M
Angiola punctostriata — M
Anomia chinensis — At
Antigona lamellaris — M
Atactodea glabrata — M
Aulacomya ater — N
Brachidontes pharaonis — M
Bulla ampulla — M
Bursatella leachi — M
Caloria indica — M
Calyptraea chinensis — At, N
Cantharus tranquebaricus — M
Cellana rota — M
Cerithiopsis pulvis — M
Cerithiopsis tenthrenois — M
Cerithium columna — M
Cerithium egenum — M
Cerithium nesioticum — M
Cerithium nodulosum (=erythraeoense) — M
Cerithium scabridum — M
Chama pacifica — M
Chelidonura fulvipunctata — M
Chiton hululensis — M
Chlamys lischkei — M
Chromodoris quadricolor — M
Chrysallida fischeri — M
Chrysallida maiae — M
Chrysallida pirintella — M
Cingulina isseli — M
Circenita callipyga — M
Clathrofenella ferruginea — M
Clementia papyracea — M
Clypeomorus bifasciatus — M
Congeria leucophaeta — N
Conus fumigatus — M
Corambe obscura (= batava) — At, Bl, N
Corbicula fluminalis — At, N
Corbicula fluminea — At, N
Crassostrea angulata — At
Crassostrea gigas — Ar, At, B, Bl, M, N
Crassostrea rhizophorae — At
Crassostrea rivularis — At
Crassostrea sikamea — At
Crassostrea virginica — At, B
Crepidula aculeata — M
Crepidula fornicata — At, B, M, N
Cuthona perca — M
Cyclope neritea — At
Cycloscala hyalina — M
Cylichnina girardi — M
Dendrodoris fumata — M
Dendrostrea frons — M
Diala varia — M
Diodora funiculata — M
Diodora ruppellii — M
Diplodonta cf. *subrotunda* — M
Discodoris lilacina — M
Divalinga arabica — M
Dosinia erythraea — M
Dreissena polymorpha — At, B, N
Elysia grandifolia — M
Elysia tomentosa — M
Ensis americanus — B, N
Ensis directus — At
Ergalatax contracta — M
Ergalatax obscura — M
Erosaria turdus — M
Favorinus cf. *ghanensis* — M
Finella pupoides — M
Flabellina rubrolineata — M
Fulvia australis — M

