#334 JANUARY 2017

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ICES COOPERATIVE RESEARCH REPORT

RAPPORT
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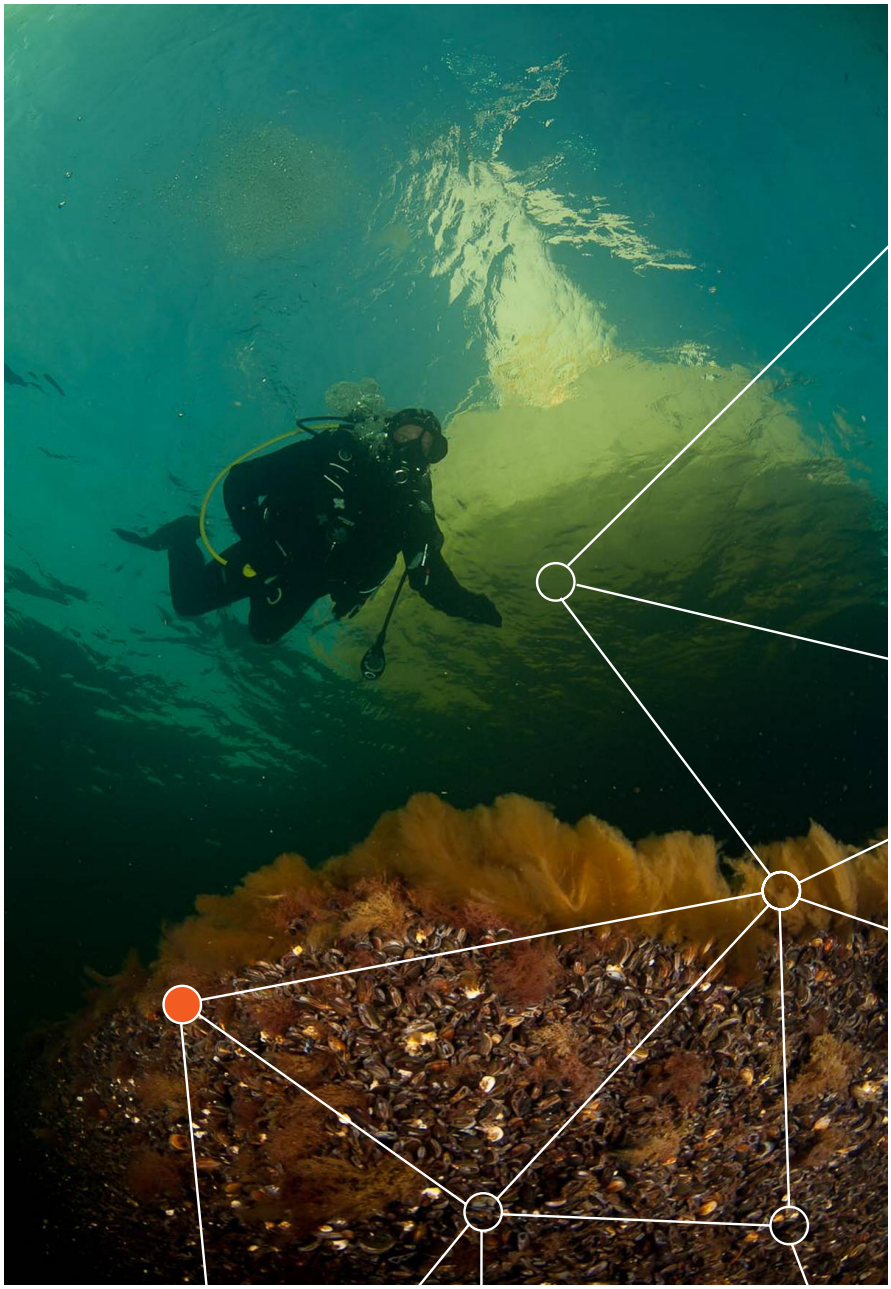

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
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Contents

Foreword

Over the past few years, new records and reports of non-native species have provided additional insight into the potential vectors and spread of introduced pathogens, plants, and animals. This five-year report brings together and summarizes the non-native species introductions reported in annual reports to the Working Group on Introductions and Transfers for the period 2003–2007. Not all countries reported every year, limiting the information on species distributions. Most of the observations are from coastal areas and embayments, and they range from marine waters to brackish and, occasionally, freshwater. One exception is an American report on a tunicate that has invaded a productive offshore area 200 nautical miles from shore, suggesting that greater effort needs to be made to determine the offshore distributions of species.

One goal of this report is to facilitate understanding of the species present in nearby countries that may disperse to neighbouring countries. The document is divided into five general sections: pathogens, phytoplankton, algae and plants, invertebrates, and fish. Rather than list each country alphabetically, each section reports on non-native species by region: Northeast Atlantic, Baltic, Mediterranean, Northwest Atlantic, Great Lakes, and northwest Pacific, and includes reports from Australia and New Zealand. This regional approach intends to provide insight into which species are spreading from country to country and how quickly they are dispersing. The summary tables at the end of the sections also present species by taxon and by region. Species such as *Crepidula fornicata*, *Eriocheir sinensis*, and *Crassostrea gigas* have been present in their non-native areas for a long time, but if they were expanding their ranges, they were included in this report. A few reports provided lists of non-native species not previously reported to ICES, and these species are also included. The editors have attempted to update taxonomic nomenclature, based on the World Register of Marine Species (WoRMS) and for algae also on www.algaebase.org.

—Judith A. Pederson

Working Group on Introductions and Transfers of Marine Organisms

1 Parasites, pathogens, and other disease agents

Ian Laing and Laurence Miossec

1.1 Introduction

In 2003, the Working Group on Introductions and Transfers of Marine Organisms (WGITMO) agreed to restructure the format of the national report to address transfers/introductions of pathogens, disease agents, and parasites. However, in 2004, when WGITMO again discussed including a section on viruses and pathogens, it was decided that, given that the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) tracks such information, the section should include limited narrative material only. For this reason, the information received for parasites, pathogens, and other disease agents in national reports is far from comprehensive.

Not all countries reported every year, and not all reporting countries reported pathogens during the years in which they submitted material. Annex 1 lists the countries that reported between 2003 and 2007. Those reporting on pathogens in each of these years were:

2003 Finland, Germany, Ireland, UK, USA

2004 Canada, Ireland, Sweden, USA

2005 Sweden

2006 Canada, France, Spain, Sweden, UK, USA

2007 Ireland, France, Sweden, UK, USA.

During this period, the two-year European project DIPNET (2004–2006), was completed, with the end result of integrating current knowledge of the transfer of pathogens between wild and cultured aquatic animal populations. This included a review of (i) disease interactions and pathogen exchanges, (ii) risk assessment and modelling of pathogen exchanges, and (iii) epidemiology and surveillance of infectious diseases in wild fish and shellfish. Findings and recommendations were disseminated to all stakeholders via a now defunct website and have also been collated into reports to the European Commission, addressing the key issues needed to ensure sustainability and responsible exploitation of aquatic environments. The last newsletter was dated 6 May 2006. There was not a comparable project, at least not to our knowledge, in the countries of the western Atlantic.

1.2 Species of special concern

In general, the shellfish parasites *Haplosporidium nelsoni* (MSX) and *Bonamia ostrae* are two species capable of spreading and causing damage to their hosts; they are thus worthy of listing as introduced parasite species of special concern. In this section, rather than list the species found in each region, lists of pathogens and parasites for marine waters (Table 1.1) and brackish and fresh waters (Table 1.2) are given at the end of the written discussions.

1.2.1 Eastern Atlantic (including the North Sea, Skagerrak, and Kattegat)

Sweden (2004–2007)

The introduced species getting most public attention during 2002 was the ectoparasite *Gyrodactylus salaris* (trematode skin flukes) found in 2001 on rainbow trout farmed in cages in the lake Södra Bullaren (province of Västergötland close to the Norwegian border). The lake discharges into two Swedish/Norwegian rivers with

salmon (Enningdalsälven and Långevallsälven). *Gyrodactylus* can survive for some time in brackish but very short time in marine waters. The parasite is native in the eastern part of Sweden, where the salmon populations are little affected. However, it has caused declines in some salmon populations on the Swedish west coast, where it turned up during the late 1980s. It is considered a great problem in Norway where native salmon die or often are heavily affected (more than 10 000 parasites have been found on one single young fish), although some may survive and get rid of the infections as do salmons from the Swedish lake Vänern. During 2002 the Fishery Board came out with recommendations to sport fishery associations to clean equipment and boats before being used in new waters and not to clean out fish in other waters nor to move them or water to other sites. In 2005 two rivers on the west coast of Sweden, previously uninfected, have been recorded as retaining the parasite *Gyrodactylus salaris*, primarily a freshwater parasite. It was found at a fish farm on the Swedish west coast and in a small river (Himleån).

An unidentified rhabdovirus was discovered in 2003 in a quarantine stock of glass eels at Helsingborg, southern Sweden. The stocking of inland waters with these fish was therefore prohibited. The rhabdovirus Eel Virus Europe X (EVEX) was found in samples of small adult eels caught at Hälleviksstrand on the island Orust, in mid-Bohuslän, and at Resö on the northern part of the Swedish west coast in 2004. IPN-V (infectious pancreatic necrosis) was recorded in a fish farm on the Swedish west coast in 2005. Again, it is primarily a freshwater virus. A new bacterial infection caused by *Francisella* sp. has been recorded in wild cod on the Swedish west coast in 2006. There is no regular monitoring programme on the bacterial health of wild fish stocks, so it is unknown how long the cod have been carrying this infection or how frequent it is among wild fish.

France (2006, 2007)

A zoosanitary surveillance programme (REPAMO) on cultured and wild populations of shellfish demonstrated the presence of *Perkinsus olseni* in wild clams *Venerupis philip-pinarum* collected in the English Channel (in Blainville and Agon-Coutainville in Normandy) in 2005. The parasite was first recorded in Portugal in 1987. Since then, it has been detected frequently in the Mediterranean Sea and Atlantic. It was observed previously in a cultivated area of clams in the Normandy–Brittany Gulf and is the first record of the parasite in wild clams in the English Channel.

Bonamia ostreae was identified for the first time in the Granville area (Normandy) in September 2005 and confirmed in November 2005 and July 2006. The prevalence of the disease remained very low (apparent prevalence 2.7%). The area was initially free of *B. ostreae*, and the origin of the infestation is unknown.

United Kingdom (2003, 2006, 2007)

An illegal consignment of large carp was intercepted at the Channel Tunnel terminal in 2002. The fish, which had been purchased in Belgium, were carrying the killer virus, Spring Viraemia of Carp (SVC), the first time this particular strain of the SVC virus (previously found in Moldova) had been identified in the UK. The fish were not allowed to enter the UK and were destroyed humanely.

Topmouth gudgeon, *Pseudorasbora parva*, continues to spread via accidental transfers, increasing the concern over the potential impact of this highly invasive species, which was discovered in 2005 to be the healthy host of a rosette-like agent.

Bonamia ostreae was detected for the first time in Northern Ireland (Lough Foyle) in 2005 and in Wales (Cleddau River) and Scotland (Loch Sunart) in 2006, the first spread of the disease in the UK since the late 1980s. The disease is suspected to have spread into previously uninfected areas through the illegal introduction of oysters from infected areas.

There was an outbreak of Viral Haemorrhagic Septicaemia (VHS) in farmed rainbow trout in North Yorkshire in 2006, the first occurrence of this disease in the UK.

An outbreak of Gaffkaemia in European lobsters at a storage site in South Wales led to suspicion that the causative organism, *Aerococcus viridans*, was endemic. Survey work is now planned.

Ireland (2003, 2005–2007)

The nematode parasite, *Anguillicola crassus*, surrounding the airbladder of the freshwater eel *Anguilla anguilla*, causing it to become inflamed, was first identified from the Waterford area (Irish south coast) in 1997. In 1999, it was found on the lower Shannon River in Lough Derg. It was also recorded from the River Erne catchment in 1999. Its level of infestation increased in silver eels captured descending the River Shannon catchment in winter 2003/2004, with up to 70% of examined eels being infested, an increase from the 11.5% observed the winter before. It was probably introduced into Ireland as a result of its infective stage being released in water used to refresh eels in vivier trucks making collections in the UK, before arriving in Ireland. However, it is possible that the infective stage could have been carried with copepods released with ships' ballast water or with water associated with fish imported to stock rivers.

Pseudodactylogyrus anguillae and *P. bini* are gillflukes of the eel *Anguilla anguilla*. *P. anguillae* was first found in eels in the west of Ireland, but it is now more widely distributed and in Lough Erne has a prevalence of >60%. *Pseudodactylogyrus bini* has also been found in Lough Erne with a prevalence of >80%. The species was probably introduced with adult *A. japonica* imported from Taiwan. Although it has already spread through much of northern Europe, it arrived only recently in Ireland.

The protozoan parasite *Bonamia ostreae* was first recorded in Ireland in 1987 in Cork Harbour in the native oyster *Ostrea edulis*. It subsequently spread to Clew Bay and Galway Bay on the west coast. In 2004, it was discovered in Achill Sound, close to Clew Bay, and in 2007 was also reported from Lough Swilly on the coast of Northern Ireland.

Spain (2005–2007)

First recorded dates of *Marteilia refringens* (1975 in Galicia, with aquaculture as possible vector) and *B. ostreae* (1979 in Galicia, with aquaculture as possible vector) were reported Cigarría and Elston, 1997).

1.2.2 Baltic coast (inside the Kattegat, Sound, and Belts)

Sweden (2003–2007)

In 2003 the swimbladder parasite *Anguillicola crassus* in eel occurred in both fresh and brackish water. It can be found in high prevalences in most freshwater lakes that have eel (H. Wickström, National Board of Fisheries, pers. comm.) and occurs in high prevalences also along the coast at least as far north in the Baltic as to Östergötland, and possibly further where eels occur (Jan Andersson, National Board of Fisheries,

pers. comm.). Overall, 60% of the eels caught in 2005 at the Oskarshamn nuclear power plant water intake (southeastern Sweden) were infested with the nematode *Anguillicola crassus* (first seen in the area in 1988), slightly less than the mean rate of infestation during the previous five-year period. Most eels had fewer than ten parasites, but one had 30. The percentages of infested eels caught by fishers in two bays in the surrounding area at the time were 50% and 64%.

The first finding of European perch rhabdo virus in farmed fish in Sweden was isolated in spring 2007 at the southern part of the Swedish east coast (the Baltic Sea). In the spring of 2007 a routine viral sample revealed an IPN-infections (Sp-type) in an inland trout farm also used for breeding of smolt from coastal wild brood stock of sea trout. The follow up by viral sampling at contact farms revealed one other site at the coast that fed sea trout smolts for delayed release. This farm was also found positive for the same type of IPN infection.

Dead perch in Lake Norrviken (just north of Stockholm) were revealed to have died in 2005 from attacks of the freshwater fungus *Branchiomyces denigrans* that had not been recorded previously in Sweden. The species, which also can infect pike and other fish, but not salmonids or carp, is well known from Germany and Poland, having caused deaths there in many farms, by penetrating the gills of fish. The fungus is believed to have arrived in Sweden with contaminated fish, but dormant spores from earlier introductions cannot be ruled out as a cause of the fish kill. High temperatures favour the growth of the fungus; spores, which are released from the gills into the water from where they infect new fish, may lie dormant for many years. Secondary diseases are common and may also cause fish death.

Finland (2003–2007)

European sheatfish virus (ESV), one of the viruses causing EHN, was isolated for the first time in Finland in 2002. A few sheatfish (*Silurus glanis*) died within two weeks of being imported from Germany. Transfer restrictions of live fish were put in place at the affected farm and, because it uses recirculated, ozone-treated lake water, with effluent run through a sewage treatment plant, the risk of spreading the virus to other farms and natural water has been practically eliminated. The whole unit was emptied and disinfected.

For the first time in 2002, *Anguillicola crassus* was found in 11 (of the 45 studied) eels ascending three rivers in Finland. Since the beginning of the 1980s, more than 1500 eels introduced into lakes have been checked for the parasite, but so far *Anguillicola crassus* has not been found in introduced eels.