Fulvia fragilis — M
Fusinus verrucosus — M
Gafrarium pectinatum — M
Gastrochaena cymbium — M
Gibborissoa virgata — M
Gibbula albida — At
Glycymeris arabicus — M
Halgerda sp.— M
Haliotis pustulata cruenta — M
Haminoea callidegenita — M
Haminoea cyanomarginata — M
Hiatula ruppelliana — M
Hinemoa cylindrica — M
Hypselodoris infucata — M
Iolaea neofelixoides — M
Laternula anatina — M
Leucotina cf. *eva* — M
Lienardia cf. *mighelsi* — M
Limopsis multistriata — M
Lithoglyphus naticoides — B
Littorina saxatilis — M
Mactra lilacea — M
Mactra olorina — M
Malvufundus regulus — M
Melibe fimbriata — M
Mercenaria mercenaria — At, M, N
Metaxia bacillum — M
Modiolus auriculatus — M
Murchisonella columna — M
Murex forskoehlii — M
Musculista perfragilis — M
Musculista senhousia — M
Mya arenaria — Ar, At, B, Bl, M, N
Mytilopsis leucophaeta — B, N
Nassarius arcularius plicatus — M
Natica gualteriana — M
Nerita sanguinolenta — M
Nuttalia obscurata — N
Ocinebrellus inornatus — At
*Octopus aegina (*incl. *O. kagoshimenis)* — M
Octopus cyanea — M
Odostomia lorioli — M
Oscilla jocosa — M
Ostrea angasi — At
Ostrea denselamellosa — At
Ostrea puelchana — At
Oxynoe viridis — M
Palmadusta lentiginosa lentiginosa — M
Paphia textile — M
Patinopecten yessoensis — At
Perna picta — M
Petricola pholadiformis — Ar, B, M, N
Pinctada margaritifera — N
Pinctada radiata — M
Planaxis griseus — M
Pleurobranchus forskalii — M
Plocamopherus ocellatus — M
Polycera hedgepethi — M
Polycerella emertoni — M
Potamopyrgus antipodarum — At, B, N
Potamopyrgus jenkinsii — Bl
Psammotreta praerupta — M
Pseudochama corbieri — M
Pseudominolia nedyma — M
Purpuradusta gracilis notata — M
Pyrunculus fourierii — M
Rapana rapiformis — M
Rapana venosa — At, Bl, M
Retusa desgenettii — M
Rhinoclavis kochi — M
Rissoina bertholleti — M
Rissoina spirata — M
Ruditapes (= Tapes) philippinarum — Ar, At, B, M, N
Sabia conica — M
Saccostrea commercialis — M
Saccostrea cucullata — M
Sepia pharaonis — M
Sepioeuthis lessoniana — M
Septifer forskali — M
Siphonaria crenata — M
Smaragdia souverbiana — M
Sphenia rueppelli — M
Spondylus cf. *multisetosus* — M
Spondylus groschi — M
Spondylus spinosus — M
Sticteulima cf. *lentiginosa* — M
Stomatella impertusa — M
Strombus mutabilis — M
Strombus persicus — M
Styloptygma beatrix — M
Syphonota geographica — M
Syrnola cinctella — M
Syrnola fasciata — M
Tellina valtonis — M
Teredo navalis — Ar, At, B, Bl, M, N
Thais lacera — M
Thais sacellum — M

Theora (= Endopleura) lubrica — M
Timoclea maurica (= roemeriana) — M
Tiostrea chilensis — At
Trapezium oblongum — M
Trochus erythraeus — M
Turbonilla edgarii — M
Urosalpinx cinerea — At, N
Vexillum depexum — M
Voorwindia tiberiana — M
Xenostrobus securis — M
Zafra savignyi — M
Zafra selasphora — M

POLYCHAETA

Alkmaria rominji — N
Amphicorina eimeri — M
Bhawania goodi — M
Boccardia semibranchiata — At
Branchiomma boholensis — M
Branchiomma cingulata — M
Branchiomma luctuosum — M
Branchionosyllis exilis — M
Branchiura sowerbyi — B
Ceratonereis mirabilis — M
Chrysopetalum debile — M
Cirriformia semicinta — M
Clymenella torquata — N
Cossura coasta — M
Dasychone cingulata — M
Desdemona ornata — M
Dispio uncinata — M
Eunice indica — M
Eusyllis kupferii — M
Eusyllis wolfi — M
Fabricia filamentosa — M
Ficopomatus (= Mercierella) enigmaticus — At, B, Bl, M, N
Glycinde bonhourei — M
Goniadella gracilis — At
Hydroides albiceps — M
Hydroides cf. *branchyacantha* — M
Hydroides dianthus — At, M, N
Hydroides dirampha — M
Hydroides elegans — M, N
Hydroides ezoensis — At, N
Hydroides heterocerus — M
Hydroides homocerus — M
Hydroides minax — M
Hydroides novaepommeraniae (=grubei) — M
Hydroides operculatus — M
Hydroides steinitzi — M
Janua brasiliensis — N
Laonome elegans — M
Leiochrides australis — M
Leonates decipiens — M
Leonates jousseaumi — M
Leonates persica — M
Lumbrineris inflata — M
Lysidice collaris — M
Lysidice natalensis — M
Marenzelleria cf. *viridis* — B, N
Marenzelleria cf. *wireni* — N
Mediomastus capensis — M
Metasychis gotoi — M
Naineris quadriticeps — M
Neanthes (=Nereis) willeyi — M
Nereis gilchristi — M
Nereis persica — M
Notomastus aberans — M
Ophryotrocha japonica — M
Opisthosyllis bruneea — M
Paleonotus chrysolepis — M
Paradyte cf. *crinoidicola* — M
Paranais frici — B
Perinereis nuntia typica — M
Pileolaria berkeleyana (= rosepigmentata) — M, N
Pista unibranchia — M
Polydora redeki — B
Pomatoleios kraussii — M
Prionospio pulchra — M
Prionospio salzi — M
Protodorvillea egena — M
Pseudeurythoe acarunculata — M
Pseudonereis anomala — M
Questa caudicirra — M
Rhodine loveni — M
Scolelepsis cf. *bonnieri* — N
Scololops chavalieri candiensis — M
Sphaerosyllis longipapillata — M
Spirobranchus giganteus — M
Spirobranchus tetraceros — M
Spirorbis marioni — M
Streblosoma hesslei — M
Streblospio benedicti — At