1.2.3 Germany, freshwater

Germany (2003–2007)

No new records of pathogens are known. One of the parasites with the greatest impact is the eel nematode *Anguillicola crassus*, but as reported in 2003, nematode infestation of the swimbladder remains unchanged (up to 90% of the caught eels are infested). In eutrophic freshwater lakes of northern Germany, ruffe (*Gymnocephalus cernuus*) continue to act as a reservoir for *A. crassus*. In some areas, the rate of infestation varies greatly from year to year.

1.2.4 Northwest Atlantic and Pacific coasts of Canada and the USA

Canada (2003–2007)

Haplosporidium nelsoni (MSX) was reported for the first time in Canada in *Crassostrea virginica* in October 2002, associated with mortalities of >90% on several leases in Cape Breton, Nova Scotia. To date, infestations remain restricted to the Bras d'Or Lakes area of Cape Breton. No evidence has been found to date of the presence of *H. nelsoni* (or *H. costale*) in historical samples from the Bras d'Or Lakes, but investigative resources were focused on the processing of new samples during 2003. The eradication of infected oyster beds is still not considered a viable option. In 2005, MSX was confirmed in oysters from an isolated population on the north shore of Cape Breton.

Infestations of *Haplosporidium costale* (SSO) in *Crassostrea virginica* remain low, with no associated mortality or clinical proliferation in Atlantic Canadian oysters. No new infestations of *Haplosporidium* sp. have been detected in *Mytilus edulis* either, at least not since a single infestation of mussels was reported in 2002. Extensive surveillance of mussels is undertaken routinely for other infestations.

No disease outbreaks of Quahog Parasite X (QPX) in *Mercenaria mercenaria* have been reported from Atlantic Canada.

Bonamia ostreae was reported for the first time in 2004 in British Columbia (it is absent from the Atlantic coast of Canada). Examination of archived samples collected from the index site between 1999 and 2000 in conjunction with seed introduction records suggested that it might have been introduced inadvertently into British Columbia around 2003 with *Ostrea edulis* seed imports from enzootic areas in Washington State, USA.

USA (2003–2007)

The most common responses on parasites introduced to the USA generally cover new introductions of pathogens, parasites, or other disease agents, but a recent paper focuses on another aspect of parasitism (in the broadest sense), that many introduced species have fewer parasites (or about half the number) in non-native habitat than in natural habitat. For example, an animal that may have 16 parasites in its native habitat often carries < 3 to new areas (Torchin *et al*., 2003). This may allow the introduced fauna to outcompete native species that carry a heavier parasite load. It is suggested in the paper cited that parasites may be important in regulating populations and need to be examined as control options for managing or controlling invasions.

WGITMO, through its Code of Practice, has highlighted the possibility of the introduction of disease agents and pests through the introduction of target species. Another possibility is the enhancement of an endemic pathogen through the introduction of a new host species. This possibility was highlighted in the WGPDMO report made available to WGITMO. To paraphrase that report, *Bonamia* sp. (a protozoan oyster parasite) was found in transplanted triploid Suminoe oysters (*Crassostrea ariakensis*), in Bogue Sound, North Carolina, which showed high mortality, likely caused by a parasite of the genus *Bonamia* (Bishop *et al*., 2006). The same parasite was also found in the native crested oyster *Ostreola equestris*. In subsequent surveys, *Bonamia* sp. was found as far south as Fort Pierce, Florida, but has not yet been detected in Chesapeake Bay or Pamlico Sound, North Carolina. The parasite does not appear to be infective at salinities below 18 psu, and does not infect the native eastern oyster (*Crassostrea virginica*). The presence of *Bonamia* sp. may restrict the culture of *C. ariakensis* to high-salinity waters. The origin of this parasite is unknown, but DNA

analyses suggest that the Bogue Sound parasite has an affinity with southern hemisphere species of *Bonamia*. Although the parasite appears to have a local distribution, there is some evidence that it may be spreading.

In 2003, unusual ectosymbiont worms were found on blue crabs (*Callinectes sapidus*) in water of low salinity (0–3 psu) in upper Chesapeake Bay. These were identified as two species of branchiobdellan annelid (crayfish leeches), *Cambarincola mesochoreus* and *C. pamelae*, which otherwise normally occur on red swamp crayfish (*Procambarus clarkii*), a native of Gulf of Mexico drainages of the southern US. The host crayfish, presumably bearing its symbionts, has been introduced to Chesapeake Bay and other Atlantic and Pacific drainages for aquaculture, bait, and research. The impact of *Cambarincola* sp. on blue crabs is currently not known, but is likely to be confined to crabs found in water of low salinity.

1.2.5 Summary statistics of pathogens and parasites

Table 1.1. Summary of the pathogens and parasites reported in marine species by ICES country reports for 2003–2007. Not all countries report every year and some countries do not have new introductions to report.

Pathogen/parasite	Year (1st report)	Location/country	Host	Establishment/ comments
Aerococcus viridans	2006	S Wales, UK	*Homarus gammarus*	Possibly widespread
Bonamia ostreae	2004, 2007 (1987)	S, W, N Ireland	*Ostrea edulis*	Spreading
Bonamia ostreae	2005, 2006 (1980)	Scotland, Wales	*Ostrea edulis*	Spreading
Bonamia ostreae	2005, 2006	Normandy (English Channel)	*Ostrea edulis*	Low
Bonamia ostreae	2006 (1982)	Spain	Unknown	Spreading
Bonamia sp.		North Carolina, Maryland	*Crassostrea ariakensis*, *O. equestris* (native)	New, spreading
Francisella sp.	2006	Sweden, west coast	Cod	Unknown
Haplosporidium costale (SSO)	2002	Canada	*Crassostrea virginica*	Low
Haplosporidium nelsoni (MSX)	2002, 2005	Cape Breton, Canada	*Crassostrea virginica*	
Haplosporidium sp.	2002	Canada	*Mytilus edulis*	Rare (one report)
Marteilia refringens	2006 (1975)	Spain		Aquaculture, spreading
Perkinsus olseni (= atlanticus)	2005	English Channel, Normandy	*Ruditapes (= Venerupis) philipparum*	Aquaculture, spreading
Pseudodactylogyrus anguillae	2003 (~1991)	West Ireland	*Anguilla anguilla*	>60%, from *A. japonica*
Pseudodactylogyrus bini	2003 (~1991)	West Ireland	*Anguilla anguilla*	>60%, from *A. japonica*
Quahog parasite (QPX)	2004, 2006	Canada	*Mercenaria mercenaria*	

Table 1.2. Pathogens and parasites reported by ICES Member Countries from 2003 to 2007 for brackish and freshwater species. The diseases for eels appear to be reports from primarily freshwater rivers and farms.

Pathogen/parasite	Year (1st report)	Location/country	Host	Establishment/ comments
Anguillicola crassus	2006 (1987)	Sweden, east coast, freshwater	*Anguilla anguilla*	50–64%
Anguillicola crassus	2002	Finland	*Anguilla anguilla*	High
Anguillicola crassus	2002 (1987)	Sweden, , east coast, freshwater	*Anguilla anguilla*	11/45, not in stocked eels, freshwater
Anguillicola crassus	2003/4 (1991, 1999)	River Shannon, West Ireland	*Anguilla anguilla;* > 60% from *Anguilla japonica*	High
Branchiomyces negrans	2005 (2005)	Sweden	Perch	Death, diseases, freshwater
Cambarinocola mesochoresu	2003	Chesapeake Bay, Maryland	*Procambarus clarkia*	Brackish (0–3 psu) from Gulf of Mexico
Cambarinocola pamelae	2003	Chesapeake Bay, Maryland	*Procambarus clarkia*	Brackish (0–3 psu) from Gulf of Mexico
Gyrodactylus salaris	2002 (1980s) native in E Sweden	Western Sweden	Salmon	Freshwater, aquaculture
Eel Virus Europe (EVEX) rhabdovirus (unidentified)	2004	Sweden, west coast	*Anguilla anguilla*	Freshwater
Sheatfish virus (ESV)	2004	Germany	*Silurus glanus*	Died, freshwater
Infectious pancreatic necrosis (IPN)	2005	West coast of Sweden		Freshwater
Spring viraemia of carp (SVC)		Channel Tunnel terminal	Carp	Eradicated, freshwater, from Moldova
Topmouth gudgeon rosette-like agent	2005	UK	*Pseudorasbora parva*	Spreading, freshwater
Viral haemorrhagic septicaemia (VHS)	2006	North Yorkshire, UK	Rainbow trout	Farm, freshwater

2 Introduction and transfer of phytoplankton

Tracy McCollin and Inger Wallentinus

2.1 Introduction

This section includes a brief narrative of phytoplankton species reported in the annual national reports, but as noted before, not every country reports each year and not all report on introduced phytoplankton species. For this reason, the extent of information received for introduced phytoplankton in national reports is far from comprehensive. In addition, the taxonomy is continually being revised and, without voucher specimens, it is impossible to revert and to verify the accuracy of previous identifications.

2.2 Species of special concern introduced in different countries

2.2.1 Eastern Atlantic coast (including the North Sea, Skagerrak, and Kattegat)

Sweden, west coast (2003–2007)

Species that might be new to the Swedish west coast are the dinoflagellates *Dissodinium pseudocalani* and *Oxytoxum criophilum* (Mats Kuylenstierna, Göteborg University, pers. comm.). In Havsstensfjord on the Swedish west coast, there were notable concentrations of raphidophyceans of the genus *Chattonella* during April, but no real bloom (Edler, 2003). The PST-producing dinoflagellate *Alexandrium pseudogonyaulax* was common in samples from the Kattegat (Anholt and Fladen) during summer 2003 (Mats Kuylenstierna, pers. comm.).

For several years, *Chattonella* aff. *verruculos*a has been reported as a potentially introduced species in Scandinavian waters. Recent research, however, using molecular techniques along with ultrastructure and pigment data, has revealed that the species does not belong to the Class Raphidophyceae, but rather to the Dictyochophyceae, so it has been transferred to the new genus *Verruca* (Edvardsen *et al*., 2004). Those authors also found that the original Japanese species *Chattonella verruculosa* appeared in the same clade and hence that the populations in Scandinavia may still have been introduced. In 2004, this alga was found in March at all but one station along the coast of Bohuslän, with a maximum of ca. 25 000 cells per litre (Skjevik, 2004).

In April and again in November 2005, small populations were noted on the Swedish west coast. In 2006, its abundance was up to ca. 30 000 cells l^{-1}, along the Swedish west coast and the coast of southern Norway. In February 2006, concentrations >200 000 cells l^{-1} were recorded on the Swedish west coast, and Danish samples had up to 1–4 million cells l^{-1} (Skejvik, 2005–2006). In March 2006, slightly lower concentrations (145 000 cells l^{-1}) were found on the Swedish west coast, but they were still 2.6 million cells l^{-1} at Århus, Denmark, and it is assumed that it caused the death of 18 t of farmed fish in the northern part of the Great Belt area (Kalundborg Fjord; Skjevik, 2005–2006). Hence, as the species can cause fish kills, there is ongoing concern when it blooms. In 2009 the native species causing fish kills in Scandinavia was renamed *Pseudochattonella farcimen* (Eikrem *et al*., 2009), while the Asian species, also found in Sweden, is *P. verruculosa*.

Diatoms	Cyanobacteria	Dictyochophyceans	Dinoflagellates
		Chattonella aff. verruculosa (= Chattonella sp., 2003*); has been moved to the class Dictyochophyceae	*Alexandrium pseudogonyaulax*, 2003
			Dissodinium pseudocalani, 2003
			Oxytoxum criophilum, 2003

Belgium (2003–2007)

On 27 February 2006, there was a massive bloom of algae off Oostende. Samples revealed that it consisted almost solely of the diatom *Coscinodiscus wailesii*. The status of that species in Belgian waters remains somewhat unclear, and records of this species are rather scarce. Phytoplankton samples in Belgian waters are only taken irregularly and often later in the year, so it is quite possible that the presence of this species may have been missed earlier.

Diatoms	Cyanobacteria	Raphidophyceans	Dinoflagellates
Coscinodiscus wailesii, 2006			

France (2003–2007)

Two species of diatom, *Eucampia cornuta* and *Chaetoceros rostratus*, were first recorded along the Atlantic coast of west Brittany (Finistère) in autumn 2003; both are warm-water species. These observations could be related to the elevated seawater temperatures registered in that year.

Other warm-water diatoms previously recorded in the area were especially abundant in 2003; both *Asteromphalus sarcophagus* and *Chaetoceros peruvianus* had elevated concentrations of between 10^3 and 10^4 cells l^{-1}, and both could be harmful to marine fauna.

Diatoms	Cyanobacteria	Raphidophyceans	Dinoflagellates
Eucampia cornuta, 2003			
Chaetoceros rostratus, 2003			
Asteromphalus sarcophagus, 2003			
Chaetoceros peruvianus, 2003			

United Kingdom (2003–2007)

A strain of the alga *Alexandrium minutum*, isolated from the Fleet Lagoon, Dorset, has an unusual toxin profile, new to the UK but similar to that of strains found in South Australia and France.

Spain (2005–2007)

Alexandrium catenella was first reported in1983 along the coast of Catalonia, with the likely vector being ballast water (Margalef and Estrada, 1987; Gomis *et al*., 1996).

Diatoms	Cyanobacteria	Raphidophyceans	Dinoflagellates
			Alexandrium catenella, 1983

2.2.2 Mediterranean Sea

Italy (2003–2007)

Asterodinium is a distinctive genus of unarmoured dinoflagellate; it was reported initially from the tropical Indian Ocean, with the description of two species, *A. gracile* and *A. spinosum*. Later *A. gracile* and the new species *A. libanum* were reported from Lebanese coastal waters. Another four individuals of *A. gracile* were reported from four stations in the Tyrrhenian Sea (northwest Mediterranean) during 1999 oceanographic cruises (Gomez and Claustre, 2003).

The dinoflagellates *Ostreopsis* cf. *siamensis* and *Ostreopsis* cf. *ovata* have been isolated from samples taken in the Tyrrhenian Sea (Penna *et al*., 2004), and the toxic algae *Coolia monotis*, *Ostreopsis lenticularis*, and *Prorocentrum mexicanum* have been found in seawater.

In 2004, the dinoflagellate *Alexandrium minutum* was found in the Bay of Siracusa (Sicily), where it developed a toxic strain, and was followed by the bloom of another harmful algal bloom (HAB) species, *Lingulodinium polyedrum* (Giacobbe *et al*., 2003).

Prorocentrum mexicanum, a dinoflagellate producing toxins in culture, was found in coastal waters of the southern Adriatic by Cabrini (2005) for the first time in summer 2001.

The dinoflagellates *Ceratoperidinium* cf. *yeye* and *Centrodinium* sp. were found in the Gulf of Trieste (Northern Adriatic Sea) for the first time in summer 2003 (Virgilio *et al*., 2004).

Trichodesmium erythreum is a colonial cyanobacterium found also in Sicily (Barone, 2004), where in 1990 it formed a large bloom several km^2 in extent that caused notable sea scum.

There was a bloom of *Alexandrium catenella* in Olbia harbour (Sardinia) in 2002, and it ended with the export of high cell densities to sea, raising concern for possible paralytic shellfish poison (PSP) toxin contamination (Vila *et al*., 2004).

The planktonic centric diatom *Skeletonema tropicum* was found for the first time in the Gulf of Naples, and also in the Mediterranean Sea generally, in autumn 2002 (Sarno *et al*., 2005). It is a species that is considered tropical and subtropical, with a distribution not beyond 30°N in the western Atlantic. Since its first observation, it has been found regularly in late summer and autumn in the Gulf of Naples.

Diatoms	Cyanobacteria	Dinoflagellates
Skeletonema tropicum, 2002	*Trichodesmium erythreum*, 2004	*Asterodinium gracile*, 1999
		Asterodinium spinosum, < 1999
		Asterodinium libanum, < 1999
		Ostreopsis cf. *siamensis*
		Ostreopsis cf. *ovata*
		Ostreopsis lenticularis
		Coolia monotis
		Prorocentrum mexicanum
		Prorocentrum mexicanum
		Alexandrium catenella, 2002
		Alexandrium minutum, 2004
		Ceratoperidinium cf. *yeye*, 2003
		Centrodinium sp., 2003
		Lingulodinium polyedrum, 2004

2.2.3 Pacific coast

Australia (2003, 2006, 2007)

Three harmful algal species of dinoflagellate were identified in Australian waters, *Alexandrium catenella*, *Alexandrium minutum*, and *Alexandrium tamarense*, but there has been no change in their distribution. The results of the Hastings national demonstration project suggest that *Gymnodinium* spp., as identified from the ports of Victoria and New South Wales but thought to be native non-toxic species, may in fact be the non-native toxic *Gymnodinium catenatum*, but again there has been no change in the distribution of that species in Australian waters.

Diatoms	Cyanobacteria	Raphidophyceans	Dinoflagellates
			Gymnodinium catenatum, 2000
			Alexandrium catenella
			Alexandrium minutum
			Alexandrium tamarense

New Zealand (2003)

The toxic dinoflagellate *Gymnodinium catenatum* was discovered in New Zealand in May 2000; it had not previously been recorded there, though recent evidence suggests that it may have been present for some time (Irwin *et al*., 2003).

Diatoms	Cyanobacteria	Raphidophyceans	Dinoflagellates
			Gymnodinium catenatum, 2000

3 Introduction and transfer of algae and plants

Inger Wallentinus and Judith A. Pederson

3.1 Introduction

Often overlooked, algae are a significant component of coastal ecosystems. As with the other sections of this report, this section describes five years of reporting from ICES WGITMO members, but again it is necessary to note that not all countries reported each year (and some not at all). With WGITMO having the second author of this section as a member, it was able to provide information and insights into the ecology of algae, their distributions, name changes, and historical context, especially for Sweden and environments. A policy was instituted of reporting whether species had spread, were spreading, exhibited no change, and/or were not reported in neighbouring countries. That reporting practice continues, but it was not initiated until midway through the reporting period. However, based on the limited data in national annual reports and inconsistent searches for species, the documentation of species apparently not present in an area is incomplete. In contrast, for the two previous "Status Reports" (ICES, 1999, 2007b) literature and databases were searched for countries, which had not been reporting on algae, plants or phytoplankton, or when the National reports were incomplete, and published introductions found were included in those "Status Reports".

We would also like to draw attention to the increasing importance of molecular approaches for studying invasive seaweeds. The review by Booth *et al.* (2007), focusing on invasions from a genetic perspective, revealed, for example, likely Australian provenance for Mediterranean invasions of both *Caulerpa taxifolia* and *Caulerpa prolifera* var. *cylindracea*. Multiple cryptic invasions of *Codium fragile* subsp. *fragile* (= *Codium fragile* subsp. *tomentosoides*), originally from Japan, include stepping-stone introductions. However, at that time little research had been directed towards examining the genetic consequences of seaweed invasions. This review was reported by UK, but since it gives examples from many countries/continents it is included here and not under UK.

Organizing the information by region (East Atlantic Ocean, Baltic Sea, Mediterranean, Northwest Atlantic Ocean, and Indo-Pacific) allows evaluation of species dispersal and potential invasions into neighbouring countries that an alphabetical listing of countries with their taxa does not. The contributions by country also include species that may not have been reported in previous national annual reports and may go back several decades. In addition, species have been included in this section that were reported during the early part of the 21st century, particularly those that are (or are not) spreading. This information is important in understanding the distribution and spread of species. We note that *Chattonella verruculosa* is now considered to be *Verrucophora farcimen* and is apparently a species native to Europe.

3.2 Species of special concern

Several species were spreading throughout Europe during the period 2003–2007. The brown alga *Sargassum muticum* spread in Belgium, Ireland, and the UK, and was established in Norway and Sweden. The red alga *Mastocarpus stellatus* was reported in Helgoland and by 2003 had spread throughout the island. In Ireland, *Asparagopsis armata* was prevalent around an aquaculture facility, but it does not appear to have spread right along the coast, although it has been present for a long time.

Along the Italian coast, the ecology, spread, and impacts of *Caulerpa racemosa* was the basis of many studies, along with attempts to eradicate the plants. The toxicity of *C. racemosa* on other macrophytes was known in the laboratory and demonstrated in the field. Another species causing problems and widespread throughout Europe is *Dasysiphonia* (= *Heterosiphonia*) *japonica* (identified as *Dasysiphonia* sp. in WGITMO reports until 2003). Other species of concern include two red algae, *Antithamnion amphigenium* and *Gracilaria vermiculophylla*, and the brown alga, *Undaria pinnatida* (see also ICES, 2007c), that continue to spread in most countries; of which only *Gracilaria vermiculophylla* has been found in the northern parts of Europe. *Gracilaria vermiculophylla* is considered to be one of the four most invasive macroalgae in Europe. Several species appear to be spreading from the African coast and Mediterranean Sea northwards, possibly associated with warming sea temperatures. Table 3.1 summarizes all species reported during this period, although not all of them were new introductions.

In addition to noting name changes, one species, *Radicilingua thysanorhizans*, has been deleted from the Italian list of non-indigenous algae.

3.3 Introduced in different countries

3.3.1 Eastern Atlantic coast (including the North Sea, Skagerrak, and Kattegat)

Norway (2003, 2005–2007)

In 2003 and 2004, *Sargassum muticum*, the Japanese drift kelp (first recorded in 1988), became well established along the southern Norwegian coast (Skagerrak, 57°–59°N 05°–10°E). It is also established in the inner basin of Oslofjord, and is found in fairly large quantities along the southwest coast, in Rogaland, and Hordaland. It has reached Sognefjord (61°00'N 04°34'E), but there have been no confirmed reports from farther north, and no obvious increase in areas where it was already established, except that it now seems able to grow between the native *Fucus* species. The year-to-year distribution of the alga seemed to be rather dynamic, and it might reflect some properties in the dominating current system along the Skagerrak coast. By 2006, its biomass had continued to increase in areas where it had become established, i.e. sheltered to semi-sheltered localities from the Swedish border (59°03'N 11°08'E) to north of Sognefjord (61°14'N 04°56'E; Jan Rueness, University of Oslo, pers. comm.). There was anecdotal information about an expansion of the taxon north of the Sognefjord area (61°10'N 04°58'E), but no scientifically confirmed sightings. Where it has become established, its density seems to expand.

The geographic range of the Japanese red alga *Dasysiphonia japonica* (Ceramiales, Rhodophyta; reported as *Dasysiphonia* sp. until 2003, first recorded in 1996) apparently widened substantially during 2002, and it was then recorded north of Ålesund and east of Arendal. It grows aggressively in the sublittoral zone below 4–6 m deep (Jan Rueness, pers. comm.). During 2003, its range increased further, and it was then recorded north of Ålesund (62°29'N 06°07'E) and in the Kragerø (58°58'N 09°38'E) area. By 2006, its range had continued to expand northwards and southeastwards, and it was then easily found and well established in the Oslofjord (59°N 10°E) and had been identified near Trondheim (63°40'N 09°34'E). Genetic analyses have revealed species similarity with specimens found at several sites elsewhere in Europe and the Mediterranean, as well as around Korea (Jan Rueness, pers. comm.).

The rhodophycean *Gracilaria vermiculophylla* has apparently not managed yet to cross into Norway from Swedish waters.

Antithamnion nipponicum (*Ceramiaceae*, *Rhodophyta*), was found at Austevoll, south-west of Bergen (60°06'N 05°03'E; Rueness *et al*., 2007).

Red algae	Brown algae	Green algae	Phanerograms
Dasysiphonia japonica, 1996 (= *Heterosiphonia japonica*)	*Sargassum muticum*, 1988		
Antithamnion nipponicum, 2007			

Sweden (2003–2007)

Gracilaria vermiculophylla, a brownish-red algal agarophyte, can reach lengths of more than 60 cm. It was first recorded during August/September 2003 at 5 of 25 shallow archipelago localities with similar habitats sampled around Göteborg (Figure 3.3.1.1; Wallentinus, 2003; Wallentinus and Jenneborg, 2003; Wallentinus and Werner, 2008).

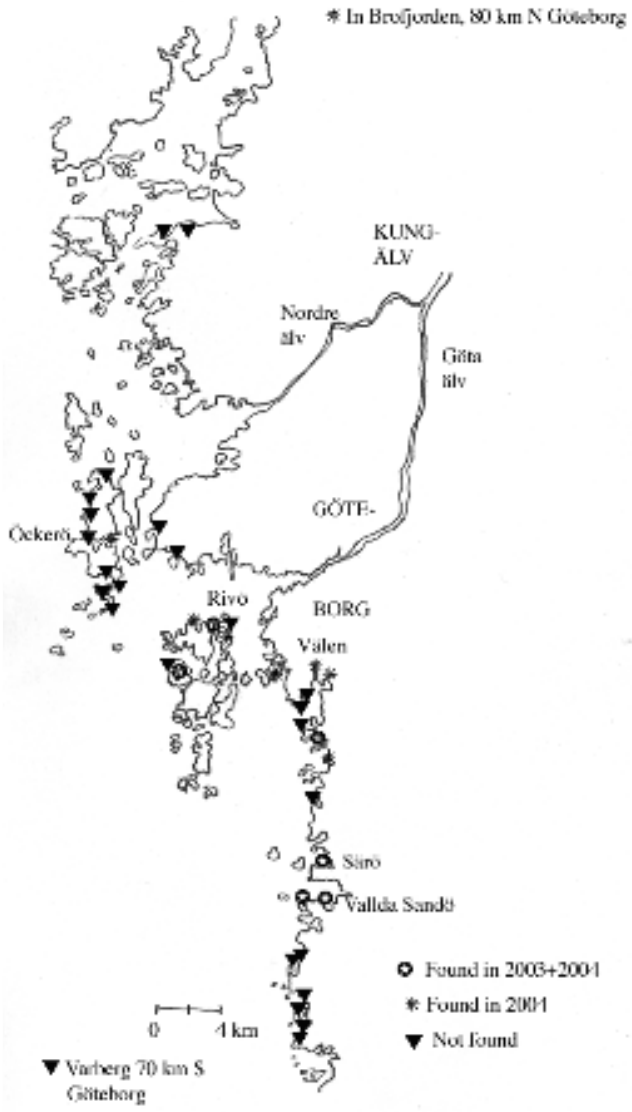

Figure 3.3.1.1. Distribution of *Gracilaria vermiculophylla* along the Swedish coast in 2003 and/or 2004. It is not possible to mark all of the sites on the map because they overlap. (I. Wallentinus, pers. comm., 2003–2004.)

The red alga was recognized by the deep (75–150 µm) male conceptacles, i.e. much deeper than in the native *G. gracilis*, and later confirmed by DNA analyses (Jan Rueness, pers. comm.). The patchy distribution points to recent introduction, but the vector is unknown. Some localities are close to harbours, but there are no shellfish aquaculture near the sites where it was found. In 2003, large-scale dredging of the harbour of Göteborg started, using two Dutch Trailing Suction Hopper Dredgers, but any ship could be the vector. The closest then known European site was Brittany in France, but *G. vermiculophylla* was also identified in samples from the landlocked Oostvoornse Meer, the Netherlands, in the 1990s (Herre Stegenga, University of Leiden, pers. comm.). In 2004, it was still present at all the stations at which it had been identified the year before, and also at an additional eight sites not visited in 2003, but it was not present at the 30 other sites visited (Figure 3.3.1.1). The maximum size measured in 2004 was 105 cm.

Several of the new sites in 2004 were close to marinas or harbours, pointing to secondary spreading by pleasure boats or fishing vessels. The record from two sites in Brofjorden, however, could either be associated with secondary spreading along the coast with boats or perhaps a new introduction, because the site there is close to the area where oil tankers arrive to discharge to a refinery. The alga was not observed in a large-scale survey of eelgrass beds in the northern and central part of Bohuslän in summer 2004, although it was searched for.

The only site in the northern archipelago of Göteborg where it was observed was in a lagoon outside a marina at the southern end of Öckerö Island. During 2004, a marina in Öckerö applied for permission to dredge in the lagoon to enlarge its capacity, and the County Administration of Västra Götaland requested that because *G. vermiculophylla* had been found at that locality, the marina as a first step had to document its dispersal in the area to be dredged. Its extent of cover in the lagoon was recorded at the start of autumn 2004. Moreover, because the alga was present in the area to be dredged, the Administration asked that the upper layer of mud with the alga be removed before dredging started. The application reverted to the regional Environmental Court (*Miljödomstol*) under the Swedish Environmental Code where the issue was addressed in March 2005. Four authorities with opposing positions commented during the review. The County Administrative Board had jurisdiction and required an inventory of the occurrence of *G. vermiculophylla* in the area to be dredged, then required the algae to be removed along with surface sediments and taken to a landfill, taking care to not spread it during dredging. The work was completed in summer 2006, but there is no record or report of whether monitoring was undertaken (Inger Wallentinus, pers. comm.).

A fisher from Vallda Sandö, ca. 30 km south of Göteborg, claimed that the alga (seen in barrels on his boat, so it could be identified) had been there for some years (how many he could not specify) and that was right along the coast from Vallda Sandö to Särö, areas that he fished. He also said that eelgrass had disappeared in some areas (there is no documentation available on eelgrass distribution in the area previously). At Rivö, close to the Göteborg harbour, *G. vermiculophylla* is forming dense mats surrounding eelgrass plants (Inger Wallentinus, pers. obs.; Lars-Harry Jenneborg, HydroGIS AB, pers. comm.). A questionnaire was sent to some 300 fishers on the Swedish west coast in autumn 2004, and 9 of the 56, who answered, claimed to have identified *G. vermiculophylla* in their areas of operation during the previous few years. As they did not need to complete their names and addresses, however, it is impossible to match the answers with the distribution map in Figure 3.3.1.1.

Salinity tolerance experiments showed that the species survived and grew for at least 22 days in salinities as low as 2 psu, demonstrating that, if only salinity is considered, the species could grow right along the coastline of Sweden to the innermost parts of Bothnian Bay, as well as along the coasts of most of the Baltic Sea countries (Nyberg *et al*., 2009). Quantification of traits of importance for the invasiveness of *G. vermiculophylla* for the three main categories – dispersal, establishment, and ecological impact, further subdivided into 13 more-specific categories (for details see Nyberg *et al*., 2009) – revealed that this species is one of the four most invasive macroalgae that have been introduced into Europe. Hence, an event tree was used to evaluate the plausible impact of its potential establishment in the brackish-water Baltic Sea.

The species can survive when kept cool and out of water (but moist) in darkness for as long as 175 days, and grew when brought to benign conditions. Furthermore, fragments of < 0.5 cm (into which it breaks easily; Nyberg *et al*., 2009) can grow to new plants, so vegetative reproduction is a shortcut to the creation of new populations.

Gracillaria vermiculophylla by then had been identified in Denmark too, on the east coast of Jutland, in Horsens Fjord, where it was first observed in 2003 (Ruth Nielsen, University of Copenhagen, pers. comm.), as well as in 2002 in Germany on the Island of Sylt (Jan Rueness, pers. comm.).

In 2005, the species was recorded much farther south than previously along the Swedish west coast, in Bua and Treslövsläge, in the centre of the province of Halland. Hence, from the first recorded identification, its distribution then had extended some 72 km north and 80 km south. During 2007 *G. vermiculophylla* was recorded from a small marina on the island Koön (57°53.4'N 11°35.3'E), inside the town of Marstrand, at the border area between the Skagerrak and the Kattegat on the Swedish west coast (Lars-Harry Jenneborg, pers. comm.; Inger Wallentinus, pers. obs.). Since it was quite common, it probably had been there for some years. By then this was the second northernmost site in Sweden, the northernmost record being a single specimen in Brofjorden in 2004, about 50 km further north.