Terebella ehrenbergi — M
Tharyx dorsobranchialis — M
Timarete ancylochaeta — M

ECHINODERMATA

Amphioplus laevis — M
Asterina burtoni — M
Asterina wega — M
Ophiactis parva — M
Ophiactis savignyi — M
Synaptula reciprocans — M

HYDROZOA

Bimeria franciscana — N
Clavopsella navis — B, N
Clytia hummelinki — M
Cordylophora caspia — At, B, N

BRYOZOA

Arachnoidea protecta — M
Bugula neritina — N
Buskia setigera — M
Celleporaria aperta — M
Celleporella carolinensis — M
Electra tenella — M
Hippaliossa acutirostris — M
Hippodina feejeensis — M
Membranipora savartii — M
Scrupocellaria jolloisii — M
Thalamoporella gothica indica — M
Tricellaria inopinata — M, N
Urnatella gracilis — Bl
Victorella pavida — At, B, N
Watersipora aterrima — At
Watersipora subtorquata — M

CNIDARIA

Bougainvillia megas — Bl
Bougainvillia rugosa — B
Diadumene cincta — At, M, N
Euphysora bigelowi — M
Garveia franciscana — B, M, N
Haliplanella lineata — At, M, N
Laodicea fijiana — M
Lytocarpus philippinus — M
Macrorhynchia philippina — M
Oculina patagonica — M
Pennaria disticha australis — M

TUNICATA

Ascidia cannelata — M
Botrylloides violaceus — M
Ecteinascidia moorei — M
Eusynstyela hartmeyeri — M
Herdmania momus — M
Metrocarpa nigrum — M
Microcosmus exasperatus — M
Molgula manhattensis — Ar, At, N
Nematostella vectensis — N
Perophora japonica — At
Phallusia mammilata — At, N
Phallusia nigra — M
Polyandrocarpa zorritensis — M
Rhodosoma turcicum — M
Styela clava — At, B, N
Symplegma brakenhielmi — M
Symplegma viride — M

PORIFERA

Callyspongia viridis — M
Chrotella cavernosa — M
Damiriana schmidti — M
Geodia micropunctata — M
Haliclona loosanoffi — M
Heteroneme erecta — M
Mycale erythraeana — M
Reniera spinosella — M
Suberites massa — N