Grazing experiments (Gustafsson, 2005) were performed in spring 2005 (in closed systems, autoclaving *Gracilaria* and water after each experiment) to determine whether any native grazer (six species tested) would consume *G. vermiculophylla*; *Ulva lactuca* was used as control. The results indicated that the invading alga will be grazed by some of the herbivores that abound on the Swedish west coast; in the tests those herbivores were *Aplysia punctata*, *Idotea granulosa*, *Littorina littorea*, and nereid polychaetes. Survival of the invading alga's thalli through the digestive system of the herbivores did not seem to be possible, so, the herbivores that do graze on *G. vermiculophylla* will not participate in dispersing the invading alga.

In 2007, there were no reports of further dispersal of this species (for the historical documentation of the spread of the species, see ICES, 2004b, 2005a, 2006).

In autumn 2003, *Dasysiphonia japonica* (i.e. "*Dasysiphonia* sp." in previous WGITMO reports) was found in the Koster archipelago, most likely having spread from the south coast of Norway, where it was now common (Jan Rueness and Marit Ruge Bjærke, University of Oslo, pers. comm.). Belatedly too, it was realized that specimens had been collected already in 2002 (Barbro Axelius, University of Stockholm, pers. comm.). Ongoing taxonomic revision showed, however, that the species genus *Heterosiphonia* was changed to *Dasysiphonia* (Kim, 2012). Probable vectors of the spread of this species could be boats or fishing, but because the main currents in the upper

water column flow from Sweden to southern Norway, driven by the generally northerly winds, a range extension from Sweden to Norway cannot be ruled out.

During 2004, *D. japonica* was very common on both sides of Kosterfjord; it was especially frequent on mussels (*Ostrea edulis* and *Modiolus modiolus*) and was also recorded in an exposed offshore "shallow" area, Persgrunden, about 20–25 km south of Koster on the Swedish west coast (Axelius and Karlsson, 2004). During 2005, it was also common on both sides of Kosterfjord. During late autumn (November–December), it is a dominant component of the flora, especially in sheltered areas (1–10 m deep) not subject to the strong currents that flow among the small islands. The southernmost known locality was then still the exposed offshore shallow area, Persgrunden, where it is found down to 19 m deep, although it is not dominant there (Jan Karlsson, pers. comm.). Again in 2006, it was common on both sides of Kosterfjord in the northeastern Skagerrak (Jan Karlsson and Annelie Lindgren, University of Göteborg, pers. comm.). In the summer of 2006, however, it was recorded for the first time much farther south (by ca. 140 km), south of the small island of Vinga, west of Göteborg, northeastern Kattegat, (Bo Gustafsson, University of Göteborg, and county administration of Halland, pers. comm.). It is not known if that record reflected secondary dispersal by fishing or leisure boats from the northern Swedish west coast (there have been no reports of the species between the two areas, and surface currents flow north) or an introduction from Denmark, where it has been found in the northern Kattegat and Limfjord since 2005 (Thomsen *et al*., 2005). The record might also be a new introduction from elsewhere, because the location is just outside Göteborg harbour. Although the species was then common along the Swedish west coast, however, it was not considered to be a real nuisance, although it may have replaced some other red algae as an epibiont on mussels (Jan Karlsson, University of Göteborg, pers. comm.).

Another red alga, *Aglaothamnion halliae*, common in harbour areas on the south coast of Norway since at least 1980, has been found in Sweden. Its identification was confirmed for the first time in Sweden in 2003 in Strömstad, Grebbestad, and Rönnäng (northern and central Bohuslän, in harbour areas on the Swedish west coast; ICES, 2004b; Marit Ruge Bjærke, University of Oslo, pers. comm.). In 2005, it was recorded in the marina at Bua, in central, northern Halland, an extension of ~100 km to the south. It is probable that it has been in Sweden much longer but not recognized, being small and similar in shape and size to some native species of the genus. In 2007, there was no report of further dispersal of the species (ICES, 2004b, 2006).

In late summer 2003, large quantities of drifting *Sargassum muticum*, the Japanese brown alga, were recorded for the first time off northern Öresund (Kullen), but no attached plants were found (Charlotte Carlsson, Länstyrelsen, Malmö, pers. comm.). The southernmost reported record of attached plants then still was from central Halland. In 2004, *S. muticum* was found within the fucoid belts around Göteborg (Inger Wallentinus, pers. obs.) while earlier establishment was in areas that were previously mostly barren shores. In late summer 2005, two attached *S. muticum* plants were found in the northern part of Helsingborg, northern Öresund (Hellfalk *et al*., 2005), and drifting plants were seen in several areas in that vicinity. For many years, only drifting specimens have been recorded along the coast south of Treslövsläge and in central Halland on the Swedish west coast, so the southern border for attached plants had clearly moved some 120 km to the south.

Laboratory experiments were carried out to test whether the low epibenthic abundance of the invasive Arctic brown alga *Fucus evanescens* relative to the congeneric *F. vesiculosus* is attributable to a more effective chemical defence against epiphyte colo-

nization. A field survey of the distribution of the common fouling barnacle *Balanus improvisus* revealed that its abundance was consistently lower on *F. evanescens* than on *F. vesiculosus*. However, contrary to those results, the experimental studies indicated that *F. vesiculosus* has a more effective anti-settlement defence than *F. evanescens*, but that both species deterred settlement by barnacle larvae, settlement being less on *F. vesiculosus* in both choice and no-choice experiments. Phlorotannins from *F. vesiculosus* also had a stronger negative effect on larval settlement and were active at a lower concentration than those from *F. evanescens*. Those results showed that phlorotannins in fucoids can inhibit settlement of invertebrate larvae, but that settlement inhibition cannot explain the lesser abundance of the barnacle on *F. evanescens* than on *F. vesiculosus*. Assessment of barnacle survival in the laboratory and in the field showed that this pattern could instead be attributed to greater mortality of newly settled barnacles, and observations suggest that the increased mortality was caused by the detachment of young barnacles from the surface of the seaweed (Wikström and Pavia, 2004).

The epiphytic community of *Fucus evanescens* was also compared with that of *F. vesiculosus* to examine the extent to which an invading seaweed can modify local biodiversity (Wikström and Kautsky, 2004). *Fucus evanescens* was much less fouled than *F. vesiculosus*, supporting both less biomass and fewer species of epiphytes. Moreover, the invasion of *F evanescens* affects the environmental conditions for many of the species associated with the *Fucus* community, but the direct effect on biodiversity is likely to be low.

During 2003, there were no major changes reported for the distribution or abundance in Sweden of any of the other introduced macroalgae – *Aglaothamnion halliae* – for its occurrence, see the report of WGITMO 2004 (ICES, 2004b, *Bonnemaissonia hamifera*, *Neosiphonia harveyi*, *Dasya baillouviana*, *Colpomenia peregrina*, *Codium fragile*, and *Fucus evanescens*, on the Swedish west coast. However, during 2004, *Codium fragile* subsp. *fragile* was more abundant than in the past and was also found in offshore areas in the central Kattegat (Jan Karlsson, University of Göteborg, pers. comm.).

Studies continued on the Swedish west coast to determine if there are any active (e.g. halogenated) substances in the introduced red alga *Bonnemaissonia hamifera*, or in other native red algal species, that can influence the settlement and growth of other organisms, including bacteria. The goal was to see if such substances have any commercial use in, for example, antifouling paints (Gunnar Cervin, University of Göteborg, pers. comm.). In an experiment by Nylund and co-workers in 2005, crude extracts from the introduced red alga *Bonnemaisonia hamifera* were tested for their ability to inhibit bacterial growth and attachment (11 strains of bacteria, representing five taxonomic groups). The extracts inhibited growth of nine bacteria at concentrations volumetrically equivalent to whole algal tissue, or lower. Extracts from four other, native red algae had weak growth-inhibiting effects on just a few bacterial strains. Surface extracts of *B. hamifera* tested on bacteria showed that metabolites are naturally present at sufficiently high concentration to inhibit bacterial growth on the surface of the alga. *In situ* quantification of bacteria on *B. hamifera* also revealed that this alga had significantly fewer bacteria on its surface than a coexisting alga, suggesting that *B. hamifera* naturally reduces its epibacterial abundance by producing a broad spectrum of growth-inhibiting secondary metabolites. This is one of a few examples where ecologically relevant effects of algal metabolites on bacterial colonization have been demonstrated.

The red alga *Dasya baillouviana*, introduced into the Swedish west coast in 1953, was more abundant in summer 2004 in some areas than previously. In Tjuvkilen (ca.

60 km north of Göteborg), for example, it occurred as dense, loose-lying patches of plants >0.5 m long, down to some depth (Inger Wallentinus, pers. obs.). It was also common in the harbour area in Göteborg (Inger Wallentinus, pers. obs.; Lars-Harry Jenneborg, HydroGIS AB, pers. comm.). The species seemed to have increased also in Danish (Ruth Nielsen, University of Copenhagen, pers. comm.) and Norwegian waters (Jan Rueness, pers. comm.). During 2005, it was common on both sides of the Kosterfjord, North Bohuslän. During late autumn (November–December), it was a dominant component there, especially in sheltered areas (1–10 m deep) with strong currents among the small islands.

The southernmost known locality for *Hetrosiphonia japonica* was still the very exposed offshore shallow area, Persgrunden, about 20–25 km south of Koster, where it existed down to 19 m deep, although not as a dominant alga (Jan Karlsson, pers. comm.).

A study was made during autumn 2005 to determine whether the generalized theories on mechanisms behind plant invasions (the Enemy Release Hypothesis, the Evolution of Increased Competitive Ability Hypothesis, and the Intrinsic Resistance Hypothesis) were applicable to macroalgae, which are generally grazed by generalist herbivores (Hill, 2006). The introduced macroalgae *Sargassum muticum*, *Codium fragile*, and *Bonnemaisonia hamifera* were tested in feeding preference experiments with two generalist mesoherbivores, and compared with several native seaweeds. Overall, the results did not support a general release from enemies, but *Bonnemaisonia hamifera* was significantly released compared with native species, whereas the two other macroalgae were preferred food items.

The saltmarsh grass *Spartina anglica* was detected as an isolated population on the island of Rörö in the northern archipelago of Göteborg, the Swedish west coast, in summer 2007 (Ferm, 2007). This first record for Sweden consisted of a population of around 7 m^2, probably having been there for some years, but did not exist there in the mid 1990s. The nearest area, where it occurs, is on the Danish island of Læsø, in the northern Kattegat, ca 70 km southwest of the Swedish site.

Red algae	Brown algae	Green algae	Phanerograms
Gracilaria vermiculophylla, 2003	*Sargassum muticum*, 1987	*Codium fragile* subsp. *fragile*, 1938	*Spartina anglica*, 2007
Aglaothamnion halliae, 2003	*Colpomenia peregrina*, 1950		
Dasysiphonia japonica (= Heterosiphonia sp.*)*, 2002			
Bonnemaissonia hamifera, 1905			
Dasya baillouviana, 1953			

Germany (2003–2007)

Mastocarpus stellatus (Gigartinales, Rhodophyta) is a cold–temperate amphioceanic North Atlantic intertidal red seaweed. Although the island of Helgoland (North Sea) lies within its biogeographic range, the species never colonized the island. There are a few single records from the 19th century (Bartsch and Kuhlenkamp, 2000; R. Kuhlenkamp, pers. comm.), but they are partly of a doubtful nature. The first record of attached plants establishing a stable population was in 1983 on basaltic rocks in the western part of the island (Kornmann and Sahling, 1994). The plants probably be-

came established unintentionally after field experiments with Icelandic strains in the late 1970s. Within 20 years, the species became prominent on all man-made and natural hard substrata around the island, and also entered the red sandstone wave-cut platform. It formed extensive stands especially on exposed sites, and its spread substantially changed the appearance of some intertidal biotopes during recent years and brought a decline of the native *Chondrus crispus* (Bartsch and Tittley, 2004; ICES, 2007b). Its impact is still unresolved, and although it initially probably colonized macroalgal-free substrata, the results of quantitative studies are missing. Further spread downshore suggests that climax spread of *M. stellatus* had not yet been attained.

Macroalgae for human consumption, for which they are advertised as marine vegetables, is becoming increasingly popular. Currently test cultures are underway using native species, the brown alga *Saccharina latissima* (= *Laminaria saccharina*) and the red alga *Palmaria palmata*.

The first German record of the West Pacific red alga *Gracilaria vermiculophylla* in the North Sea was in 2002. Local populations in the North Sea were becoming more common, and its spread was continuing in 2007. For its appearance along the German Baltic coast see below.

Red algae	Brown algae	Green algae	Phanerograms
Mastocarpus stellatus, late 1970s Helgoland); native North sea coast			
Gracilaria vermiculophylla, 2002			

Belgium (2003–2007)

After a presence for some years in the Spuikom of Oostende, there were no records of *Sargassum muticum*, *Codium fragile* subsp. *fragile* for some years from 2002. This was probably because of changes in the water regime of the pond. However, in 2007, a large population of *Sargassum muticum* was discovered in the inner port of Zeebrügge, where it formed a large belt just below the waterline, right along the banks of the saltwater channel leading to Brugge. In the Spuikom of Oostende too, the species was again found.

Polysiphona senticulosa, a red alga, was first recorded in March 2001 from the Spuikom in Oostende, where it was also present in 2002. During subsequent years, it was not found again until 16 March 2006 when it was again very abundant.

After the first record of *Undaria pinnatifida* in 1999 (ICES, 2007c) that species was still present in Zeebrügge marina, but apparently not spreading as a consequence of coot, *Fulica atra*, predation.

In 2007, *Gracilaria vermiculophylla* (an invader) was not found, but the native *G. gracilis* was found.

Red algae	Brown algae	Green algae	Phanerograms
Polysiphona senticulosa, 2001	*Sargassum muticum*, 1999	*Codium fragile* subsp. *fragile*, 1998	
	Undaria pinnatifida, 1999		

France (2003–2007)

Kraan and Barrington (2005) reported that a commercial seaweed farm cultivating *Asparogopsis armata* was set up in the mid-1990s on the Island of Ouessant, Brittany, northwest France, By the mid-2000s, it encompassed 2 ha, with 14 km of cultivation ropes. The annual yield then was estimated at 8 t (ww). Wild plants are used as seed stocks and gametophytes propagated vegetatively.

Red algae	Brown algae	Green algae	Phanerograms
Asparogopsis armata, 1922			

UK (2003–2007)

There is concern over the spread of the brown alga *Sargassum muticum* into the Menai Strait SAC (Special Area of Conservation), and the Countryside Council for Wales (CCW) is considering how to deal with it. In 2004, the species continued to spread around the Welsh coast, and was then well established along much of North Wales, and continued to spread (Figure 3.3.1.2). By 2005, it was spreading north up the English west coast, and had been found in Loch Ryan (Dumfries and Galloway), the first record for the species in Scotland. A small population was also found in February 2004 during a survey of Loch Ryan, and a subsequent survey by Scottish Natural Heritage (SNH) confirmed that the seaweed had then became established at several other sites around that loch. Issuing a press release to raise awareness of the find in the hope that further sightings would be reported, it was then identified around Great Cumbrae (Scottish Islands).

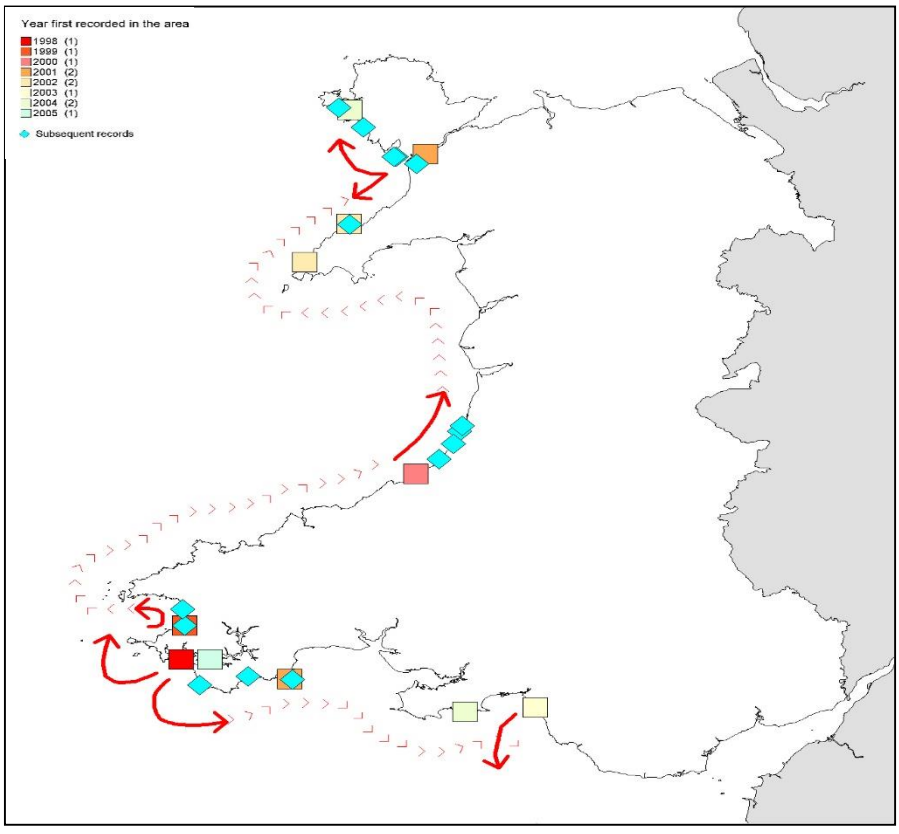

Figure 3.3.1.2. Spread of *S. muticum* in Wales.

Sediment cores were collected under and outside canopies of *S. muticum* in Strangford Lough (where it was first recorded in 1995) and Langstone Harbour, English Channel (where it was first found in 1974), to investigate modification of the infaunal assemblages. At both study sites, community analyses highlighted significant differences between the assemblages under the canopies and those in adjacent unvegetated areas. In Strangford Lough, the invertebrate community under the canopy contained a greater abundance of smaller, opportunistic, *r*-selected species than outside the canopy. By contrast, the communities under and outside the canopy at Langstone Harbour were similar in species composition, diversity and dominance, but overall faunal abundance was greater under the canopy. Sediment characteristics were not affected by *S. muticum* canopies, but the infaunal changes may be related to environmental modification; shading, flow suppression, and temperature stratification were also investigated. The differences between these two sites indicate that localized conditions and/or the duration of colonization of *S. muticum* are important in determining the nature of habitat modification (Strong *et al*., 2006).

The range of *S. muticum* in Wales appeared to have remained stable, although anecdotal records of increased abundance in North Wales had been documented. However, in Scotland, it was spreading and was already present in Loch Fyne in summer 2006, the fourth record in Scotland since first being recorded in Loch Ryan in 2004, and populations had also been found at Great Cumbrae Island and on the North Ayrshire coast, indicating spread north along the west coast of Scotland. It may also be present in other locations in the Firth of Clyde.

During 2004, *Dasysiphonia japonica* was confirmed as present at Alturlie Point near Inverness in the inner Moray Firth, the first occurrence of the species in Scotland, and following complaints made about its detrimental effects on a salmon netting station. Its source or direction of spread is not known. Initially, it was confused with *Halurus flosculosus*, but identification has now been confirmed. The species had previously not been recorded farther north than Wales (found there in 1999), was first recorded in Europe in 1984, and established populations were in 2004 found in the Netherlands, Spain, France, Norway and Sweden. By 2005, it had become widespread along the south coast from Devon to the Isle of Wight.

Caulacanthus okamurae had crossed the Channel to Devon and Cornwall, where it was found at Plymouth in 2004 and at Looe in 2005 (Mineur *et al*., 2006).

The range of *Undaria pinnatifida* does not appear to be extending.

Red algae	Brown algae	Green algae	Phanerograms
Dasysiphonia japonica, 2004 Scotland (1999 Wales)	*Sargassum muticum*, 1973		
Caulacanthus okamurae, 2006 (2004)	*Undaria pinnatifida,* 1994		

Ireland (2003, 2005–2007)

The red alga *Asparagopsis armata* was first recorded in Ireland in 1939, having arrived accidentally. The species is currently in culture on longlines in Ard Bay on the west coast. It is produced for its volatile halocarbons, which are used in cosmetics, and that is the only farm where it is produced (Morrissey *et al*., 2001). The plant has two conspicuous life-history stages, the Falkenbergia tetrasporophyte phase known in the

wild in Ireland from the northwest and south coasts, and the gametophyte stage, which is known only from the west and south coasts. The gametophyte stage is common in the region of the farm in spring, and it is thought that the existence of the farm has increased the local abundance of that stage. The species is not known to undergo sexual reproduction in Ireland, and elsewhere it is uncommon.

Sargassum muticum was first recorded in Ireland in 1995, having come from the Northern Irish coast in Strangford Lough, and it was probably present a few years before its discovery. In 2001, a plant fragment 1.5 m long was found on the southeast coast in the fishing harbour and marina of Kilmore Quay, and by 2002, there were notable stands present. By March 2004, plants 10–50 cm long were extending east from Kilmore Quay for 2 km in rock pools and near low water. Also in 2001, the species was found both on the southwest coast in Kenmare Bay, where it became locally common in 2002, and on the west coast in Betraghboy Bay. A fresh population was recorded on the northwest coast in 2002 at Drumcliffe Bay, and it is suspected that oyster movements may have been responsible for its establishment on the south and west coasts. Its presence in Kilmore Quay may have been the result of natural drift or perhaps it was carried there by leisure craft. Two new localities for the species were added in 2003, the marine reserve at Lough Hyne on the southern coast (Cynthia Trowbridge, pers. comm.), and a small population in a pool at Fanad Head (Christine Maggs, pers. comm.). Studies on the physiology of the species are being undertaken at the National University of Ireland. In 2006, *S. mutica* was found for the first time in Carlingford Lough, northeast coast of Ireland. Many detached specimens were also stranded on the upper shore there.

Red algae	Brown algae	Green algae	Phanerograms
Asparagopsis armata, 1939	*Sargassum muticum*, 1995		

Spain (2005–2007)

The invasive brown alga *Undaria pinnatifida* was first reported in Spain in the Ria de Arousa, Galicia (NW Spain) 1988, and continues to spread (Pérez-Ruzafa *et al*., 2002; Caamaña, 1990). Another invasive brown alga, *Sargassum muticum*, was first reported in 1985 in Guetaira, Bay of Biscay was also spreading; aquaculture is the likely vector (Fernández *et al*., 1990).

Two algae, the brown alga *Colpomenia peregrina* (first recorded in the Atlantic coast of Spain < 1923) and *Codium fragile* subsp. *fragile*, found in Asturias (Bay of Biscay) since the 1950s (J. Rico, pers. comm.). The red alga *Asparagopsis armata* and its tetrasporophyte *Falkembergia rufolanosa* have also been found in the Bay of Biscay (Asturias, since the 1920s). Similarly as reported in 2002, two red algal species reported from the Asturias (Bay of Bascay) were *Grateolupia filicina,* present in 1990, and *Bonnemaisonia hamifera,* present before < 1991.

Two phanerograms were reported in the North Atlantic. The first report of *Spartina densiflora* was during the XVI century in the Gulf of Cádiz (Castillo *et al*., 2005; Nieva *et al*., 2001, 2003) being later reported (≤ 1937) in the Mediterranean coast of Spain in Estany de Remolar (Castelldefels, Barcelona, NE Spain). *Spartina versicolor* was first reported in 1993 in Asturias (Bueno Sanchéz, 1997; Torre Fernández, 2003; Vila *et al*., 2001).

Red algae	Brown algae	Green algae	Phanerograms
Bonnemaisonia hamifera, < 1991	*Undaria pinnatifida*, 1988 (Atlantic coast)	*Codium fragile* < 1957; 2002	*Spartina densiflora*, XVI century
Asparagopsis armata- Falkenbergia rufolanosa, 1920s; 2002	*Sargassum muticum*, 1985		*Spartina versicolor*, 1993
Grateolupia filicina, 1996	*Colpomenia perigrina*, < 1923		

3.3.2 Baltic Sea coasts (inside the Kattegat, Sound, and Belts)

Sweden (2003–2007)

During 2003, there were no major changes reported for the distribution or abundance in Sweden of the charophyte *Chara connivens* in the province of Uppland on the Swedish east coast. However, in 2006 it was found at some new stations outside the town of Öregrund (60°28.5'N 18°33.4'E) and in Lövstabukten further north, southeast of the town of Gävle (Hjelm *et al.*, 2007).

Red algae	Brown algae	Green algae	Charophyte
			Chara connivens, < 1950s

Germany (2003–2006)

Gracilaria vermiculophylla appeared along the Baltic coast in the Kiel Fjord near the port (marina) of Schilksee in 2005 (Nehls, 2004; Nehring, 2005). Local populations in the Baltic Seas were becoming more common, and its spread was continuing in 2007. In the Baltic, a survey between Flensburg and Warnemünde revealed its key distribution to be in the Kiel Bight. Along the western part of the Kiel Fjord, south of the entrance to Kiel Canal, *G. vermiculophylla* coverage then reached 50–100%. The easternmost finding of the survey was near Wismar (southeastern Lübeck Bight), where coverage was < 1%. Experiments revealed that the alga grows in salinity as low as 5.5 psu, demonstrating its potential to spread and establish in a wide area of the western Baltic. Preliminary results showed that it may have the potential to compete with the native *Fucus vesiculosus* in shallower areas that are less exposed. Clearly, the alga has high potential to spread, and it may ultimately colonize many of the shallower areas.

Red algae	Brown algae	Green algae	Charophyte
Gracilaria vermiculophylla, 2005			

Mediterranean Sea

Spain (2005, 2007)

Several algal species have been identified as introduced. The green alga *Caulerpa taxifolia* was first reported along the Mediterranean coast, with the likely vector being the aquarium trade (Meinesz *et al.*, 1998; Aranda *et al.*, 1999), first recorded in Mediterranean Spain in 1992. The green alga *Caulerpa racemosa* was first reported in 1998 in Mallorca, again with the aquarium trade assumed to be the source of the introduction (Aranda *et al.*, 1999; Ballesteros *et al.*, 2000). The red alga *Lophocladia lallemandii* grows as an epiphyte and was reported in the South Mediterranean and spreading, first noted in Mediterranean Spain 1987 (Soto and Conde, 1988; Conde *et al.*, 1996; Patzner, 1998).

Acrothamnion preissii has apparently been found in Mallorca, but its taxonomy is uncertain (Ferrer *et al*., 1994). *Antithamnion amphigenium*, a red alga, has been found in Mallorcain 1990, and is spreading (Ribera Siguan and Soto Moreno, 1992; Ballesteros *et al*., 1997; Aranda and Solano, 1999) and *Antithamniion preissii* was reported in 1994 (Ferrer, *et al.,* 1994). *Womersleyella setacea* is a pan-tropical red alga reported in the Balearic Islands in the early 1994 (Ballesteros *et al*., 1997) which had previously been reported from the Alboran Island in 1988/1992 (Rindi and Cinelli, 1995; Ballesteros, 1993). A red alga also found in the Mediterranean Sea (and on the Spanish Atlantic coast) is *Asparagopsis armata* and its tetrasporophyte *Falkenbergia rufolanosa*. It was first reported in the Mediterranean Sea in the 1920s. *Grateolupia filicina* was reported in the Mediterranean.

The two algae known as oyster thieves, the brown *Colpomenia peregrina* and the green *Codium fragile* subsp. *fragile* (in 2005), have been reported in the Mediterranean Sea. The brown *Demarestia viridis* was first reported in 1984 at Malaga (Bourdouresque and Verlaque, 2002).

Spartina densiflora was reported in Estancy de Remolar in 1937 (Castelldefels, Barcelona, Spain, originally identified as *S. juncea*; Javier *et al.,* 2005).

Red algae	Brown algae	Green algae	Phanerograms
Acrothamnion preissii, < 1994	*Colpomenia perigrina* < 1983	*Caulerpa taxifolia*, 1992	*Spartina densiflora*, 1937: Bolos 1947 as *S. juncea*
Antithamnion amphigenium, 1990	*Demarestia viridis*, 1984	*Caulerpa racemosa*, 1998	
Lophocladia lallemandii, 1987		*Codium fragile* subsp. *fragile*, (2005)	
Womersleyella setacea, early 1990s			
Asparagopsis armata and *Falkenbergia rufolanosa*, 1920s			
Grateolupia filicina, 2002			

France (2003–2007)

Califa 2000 was a survey carried out in September 2000 to assess the distribution of *Caulerpa taxifolia* and *Caulerpa racemosa* in the harbour at Hyères, Porquerolles Island included, and Toulon harbor, in the Mediterranean Sea, southern France (see Verlaque *et al.,* 2003; Booth *et al*., 2007; ICES, 2007b).

The results confirmed the presence of these two species in the area (Belsher *et al*., 2003). *C. taxifolia* was observed between −2 and −15 m and *C. racemosa* between −20 and −30 m. Both were found along with the native *C. prolifera*, and the spread of the invaders has likely been driven by leisure craft.

Red algae	Brown algae	Green algae	Phanerograms
		Caulerpa taxifolia, 1984	
		Caulerpa racemosa, 1997	

Italy (2003–2007)

In 2003, two new species, *Batophora* sp., and *Hypnea cornuta*, were reported from the Mediterranean Sea and one species, *Lomentaria hakodatensis* was taxonomically still under debate. *Batophora* sp. (Daycladales, Chlorophyta), found near Taranto (Ionian Sea), was the first record of the genus in the Mediterranean (Bottalico *et al*., 2002). *Hypnea cornuta* (Gigartinales, Rhodophyta), found in the Mar Piccolo of Taranto (Ionian Sea), was the first record in Italy (Cecere and Petrocelli, 2002). *Lomentaria hakodatensis* was found in Venice and had already been reported from various localities in the Mediterranean and Atlantic; it may be a synonym of *L. firma* Zanardini, described earlier from the Adriatic (D. Curiel and M. Cormaci, pers. comm.).

Radicilingua thysanorhizans has to be deleted from the Italian list of non-indigenous species of algae (Ribera Siguan, 2002).

The distribution of the green alga *Caulerpa racemosa* (Caulerpales, Chlorophyta) has been expanding in the Adriatic (Otranto and Monopoli: Bottalico *et al*., 2002), in the Tyrrhenian (Calabria: Cantasano, 2002), and in the Ligurian Sea (Cinque Terre: A. Molinari, pers. comm.). Its physiology has been studied in the Naples area (Raniello *et al*., 2004), where it had been formally recorded since 1997, though by 2006 it had spread along a substantial part of the coast. It only grows rapidly during summer on all kinds of substrata, from the surface down to 70 m. The extent of its colonization has now been reassessed, however. Its presence has been documented along the coasts of 11 countries from France to Croatia, developing in both polluted and unpolluted areas. It now covers at least 600 km of coast (Piazzi *et al*., 2003, 2005a). In 2007, a population was found in the protected area of Isole Ciclopi (East Sicily, 37°33'25"N 15°09'16"E, depth 13 m; Giaccone *et al*., 2010). One variant, *Caulerpa racemosa* v. *cylindracea*, negatively impacts coralligenous communities along the coast of Tuscany. The feasibility of manually eradicating it has been evaluated through experimental removals from patches of different size in four habitats. Regrettably, however, manual removal alone is not sufficient to prevent regrowth from fragments left *in situ*, and a combination of destructive methods of control, such as mechanical scraping and use of a benthic vacuum is thought to offer the best chance of success and best habitat conservation (Ceccherelli and Piazzi, 2005).