ANTHOZOA

Aiptasia pulchella — At

ARTHROPODA

Ammothea hilgendorfi — M, N
Anoplodactylus digitatus — M

SIPUNCULA

Aspidosiphon (= Akrikos) mexicanus — M

ENTEROPNEUSTA

Saccoglosus guernei — M

FISH

Abudefduf vaigiensis — M
Acanthurus monroviae — M
Acipenser baeri — At
Acipenser gueldenstaedti — B
Acipenser ruthenus — B
Acipenser stellatus — B
Alepes djedaba — M
Apogon pharaonis (= nigrippinis) — M
Arius parkii — M
Atherinomorus lacunosus — M
Beryx splendens — M
Callionymus filamentosus — M
Carcharhinus altimus — M
Carcharhinus falciformis — M
Centrolabrus exoletus — M
Chaunax suttkusi — M
Chilomycterus spilostylus — M
Coryogalops ochetica — M
Crenidens crenidens — M
Cynoglossus sinusarabici — M
Cyprinus carpio — B
Dicentrarchus labrax — Bl
Diodon hystrix — M
Diplodus bellottii — M
Dussumieria elopsoides — M
Enchelycore anatina — M
Epinephelus coioides — M
Epinephelus malabaricus — M
Etrumeus teres — M
Fistularia commersonii — M
Fistularia petimba — M
Galeocerdo cuvier — M
Gambusia affinis holbrooki — Bl
Gephyroberyx darwini — M
Gymnammodytes semisquamatus — M
Halosaurus ovenii — M
Hemiramphus far — M
Heniochus intermedius — M
Herklotsichthys punctatus — M
Himantura uarnak — M
Hippocampus fuscus — M
Huso huso — B
Hypophthalmichtys molytrix — Bl
Hyporhamphus affinis — M
Lagocephalus spadiceus — M
Lagocephalus suezensis — M
Lateolabrax japonicus — Bl
Leiognathus klunzingeri — M
Liza carinata — M
Lutjanus argentimaculatus — M
Makaira indica — M
Microchirus (= Zevaia) hexophthalmus — M
Micromesistus poutassou — Bl
Mugil labrosus — B
Mugil soiuy — Bl, M
Muraenesox cinereus — M
Neogobius melanostomus — B
Oncorhynchus clarki — B
Oncorhynchus gorbuscha — B, Ar
Oncorhynchus keta — B, Bl
Oncorhynchus kisutch — B
Oncorhynchus mykiss – Ar, At, B, Bl, N
Oncorhynchus nerka — B
Oncorhynchus tshawytcha — B
Oreochromis niloticus niloticus — M
Oxyurichthys petersi — M
Pagellus bellottii — M
Papilloculiceps longiceps — M
Parexocoetus mento — M
Pelates quadrilineatus — M
Pempheris vanicolensis — M
Petroscirtes ancylodon — M
Pinguipes brasilianus — M
Pisodonophis semicinctus — M
Platycephalus indicus — M
Plecoglossus altivellis — Bl
Plotosus lineatus — M
Pomadasys stridens — M
Psenes pellucidus — M
Pseudupeneus prayensis — M
Pteragogus pelycus — M
Pterois miles — M
Rachycentron canadum — M
Rastrelliger kanagurta — M
Rhabdosargus haffara — M
Rhizoprionodon acutus — M
Rhynchoconger trewavasae — M
Roccus saxatilis — Bl

Salvelinus fontinalis — B
Salvelinus namaycush — B
Sargocentron rubrum — M
Saurida undosquamis — M
Scarus ghobban — M
Scomberomorus commerson — M
Scorpaena stephanica — M
Seriola carpenteri — M
Seriola fasciata — M
Seriola rivoliana — M
Siganus luridus — M
Siganus rivulatus — M
Silhouetta aegyptia — M
Sillago sihama — M
Solea boscanion — M
Solea senegalensis — M
Sorsogona prionota — M
Sphoeroides pachygaster — M
Sphyraena chrysotaenia — M
Sphyraena flavicauda — M
Sphyrna mokarran — M
Spratelloides delicatulus — M
Stephanolepis cf. *dispros* — M
Synagrops japonicus — M
Synaptura lusitanica — M
Syngnathus rostellatus — M
Terapon puta — M
Tetrosomus gibbosus — M
Torquigener flavimaculosus — M
Trachyscorpia cristulata echinata — M
Tylosurus choram — M
Upeneus moluccensis — M
Upeneus pori — M