In addition to detailed information that is now available on all Italian localities where *Caulerpa racemosa* has been found (Piazzi *et al*., 2005a), its expansion, starting from a small initial point near Taranto in 1996, has been monitored continuously (Cecere *et al*., 2005). Moreover, work on interactions of *Caulerpa* species with native algae has continued. Near Leghorn, where *Caulerpa racemosa* and *C. taxifolia* co-occur, macroalgal communities were more different from reference areas when invaded by *C. racemosa*; the structure of invaded communities was also related to the invader in terms of growth habit (Piazzi *et al*., 2003; Balata *et al*., 2004). In habitats where four introduced macroalgae are present with high percentages of macroalgal abundance, the native community was badly affected (Piazzi and Cinelli, 2003). The effect of the increase in sediment deposition on the spread of *Caulerpa racemosa* var. *cylindracea* and the interactive effects of sedimentation and *C. racemosa* on native macroalgal assemblages continue to be evaluated by means of field experiments near Leghorn (Piazzi *et al*., 2005b). Results showed that *C. racemosa* was not affected by increased sedimentation rate, and synergistic mechanisms between sediment deposition and *C. racemosa* colonization resulted in a strong decrease in percentage cover of the main algal species in areas where the two disturbances overlapped.

As output of the European project ALIEN, in-depth studies of macroalgae in Italian waters have included work on the effect of temperature on growth and photosynthesis of *Caulerpa racemosa* var. *cylindracea* (Raniello *et al*., 2004, 2005; Flagella *et al*., 2005a), molecular aspects of *Caulerpa* ecology (Patti, 2004; Varela-Alvarez *et al*., 2006), and studies of the ecology of *Asparagopsis taxiformis* (Flagella *et al*., 2005b). Furthermore, effort has been devoted towards increasing knowledge of the potential for re-establishment of Mediterranean assemblages when they have been invaded by alien species, and in the process useful information has been acquired on how to manage and control invaders (Piazzi and Ceccherelli, 2006). For instance, the capacity for recovery of macroalgal rocky assemblages south of Leghorn that had been colonized by *Caulerpa racemosa* was evaluated after its attempted eradication. An experiment was performed over a year starting in 2003 to compare the structure of native assemblages invaded by the alga and others where the alga was removed with assemblages that had not been invaded. That particular site had been invaded by *Caulerpa racemosa* in 1996 and, at the start of the experiment, populations of the alga consisted of a wide layer of stolons on the seabed. The one-year period was considered sufficient to be able to predict recovery of cleared surfaces by endemic algal assemblages. In invaded plots, total percentage cover and species richness were lower, the encrusting layer was not developed, and in the turf layer, the most common species were the same as in the control locations, though fewer species were observed. In plots where eradication had been attempted, total percentage cover and richness increased, and the encrusting layer, completely absent before the eradication, showed a slight recovery in abundance one year after the eradication. Recovery was related to a significant increase in species richness and cover of macroalgae, revealing a pattern similar to that described after the removal of other impacting effects, such as sewage outfall. However, the abundance of each layer of vegetation did not change significantly through time, suggesting only slight changes in the complexity of the assemblage, in contrast to the situation following other examples of recovery. In fact, most of the algae that recolonized plots from which *C. racemosa* had been eradicated were turf species and, although several encrusting and erect species recolonized the eradicated plots, their cover was low. This work is consistent with the results of other studies that have shown that *C. racemosa* substantially modifies Mediterranean macroalgal communities.

Other work carried out has looked at the colonization success of *Caulerpa* species. Whereas two varieties of *C. racemosa* present in the Mediterranean Sea are mainly documented as forming shallow stands, *C. racemosa* var. *cylindracea* covers a wide range of depths, from the intertidal zone down to at least 60 m. Therefore, the physiological response of the organism to the irradiance regime was investigated by Raniello *et al*. (2004, 2006) along gradients of depth and daylight. Unsurprisingly, light is the main factor influencing photosynthetic performance and growth, and a marked acclimatization capacity of photosynthetic traits may be related to the invasive success. Efficient acclimatization of photosynthesis and pigments to different microhabitat conditions and seasonal change is also evident during the circadian cycle and along the depth–radiance gradient, and the results of the research point to a well-defined function of siponaxanthin, not only in acclimatization to deep light regimes, but also in photoprotection of shallow stands through regulated conversion into lutein, with the dual role contributing to the alga's ability to become distributed over a wide range of depths.

Allelopathy has been postulated as a factor in the colonization success of *Caulerpa racemosa* var. *cylindracea*. In order to reveal possible phytotoxic activity, secondary

metabolites (terpenoids, including caulerpenyne) were isolated from a population growing in the Gulf of Naples and tested on leaf tissue of the native seagrass *Cymodocea nodosa*, which often co-occurs with *Caulerpa* in nature (Raniello *et al*., 2007). The approach followed included the extraction, purification, and identification of putative allelochemicals from tissues of *C. racemosa* var. *cylindracea*. Toxicity was then tested on leaf fragments of *C. nodosa*, assessed through the effect on the photosynthetic performance of the seagrass, represented by variations in chlorophyll fluorescence. The aim was to provide preliminary evidence of allelopathic interactions between the two plants, and the results provide the first evidence of a toxic effect of caulerpenyne on marine macrophytes, although the toxicity of this compound to sea urchin eggs, mice, and mammalian cells had already been documented by classical toxicity assay.

Caulerpa taxifolia, established in Liguria and expanding along the Tyrrhenian coasts of Sicily, Calabria, and Toscana, has also now been found in Campania (Russo *et al*., 2004) and Sardinia (Cossu *et al*., 2004). In 2006, its range expanded further in Sicilian waters.

Genetic polymorphism has been compared between putative native (Red Sea) and introduced (Mediterranean) populations of the marine angiosperm *Halophila stipulacea* through rDNA ITS region (ITS1-5.8S-ITS2) sequence analysis. A high degree of intra-individual variability of ITS sequences has been found (Ruggiero and Procaccini, 2004). It is now present in Sicily (Procaccini *et al*., 1999), but the genetic study revealed great intra-individual variability and could not detect phylogeographic affinities with the native Red Sea population.

The known distribution of *Womersleyella setacea* has now been extended to three localities in the Apulian region (Cecere *et al*., 2005). Other algal species have also expanded in the same area of the Gulf of Taranto (Cecere and Petrocelli, 2004; Mastrototaro *et al*., 2004).

An extensive revision of the status of macroalgal non-indigenous species in Italy, including taxonomic and biogeographic considerations, started in 2004; cancellation of some species from earlier lists and addition of new ones is expected. Notably, studies are in progress to analyse the role of man-made structures as a vehicle for expansion of exotic species. The research includes studies on the factors that promote the spread of the invasive green alga *Codium fragile* subsp. *fragile* on coastal defence structures along the northeast coast of Italy, and on interactions between this macroalga and the mussel *Mytilus galloprovincialis*, the main constituent of hard-bottom habitats in that region (Bulleri *et al*., 2003, 2006a). The distribution and dynamics of the invading green alga have also been investigated on and around breakwaters in the northern Adriatic (Bulleri *et al*., 2006a, 2006b, 2007), and the mechanisms underlying its establishment have been investigated. It is clear from the results that the artificial structures are providing habitats suitable for non-indigenous marine species and are functioning as corridors for their expansion (Bulleri and Airoldi, 2005). Furthermore, the landward side of breakwaters supported greater numbers of thalli of *C. fragile* subsp. *fragile* than seaward sides. Thalli grew longer and more branched in the sheltered habitats, leading to an overall greater biomass of the alga on the landward side of breakwaters. The presence of sheltering man-made hard substrata in the vicinity of major ports and sources of eutrophication could therefore enhance the dispersal of invasive species. Hence, the effects of artificial structures and introduced species on coastal assemblages cannot be evaluated separately, but their synergistic nature needs to be considered in developing strategies for conserving biodiversity in coastal habitats.

In terms of the interactions between the invading green alga and the native mussel *Mytilus galloprovincialis*, experimentation had already demonstrated complex effects of the mussels on *Codium fragile* subsp. *fragile*, ultimately affecting the success of the invasive alga. Specifically, the pre-emptive take-up of space by mussels effectively reduces the rates of recruitment of *C. fragile* subsp. *fragile*. Bulleri *et al*. (2006b) experimentally analysed the effects of *C. fragile* subsp. *fragile* on the mussels. Such effects can differ depending on the stage of development of *C. fragile*. On the one hand, juvenile thalli of *C. fragile* subsp. *fragile*, also referred to as primordia, form complex three-dimensional clumps that enhance settlement and recruitment of mussels relative to the smooth bare surface of the quarried blocks used to build breakwaters. On the other hand, adult canopies of *C. fragile* subsp. *fragile* do affect the recruitment, survival, and growth of understory mussels, the direction of such effects potentially varying from positive to negative. Removal of the canopy of *C. fragile* negatively affects the density of mussels 2–4 months after the start of the experiment, but there are no effects on the mean size of individuals, or on the size–frequency distribution. Clearly, therefore, recolonization of space by mussels is enhanced by the presence of *C. fragile* subsp. *fragile*, but given that mussels can reduce recruitment rates of *C. fragile* subsp. *fragile*, quick recovery of mussel beds after disturbance could be a crucial tool in controlling the abundance of the invading alga on breakwaters.

Asparagopsis taxiformis, recorded from the Egyptian coast in 1800, was first observed in the Gulf of Naples in 2000, where it suddenly appeared invasively. It represents the gametophytic life stage in a heteromorphic diplo-haplontic life cycle; the tetrasporophytic stage is known as *Falkenbergia hillebrandii*. Even if both phases are present throughout the year on rocky substrata down to 20 m, only the gametophyte forms a continuous belt, more noticeable during the cold season. In 75% of surveyed sites, both species were present, but *Caulerpa racemosa* had greater coverage (Flagella *et al*., 2003). DNA sequences studied from specimens all over the world demonstrated that all Mediterranean specimens belonged to one of the Indo-Pacific lineages (Andreakis *et al*., 2003a, 2003b). *Asparagopsis taxiformis* has also now been recorded in Sicily (Barone *et al*., 2003). It might have a pre-Tethian origin and is probably cryptogenic, but it is now in an expansion phase around the Italian peninsula and Sicily.

The macroalga *Ulva ohnoi* (Ulvales, Chlorophyta) has been identified in ballast water arriving from Port Said (Egypt). The species was described for the first time in Japan (Hiraoka *et al*., 2003), but has not been identified in the Mediterranean and has not been added to the list of new introductions.

A list of alien macrophytes in the Mediterranean Sea has been published by Cormaci *et al*. (2004). For each species, a brief description, world and Mediterranean distribution, chorology, and the possible vector are stated. The list consists of 52 Rhodophyta, 15 Ochrophyta, 13 Chlorophyta, and 1 Monocotyledones, a total of 81 taxa at specific and infraspecific level and three at generic level. Several taxa currently considered in the literature as introduced are not included, the exclusions justified by them being considered non-introduced or non-valid taxa. Consequently some of the species listed in the previous WGITMO Italian national reports need to be reconsidered in this respect. New information was made available for some of the species reported in earlier years. The red alga *Hypnea cornuta* and the green alga *Codium fragile* subsp. *fragile* were added in 2000 to the alien flora of Taranto (Cecere and Petrocelli, 2004; Cecere *et al*., 2004). *Undaria pinnatifida* in Venice Lagoon is playing an important role in the algal community in the canals of the historical city centre (Curiel *et al*., 2003, 2004). A green alga belonging to the genus *Prasiola*, known from polar and cold temperate regions, was recorded in 2002 in Venice Lagoon (Miotti *et al*., 2005) on three occa-

sions, with few and small specimens, the first record of the species in Italy, although it has been reported from the Black and Azov seas, and doubtfully from the Aegean. The red alga *Dasysiphonia japonica*, native to the Pacific Ocean (Korea) and introduced to northern Europe, has been present in Venice Lagoon since the 1990s, according to Sfriso (2006), but it was misclassified until recently because of its taxonomic complexity. It is common in the infralittoral on the marine side of the outer islands and lagoon mouths. Overall, 20 alien algal species have been reported so far in Venice Lagoon (Curiel *et al*., 2006).

In Liguria, the heavy urban and industrial coastal development in the 1960s led to a massive decline of *Posidonia oceanica* meadows, which were present earlier as a wide and continuous belt along the coast. That decline was especially obvious adjacent to major coastal cities such as Genoa. Recolonization of the regressed meadows by the seagrass *Cymodocea nodosa* and/or the invasive alga *Caulerpa racemosa* has been frequent. After regression of *P. oceanica*, the meadow can become a dead "matte" or be replaced by stands of other species, thus undergoing a phase shift in the community. Using three environmental indices, the conservation index (CI), the substitution index (SI), and the phase-shift index (PSI), Montefalcone *et al*. (2007) studied a system of five adjacent *P. oceanica* meadows facing the Genoa waterfront over different spatial scales (metres–kilometres), investigating the influence of local factors on the status and the potential recovery of the original *Posidonia* meadows. Mapping of PSI showed that the meadows closest to the centre of Genoa and the harbour underwent an almost total phase shift and have no real potential for recovery: attempts to re-establish *P. oceanica* there may hence be futile and a waste of money. In contrast, the meadows farthest from the centre of Genoa and harbour showed a comparatively low level of phase shift and could still recover fully, given specific management actions.

Womersleyella setacea in Italy affects coralligenous algae.

Red algae	Brown algae	Green algae	Phanerograms
Asparagopsis taxiformis, 1800s, and *Falkenbergia hillebrandii*	*Undaria pinnatifida*, 1992	**Batophora* sp., < 2002	*Halophila stipulacea*, < 1980
Hypnea cornuta, 2000		*Caulerpa racemosa*, 1993	
Lomentaria hakodatensis, 2001		*Caulerpa taxifolia, 1991*	
Asparagopsis taxiformis, 1800s, and *Falkenbergia hillebrandii*		*Codium fragile* subsp. *fragile*, 1973	
Dasysiphonia japonica, 1990s		*Prasiola* sp., 2002	
Womersleyella setacea, 1986		*Prasiola* sp., 2002	

Croatia (2007)

Since 1994, on the Croatian side of the Adriatic Sea, two invasive species of the alga *Caulerpa* have been identified. *Caulerpa taxifolia* has been found in three distant areas: in Stari Grad Bay (Hvar Island) during summer 1994, in Malinska (Krk Island) at the end of 1994, and in Barbat Channel (between the Islands of Dolin and Rab) in late 1996 (Špan *et al.*, 1998). It was thought that the alga had been brought into Stari Grad Bay and Malinska in 1991, and into Barbat Channel in 1995. Particularly vulnerable to its presence is the common sea grass (*Posidonia oceanica*) that supports major ecosystems of Mediterranean marine life while protecting the shores from erosion. Fauna suffers too, particularly species such as sponges and sea urchins. The algae can be

vacuumed or covered by black foil which would block the light they need to grow, but other organisms are also affected by these methods. The number of locations at which the invading green alga *Caulerpa racemosa* on the Croatian side of the Adriatic has increased since 2000, to 43 sites.

Red algae	Brown algae	Green algae	Phanerograms
		Caulerpa taxifolia, 1994	
		Caulerpa racemosa, 2000	

3.3.3 Northwestern Atlantic and Canadian and US Pacific coasts

Canada (2003–2007)

Codium fragile subsp. *fragile* was identified for the first time in Québec in 2003 (Magdalen Islands). Various possible vectors have been considered (cargo ships, boats, accidental and deliberate introductions). In particular, there is a possibility that it was introduced with a transfer of oysters from New Brunswick. It is spreading around Prince Edward Island too, where its presence was first noted in 1997. Its population is classified as large in Malpeque Bay, Cascumpec Bay/Mill River and Enmore River. The species is confirmed as present at low density in Rustico Bay, Tracadie Bay/Winter Bay, Savage Harbour, St Peters Bay, Murray River, and Sunbury Cove, a section of Bedeque Bay. No new sightings were recorded for 2005 or thereafter, the previous most recent ones being for Rustico Bay in 2004 and Tracadie Bay/Winter River and St Peters Bay in 2003. Efforts to control the spread of the invader were unsuccessful and abandoned as impractical.

There is a possibility that the European subspecies *Codium fragile* cf. *atlanticum* (which is now subsp. *fragile)* might be present in the Malpeque area of Prince Edward Island, and if molecular testing proves this finding correct, it will be the first record of this subspecies in Canada.

On the Pacific coast of Canada, the aquatic nuisance species *Spartina anglica*, which poses a serious threat to fish and wildlife habitat, was discovered in July 2003 during a survey for Vancouver Port expansion. Work on its removal continues, and information on that project is contained in the 2005 national report for Canada.

Red algae	Brown algae	Green algae	Phanerograms
		Codium fragile subsp. *fragile*, Atlantic 1991	*Spartina anglica*, 2003 (West coast)

United States

The rhodophyte *Pryopia* (= *Porphyra*) *suborbiculata* is a red alga that is probably native to the western Pacific (China and Japan) and now ranges from Mexico to Australasia. Using molecular and morphological data, Broom *et al*. (2002) examined the taxonomy of three species of *Pryopia* (= *Porphyra*). Their reassessment of the taxonomy suggests that *Pryopia* (= *Porphyra*) *lilliputiana* from New Zealand and *Pryopia* (= *Porphyra*). *carolinensis* from North Carolina and Waterford, Connecticut (Long Island Sound), were conspecific with *P. suborbiculata* from the Pacific. Ship-fouling (of small thalli) was the likely vector (see also Coll and Cox, 1977).

In 2006, *Pryopia* (= *Porphyra*) *katadae*, a Japanese red alga, was identified using molecular methods at unspecified locations north and south of Cape Cod, but it had been there for some time. Ballast water and fouling were thought to be the likely vectors.

Although the edible Asian red alga, *Pryopia* (= *Porphyra*) *yezoensis* (Nori) was cultivated in Cobscook Bay, Maine, from 1991 to 1998, and was carefully monitored, no evidence of reproduction was seen. However, "wild" plants were collected near Portsmouth, NH, in 1999, and identified by molecular methods. Subsequently, populations were found at several locations from Maine to Long Island. Molecular analysis indicated that at least two strains were present, but both were distinct from the cultivated form. In 2005, three Asiatic species or strains of *Porphyra* were reported from Long Island Sound and the Gulf of Maine. They are cryptic species and have been confused with other native taxa (Neefus *et al.*, 2008).

The Northwest Pacific red alga *Antithamnion nipponicum* (formerly known as *A. pectinatum* in Atlantic waters and *A. hubbsii* in US Pacific waters) is now reported from Beaufort, NC (2003), Baja California, Mexico (1962, as *A. hubbsii*), and Halfmoon Bay, CA (2003). It has been introduced to New England waters (Buzzards Bay to Long Island Sound, first reported 1985), the Azores, and the Mediterranean. Fouling, ballast water, and oysters are all possible vectors.

The West Pacific red alga *Gracilaria vermiculophylla* was identified by molecular methods. In 1999 and 2000, nuisance blooms of a fouling, drifting species of *Gracilaria* were noted in the Cape Fear River, near Wilmington, NC, and in Hog Island Bay, VA, a coastal lagoon just north of the mouth of Chesapeake Bay. These were initially assumed to be native *Gracilaria* species, but mitochondrial DNA analyses revealed the dominant species to be the introduced *G. vermiculophylla*, a species found on the US west coast too, at Elkhorn Slough, CA, where specimens were collected in 1994. More extensive genetic surveys are needed to determine the range of this introduced species in US waters, though it has been reported in European waters from Spain to Sweden.

The US Pacific coast has also been subject to extensive invasion. In 2003, despite aggressive eradication efforts, it was not clear whether *Caulerpa taxifolia* had been eradicated along the Californian coast, where it had been identified in 2002. By 2004 there were no new reports that could confirm whether it had been eradicated along that coast, but by 2006, eradication efforts in the previously infested areas of Aqua Hedionda Lagoon and Huntington Harbor appeared to have been successful. No new plants had been found after 2002, but monitoring continues.

Undaria pinnatifida (first recorded in 2000) continues to be reported and increasing in abundance in Monterey Bay, CA, having expanded its range from southern California to Monterey Bay.

The brown alga *Ascophyllum nodosum* (>100 plants) was found on hard substratum and marsh vegetation, ranging from the mid-intertidal to subtidal, in San Francisco Bay. The plants, some as large as 40 cm in diameter, appeared to be healthy and growing along approximately 50 m of shoreline in 2002. All of the plants found were removed in an attempt to eradicate the population, and there has been no new information for either *Undaria pinnatifida* or *Ascophyllum nodosum*.

The mat-forming red alga *Caulacanthus ustulatus* was reported as a recent invader in California, where it was first reported in 1999 at Cape Fermin, near San Pedro. It subsequently spread into Elkhorn Slough and San Francisco Bay. Earlier records were from Baja California (1961), British Columbia (1974), and Prince William Sound, Alaska (1996). Molecular analyses reveal two major lineages, an East Atlantic and an Indo-West Pacific group. Populations from the British Columbia populations belonged to the Indo-West Pacific lineage, as did local introduced populations in Britta-

ny, France. Pacific oysters (from Asia), ship fouling, and ballast water are likely vectors.

The two species of western Pacific brown algae *Sargassum filicinum* and *Sargassum horneri*, native from northern Japan to the Philippines, were discovered in southern California in 2003 (Miller *et al*., 2007). *Sargassum filicinum* was found in Long Beach Harbor in 2003, growing either on the substratum or attached to another introduced species of *Sargassum*, *S. muticum*. In 2006, several populations of *S. filicinum* were found growing on Santa Catalina Island. *Sargassum horneri*, a similar species, was also discovered in 2003 in Long Beach Harbor, and a single specimen of *S. horneri* was found in a kelp bed on Santa Catalina Island (Miller *et al*., 2007).

The grey mangrove *Avicennia marina* has a wide Indo-Pacific range, from Arabia and South Africa to China and New Zealand. In the 1960s, researchers planted a few trees in a reserve in Mission Bay, San Diego, CA, as a source of leaves for their research. By the 1980s, these mangroves had spread, and were classified as invasive. Eradication was attempted and was thought to be successful, but by 2007, the mangroves had regrown, and eradication attempts had to be renewed.

The Japanese eelgrass *Zostera japonica* has a broad native range from Vietnam to Japan. It was first found in the Northeast Pacific in Willapa Bay, WA, in 1957, and subsequently spread north to British Columbia by 1979 and south to Coquille Bay, OR, by 2005 (ICES, 2006). The species forms extensive beds in the intertidal zone, covering areas of bare mudflats, modifying habitat and foodwebs in estuaries. In 2002, it was detected in Humboldt Bay, CA, and eradication started in 2003, with a combination of hand removal and herbicides.

Red algae	Brown algae	Green algae	Phanerograms
Pyropia (= Porphyra) suborbiculata < 1947	*Undaria pinnatifida* (West coast), 2000	*Caulerpa taxifolia* (West coast), 2000 (eradicated)	*Avicennia marina* (West coast), 1960s
Pyropia (= *Porphyra*) *yezoensis*, 1971 (farmed 1991–1998 but different subspecies)	*Sargassum filicinum*, 2003 (West coast)		*Zostera japonica* (West coast), 1957
Pyropia (= *Porphyra*) *katadae* < 2005	*Sargassum horneri*, 2003 (West coast)		
Gracilaria vermiculophylla (Atlantic coast), 1999–2000; (West coast) 1994	*Sargassum muticum* (West coast), < 1947		
Antithamnion nipponicum (= *A. pectinatum* and *A. hubbsii*); (West coast), 2003; (Atlantic coast) 1985	*Ascophyllum nodosum* (West coast), 2002, removed		
Caulacanthus ustulatus, 1996 (West coast)			

3.3.4 Pacific Ocean

Australia (2003, 2006, 2007)

In all, 68 species of alga are currently recognized as introduced (23) or cryptogenic (45) in Australian waters (Hayes, unpublished data). Most, though, are not consid-

ered pests (i.e. causing significant social, economic, or environmental degradation). Those considered by the NIMCG as pest species are discussed below.

The brown alga *Undaria pinnatifida* showed no change in distribution.

In 2004–2005, the red alga *Grateloupia turuturu* was collected from the Bicheno area of eastern Tasmania (Saunders and Withall, 2006).

Range extension of the green macroalga *Caulerpa taxifolia* was confirmed in July 2007. The finding of the species in Wallagoot Lake in southern New South Wales was some 120 km farther south than the previously known limit of the species. Its distribution is now just 80 km north of the Victorian border. The number of estuaries affected is now 13. Populations in New South Wales have not been confirmed as exotic strains of the species.

In May 2007, the green macroalga *Codium fragile* subsp. *fragile* was confirmed from *ad hoc* samples collected from ten New South Wales estuaries, but whether this constitutes a significant range extension from previously known populations is still an open question.

Red algae	Brown algae	Green algae	Phanerograms
Grateloupia turuturu, 2004	*Undaria pinnatifida*, 1988	*Caulerpa taxifolia*, 2000	
		Codium fragile subsp. *fragile* < 1999	

New Zealand (2003)

In February 2002, *Caulerpa taxifolia* was found in a marine aquarium exhibit at the Auckland Zoo. Molecular analyses indicated that it was closely related to tropical strains of *C. taxifolia* and not to any invasive strain. Investigations revealed that the plant had been purchased from a local aquarium supplier several years earlier when "live" (untreated) rocks and corals were being imported from tropical locations by the aquarium trade, a practice since banned. A survey of other commercial aquaria and retail outlets failed to uncover any additional *C. taxifolia*, but an education programme was implemented to inform marine aquarium enthusiasts of concerns about the species. There have been no additional reports since its removal from the Auckland Zoo.

An unknown species of *Dasya* sp. was collected from Nelson during a port survey, but it has yet to be determined whether the species is a new introduction or an undescribed native one.

Port surveys have also reported a significant range extension for *Griffithsia crassiuscula*, and one new locality for *Polysiphonia subtilissima*. *Codium fragile* subsp. *fragile* was reported from Waitemata Harbour in 1975 and may now have increased its range, but difficulties in distinguishing it from the native *C. fragile* subsp. *novae-zelandiae* mean that any spread cannot be confirmed until more research is undertaken.

Cranfield *et al*. (1998) identified 19 species of adventive seaweeds in New Zealand. Port baseline surveys have detected one new species of introduced alga, *Dictyota furcellata*. Although this species had previously been collected in Manakau Harbour, it was not identified until it was also collected from Tauranga Harbour during the port survey of March 2002.

Undaria pinnatifida was first introduced into New Zealand in ballast water in 1987 (ICES, 2007c) and has since spread around the coast. Given the high costs of attempt-

ing to eradicate it and the limited success to date, the government's approach to its management is to slow its spread around the mainland and to reduce the chances of it reaching remote locations such as the Subantarctic and Chatham Islands. This is in addition to other initiatives implemented by a number of regional councils and the aquaculture industry to manage *Undaria* in their areas. On March 2000, a fishing vessel with *Undaria* on its hull sank near a remote New Zealand island. Using the Biosecurity Act, the Ministry of Fisheries ordered the vessel to be moved to reduce the risk of the invading species getting from the vessel to the island. Although attempts to salvage the vessel were unsuccessful, the powers of the Biosecurity Act enabled an adaptive management approach to be undertaken whereby a three-year monitoring and eradication programme was put into place. This programme appears to have eradicated *Undaria* from the vessel. The gross distribution of *Undaria* has not changed, and the species has not been detected in the Chatham Islands, the Subantarctic islands, or Fiordland.

Red algae	**Brown algae**	**Green algae**	**Phanerograms**
Dasya sp., < 2003	*Dictyota furcellata*, < 2002	*Codium fragile* subsp. *fragile*, 1975; 2003	
Griffithsia crassiuscula, 1950s	*Undaria pinnatifida*, 1987	*Caulerpa taxifolia*, 2002 (removed)	
Polysiphonia subtilissima, < 1991			

Table 3.1. Algae and plants identified in the WGITMO annual national reports from 2003 to 2007. Asterisks indicate that the date of first report may be earlier. Two dates: Years before ";" means that the species has been reported earlier in the literature (in most cases given in CRR 284 (ICES, 2007b), but also checked against references), years after ";" that the species appeared recently in the national report. Earlier dates are included to provide a historical perspective on the spread and dispersal of algae. Impacts, probable vectors, and status have been taken from the literature when classified as unknown and not given in the national reports.

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
**Batophora* sp.	< 2002; 2003	Italy	Unknown	Epiphyte	Unknown	Western Atlantic, probably Caribbean	Chlorophyte
Caulerpa racemosa	1997; 2003	France, Mediterranean	Spreading	Competition	Aquarium, dispersal	SW Australia	Chlorophyte
Caulerpa racemosa	1998; 2006	Spain, Mediterranean	Spreading	Competition	Aquarium, dispersal	SW Australia	Chlorophyte
Caulerpa racemosa	1993, 2002–2007	Italy	Expanding	Competition	Aquarium, dispersal	SW Australia	Chlorophyte
Caulerpa racemosa	2000; 2007	Croatia	Increasing	Competition	Aquarium, dispersal	SW Australia	Chlorophyte
Caulerpa taxifolia	1984; 2003	France; Mediterranean	Spreading	Competition	Aquarium, dispersal	SE Australia	Chlorophyte
Caulerpa taxifolia	1992; 2005	Spain, Mediterranean	Established	Competition	Aquarium, dispersal	SE Australia	Chlorophyte
Caulerpa taxifolia	1992; 2003–2007	Italy	Spreading	Competition	Aquarium, dispersal	SE Australia	Chlorophyte
Caulerpa taxifolia	1998; 2005–2007	Croatia	Spreading	Competition	Aquarium, dispersal	SE Australia	Chlorophyte
Caulerpa taxifolia	2000; 2002–2006	USA, west coast	Eradicated	Eradicated	Aquarium release	SE Australia	

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Caulerpa taxifolia	2000; 2002–2007	Australia	Spreading	Competition	Shipping	SE Australia	Chlorophyte
Caulerpa taxifolia	2002; 2003	New Zealand	Aquarium exhibit	Removed	Live rocks	SE Australia	Chlorophyte
Codium fragile, subsp. *fragile*	1938	Sweden, west coast	Established	Competition, ecosystem	Shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. *fragile*	1998; 2002, 2006	Belgium	Unknown, irregular	Competition, ecosystem	Aquaculture, shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. *fragile*	1939	UK	Established	Competition, ecosystem	Aquaculture, shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. fragile	< 1957; 2005*	Spain, bay of Biscay	Common NE coast	Competition, ecosystem	Aquaculture, shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. *fragile*	1973; 2004–2007	Italy	Expanding	Competition, ecosystem	Aquaculture, shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. fragile	1981, 2006*	Spain, Mediterranean	Unknown	Competition, ecosystem	Aquaculture, shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. *fragile*	1991; 2002–2006	Canada, Atlantic	Became a nuisance	Competition, ecosystem	Aquaculture, shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. *fragile*	< 1999; 2002, 2007	Australia	New location, expansion?	Competition, ecosystem	Shipping	Northwest Pacific	Chlorophyte
Codium fragile subsp. *fragile*	1975; 2003–2004	New Zealand	Established	Competition, ecosystem	Shipping	Northwest Pacific	Chlorophyte
Prasiola sp.	2002; 2006	Italy	Unknown	Unknown	Unknown	Unknown	Chlorophyte
Chara connivens	< 1950s; 2005–2006	Sweden, east coast	New records localized	Unknown	Solid ballast	Western Europe, North Africa	Charophyte

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Chara connivens	1980s; 2003	Estonia	Established	Unknown	Unknown	Western Europe, North Africa	Charophyte
Ascophyllum nodosum	2002; 2004–2005	USA, Pacific	Eradicated	Risk of competition	Packing material	Atlantic	Phaeophyte
Colpomenia peregrina	1950; 2007	Sweden, west coast	Established	Competition, oyster thief	Drifting on bivalves	Northeast Pacific	Phaeophyte
Colpomenia peregrina	< 1923; 2005	Spain; Atlantic	Established	Competition, oyster thief	Bivalve aquaculture	Northeast Pacific	Phaeophyte
Colpomenia peregrina	< 1983; 2005	Spain, Mediterranean	Unknown	Competition, oyster thief	Bivalve aquaculture	Northeast Pacific	Phaeophyte
Demarestia viridis	1984; 2006	Spain, Mediterranean, Málaga	Unknown	Unknown	Unknown	Cold waters in both hemispheres	Phaeophyte
Dictyota furcellata	< 2002; 2003	New Zealand	Spreading	Unknown	Shipping?	Australia?	Phaeophyte
Sargassum filicinum	2003; 2007	USA, west coast	Spreading	Competition with native algae	Unknown	Northwest Pacific, Japan	Phaeophyte
Sargassum horneri	2003; 2007	USA, west coast	Spreading	Competition with native algae	Unknown	Northwest Pacific, Japan	Phaeophyte
Sargassum muticum	1988; 2003–2007	Norway	Spreading	Competition with algae	Secondary dispersal	Northwest Pacific	Phaeophyte
Sargassum muticum	1987; 2003–2005	Sweden, west coast	Spreading	Competition wth algae	Secondary dispersal	Northwest Pacific	Phaeophyte
Sargassum muticum	1999; 2002–2007	Belgium	Spreading	Competition with native algae	Aquaculture/ dispersal	Northwest Pacific	Phaeophyte

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Sargassum muticum	1995; 2003–2007	Ireland	Spreading	Competition with native algae	Aquaculture/ dispersal	Northwest Pacific	Phaeophyte
Sargassum muticum	1973; 2003–2007	UK	Spreading northwards, rapidly	Competition with native algae	Aquaculture/ dispersal	Northwest Pacific	Phaeophyte
Sargassum muticum	1985; 2005–2007	Spain, Atlantic	Spreading	Competition with native algae	Aquaculture	Northwest Pacific	Phaeophyte
Sargassum muticum	< 1947	USA west coast	Spreading	Competition with native algae	Aquaculture/ dispersal	Northwest Pacific	Phaeophyte
Undaria pinnatifida	1999; 2003–2007	Belgium	Not spreading	Highly competitive with other algae	Shipping	Northwest Pacific	Phaeophyte
Undaria pinnatifida	1994; 2007	UK	Not spreading	Highly competitive with other algae	Shipping	Northwest Pacific	Phaeophyte
Undaria pinnatifida	1988; 2006	Spain, Atlantic	Spreading	Highly competitive with other algae	Shipping/Oysters	Northwest Pacific	Phaeophyte
Undaria pinnatifida	1992; 2004–2005	Italy	Common in local areas	Highly competitive with other algae	Shipping/Oysters	Northwest Pacific	Phaeophyte
Undaria pinnatifida	2000; 2003–2005	US west coast	Spreading	Highly competitive with other algae	Shipping	Northwest Pacific	Phaeophyte
Undaria pinnatifida	1988; 2004	Australia	Unknown	Highly competitive with other algae	Shipping	Northwest Pacific then Mediterranean	Phaeophyte
Undaria pinnatifida	1987; 2004	New Zealand	Spreading	Highly competitive with other algae	Shipping	Northwest Pacific then Mediterranean	Phaeophyte
Acrothamnion preissii	1969; 2005	Italy	Dominant	Competition with seagrass and algae	Shipping	Indo-Pacific	

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Acrothamnion preissii	1994	Spain, Mediterranean	Spreading	Competition with other epiphytes	Shipping	Pacific	Rhodophyte
Aglaothamnion halliae	2003; 2003–2006	Sweden, west coast	Spreading	Probably low	Fishing boats	Northwest Atlantic, subtropical	Rhodophyte
Antithamnion amphigenium	1990; 2006	Spain, Mediterranean	Spreading	Unknown	Shipping	Northwest Pacific, Australia	Rhodophyte
Antithamnion nipponicum (= *A. pectinatum* and *A. hubbsi*)	2007	Norway	New record	Competition	Hull fouling, ballast water	Northwest Pacific	Rhodophyte
Antithamnion nipponicum (= *A. pectinatum* and *A. hubbsi*)	1985; 2006	USA, east coast	Established	Competition	Hull fouling, ballast water, Pacific oysters	Northwest Pacific	Rhodophyte
Antithamnion nipponicum (= *A. pectinatum* and *A. hubbsi*)	2003	USA, west coast	New record	Competition	Hull fouling, ballast water, Pacific oysters	Northwest Pacific	Rhodophyte
Asparagopsis armata – *Falkenbergia rufolanosa*	1939; 2002	Ireland	Localized	Aquaculture species	Shipping, recent aquaculture escapee	Southwest Pacific	Rhodophyte
Asparogopsis armata – *Falkenbergia rufolanosa*	1922; 2005–2006	France	Wild set, commercial activity	Unknown	Shipping, Recent aquaculture escapee	Southwest Pacific	Rhodophyte

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Asparagopsis armata – Falkenbergia rufolanosa	1933; 2003	Spain, south coast	Unknown	Unknown	Shipping	Southwest Pacific	Rhodophyte
Asparagopsis armata – Falkenbergia rufolanosa	1920s; 2005*	Spain, Mediterranean	Unknown	Unknown	Shipping	Southwest Pacific	Rhodophyte
Asparagopsis taxiformis (= *Falkenbergia hillebrandii*, 2000)	1800s, 2003*	Spain , S coast; Andulasia		Unknown	Unknown	Tropical/subtropical	Rhodophyte
Asparagopsis taxiformis (= *Falkenbergia hillebrandii*, 2001)	1800s; 2001, 2004–2006*	Italy	Expanding	Unknown	Unknown, could be pre-Tethian or Lessepsian	Indo-Pacific, tropical/subtropical	Rhodophyte
Bonnemaissonia hamifera	1905; 2003–2006	Sweden, west coast	Present, no change	Competition, reduce epiphytic growh	Fouling	Northwest Pacific	Rhodophyte
Bonnemaissonia hamifera	< 1991; 2005*	Spain, Bay of Biscay	Unknown	Unknown	Fouling	Northwest Pacific	Rhodophyte
Caulacanthus okamurae	2004; 2006	UK, near Plymouth	Crossed Channel	Unknown	Unknown	Indo-West Pacific, South Korea/Japan	Rhodophyte
Caulacanthus ustulatus	1996; 2006	USA, west coast	Spreading	Habitat alteration (mat-forming)	Oysters, ship fouling , ballast water	Indo-West Pacific	Rhodophyte

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Dasya baillouviana	1953; 2004–2005	Sweden, west coast	Increased abundance	Competition with algae	Shipping	Mediterranean, Atlantic	Rhodophyte
Dasya sp.	< 2003	New Zealand	Unknown	Unknown	Unknown	Unknown	Rhodophyte
Dasysiphonia japonica	1996; 2003–2007	Norway	Spreading	Competition with native algae	Shipping	Northwest Pacific	Rhodophyte
Dasysiphonia japonica	2002; 2003–2007	Sweden, west coast	Spreading	Competition with native algae	Boats or fishing activity	Northwest Pacific	Rhodophyte
Dasysiphonia japonica	1999; 2004–2006	UK, Wales, S coast	Spreading	Competition with native algae	Aquaculture	Northwest Pacific	Rhodophyte
Dasysiphonia japonica	2004; 2004–2007	UK, Scotland	Spreading	Competition with native algae	Aquaculture, shipping	Northwest Pacific	Rhodophyte
Dasysiphonia japonica	1990s; 2006–2007	Italy	Common	Unknown	Aquaculture, shipping	Northwest Pacific	Rhodophyte
Gracilaria vermiculophylla	2003; 2003–2007	Sweden, west coast	Spreading	Competition with native algae	Shipping	West Pacific	Rhodophyte
Gracilaria vermiculophylla	2002; 2003–2007	Germany, North Sea coast	Spreading	Competition with native algae	Shipping, aquaculture	West Pacific	Rhodophyte
Gracilaria vermiculophylla	2005; 2005–2007	Germany, Baltic coast	Spreading	Competition with native algae	Shipping	West Pacific	Rhodophyte
Gracilaria vermiculophylla	1999–2000; 2006*	USA, Atlantic	Spreading	Competition with native algae	Shipping, aquaculture	West Pacific	Rhodophyte
Gracilaria vermiculophylla	1994; 2006*	USA, Pacific	Localized record	Competition with native algae	Shipping, aquaculture	West Pacific	Rhodophyte

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Grateloupia subpectinata (= *filicina* var. *luxurians*)	1978; 2003	Spain, Bay of Biscay	Unknown	Competition with native algae	Unknown	Indo-Pacific	Rhodophyte
Grateolupia turuturu	2004; 2006	Australia	Localized record	Competition with native algae	Unknown	North Pacific	Rhodophyte
Griffithsia crassiuscula	1950s; 2003	New Zealand	Expanding	Unknown	Unknown	Indo-Pacific	Rhodophyte
Hypnea cornuta	2000; 2003, 2005	Italy	Unknown	Unknown	Unknown	Confusing records	Rhodophyte
Lomentaria hakodatensis	2001; 2002–2003	Italy	Unknown	Unknown	Aquaculture	Northwest Pacific	Rhodophyte
Lophocladia lallemandii	1984	Spain, Mediterranean	Spreading	Epiphyte	Unknown	Indo-Pacific?	Rhodophyte
Mastocarpus stellatus	late 1970s; 2003 (native North Sea coast)	Germany, Helgoland	Spreading	Competition with native algae	Field experiments	Northwest Atlantic	Rhodophyte
Polysiphona senticulosa	2001; 2002, 2007	Belgium	Unknown	Unknown	Aquaculture, dispersal	Northwest Pacific	Rhodophyte
Polysiphonia subtilissima	< 1991; 2003	New Zealand	Unknown	Unknown	Unknown	Northwest Atlantic	Rhodophyte
Pyropia katadae (= *Porphyra katadae*)	2005; 2006	USA, Atlantic	Established	Competes with native algae	Ballast water and hull fouling	Japan	Rhodophyte

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Pyropia suborbiculata (= *Porphyra suborbiculata*)	< 1947; 2006	USA, Atlantic	Established	Competes with native algae	Ballast water and hull fouling	Pacific	Rhodophyte
Porphyra yezoensisi (Pyropia yezoensis)	1999 (cultivated 1991–1998); 2006	USA, Atlantic	Established	Competes with native algae	Shipping (not from aquaculture)	Pacific	Rhodophyte
Womersleyella setacea	1988; 1993; 2006	Spain, Mediterranean	established	Impact on bentic communities and fishery	Shipping/fishery	Subtropical/tropical Pacific	Rhodophyte
Womersleyella setacea	1986; 2005–2006	Italy	Spreading and dominant	Impacts coralligenous algae	Shipping/fishery	Subtropical/tropical Pacific	Rhodophyte
Avicennia marina	1960s; 2007*	USA, west coast	Eradication, reestablished	Competes with native mangroves	Planted	Indo-Pacific	Phanerogam
Halophila stipulacea	< 2001; 2003, 2005	Italy	Unknown	Unknown	Lessepsian intro-duction	Indian Ocean, Red Sea	Phanerogam
Spartina angelica	2007; 2008	Sweden, west coast	Localized	Alters mudflats	Probably secondary natural dispersal	Northeast Atlantic	Phanerogam
Spartina angelica	1961/62; 2003	USA, west coast	Unknown	Unknown	Planted	Northeast Atlantic	Phanerogam
Spartina angelica	2003; 2005	Canada, British Columbia	Localized	Alters mudflats	Humans, animals, boats	Northeast Atlantic	Phanerogam
Spartina densiflora	16th century, 2005*	Spain, Atlantic S coast	Unknown	Unknown	Unknown	North Pacific	Phanerogam

Genus and species	Date of first report	Reporting country	Status	Impacts	Probable vector	Country of origin	Taxon
Zostera japonica	1957; 2000, 2007*	USA, west coast	Unknown	Competes with native seagrasses	Humans, animals	West Pacific	Phanerogam

4 Invertebrates

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4.1 Introduction

This review, as elsewhere in this report, is a summary of national reports submitted between 2003 and 2007. First records of non-indigenous invertebrates contained in the national reports for 2003–2007 are mentioned in text, but species observed earlier and not reported in earlier annual national reports are also included where relevant, generally as the date of the first report and the national report year in which they were recorded.

Most deliberate introductions of live invertebrates have been for aquaculture, direct human consumption, or for recreational purposes such as gamefishing. In aquaculture, introductions of molluscs were most common, although in a few countries, crustacean introductions dominate. Of the molluscans, the Pacific Oyster, *Crassostrea gigas*, continued to dominante introductions, As noted in the previous summary report of introductions (for 1992–2002; ICES, 2007b;), and a Species Alert report that highlights changes in relation to climate (ICES, 2009).

4.2 Species of special concern

The large Asian gastropod mollusc *Rapana venosa* and the red king crab *Paralithodes camtschaticus* were mentioned as two species of key concern in the previous summary report, and WGITMO subsequently prepared detailed reports on them, which were published as ICES Cooperative Research Reports (ICES, 2004a, 2005b, 2006, 2007a, 2007b, 2008). Both species are well established in ICES Member Countries. For *R. venosa* a few additional records along the French Atlantic coast have been reported, but it remains unclear whether or not the species is now established. Widespread establishment of this predatory snail may impact the oyster industry. *Paralithodes camtchaticus* is well established in Norway and a fishery for this large crab was established.

Recent new invertebrate introductions of concern include *Rangia cuneata* (Atlantic Rangia) in Belgium in 2006, *Mnemiopsis leidyi* in Europe, *Eriocheir sinensis* in Canada, and *Homarus americanus* and *Callinectes sapidus* in Europe. In summer 2006, the invasive ctenophore *M. leidyi* was first recorded in the western Baltic Sea. Its abundance increased from < 30 ind. m^{-3} in mid-October to >90 in late November 2006. Thereafter, it was also recorded in Norway and Sweden and subsequently in almost all Baltic countries. Its presence in the Baltic Sea is of great concern because it is assumed to have contributed to the decline of the commercial fisheries in the Black Sea. It may also have invaded the North Sea already in the 1990s, with records from the Netherlands. However, that invasion may have been overlooked initially because the species was then misidentified as a native comb jelly. The Chinese mitten crab *Eriocheir sinensis* was found repeatedly during the reporting period in the St Lawrence estuary and Great Lakes, Canada. Such records are of concern given its negative impacts in Europe and along the west coast of the USA.

Records of the American lobster *Homarus americanus* in Europe are indicative of releases from live imports, either intentional or unintentional. The concern with this species is competition with the already depleted population of the native European lobster, and hybridization between the two species.

The repeated findings of the North American blue crab *Callinectes sapidus* in various European countries is worrying too because this large predatory crab may negatively affect native species. Although there have been more than 30 sightings (e.g. western Baltic, North Sea, Iberian Peninsula, Mediterranean, and Black seas) including egg-carrying females, it is still unclear whether or not the species is established in northern Europe.

This list of species introductions is definitely an underestimate, because not all countries submitted national reports at all WGITMO meetings. Furthermore, information on certain species groups is only given without taxonomic identification, e.g. when importing "bait worms", making species identification impossible.

As many of the newly introduced species are likely introduced by shipping, reports of the ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV) should also be consulted.

4.3 Introduced in different countries

4.3.1 Eastern Atlantic coast (including the North Sea, Skagerrak, and Kattegat)

Iceland

Although no formal reports were submitted, a Belgian national report noted that the giant chironomid *Telmatogeton japonicus* is known from around Iceland.

Ireland (2003–2004; Notes 2005–2006)

For 2003 and 2004, Ireland reported the abalone *Haliotis tuberculata* and *Haliotis discus hannai* as hatchery-produced and later cultivated in barrels suspended from long-lines.

Production in Ireland of the Pacific clam *Venerupis* (= *Ruditapes*) *philippinarum*, which takes place all around Ireland, is based on Irish hatchery seed; no imports of seed are known. Cultivation is on screened trays buried in the substratum beneath mesh.

The Pacific oyster *Crassostrea gigas* is produced in Irish hatcheries and is supplemented with imports from registered hatcheries in France and the UK (including Guernsey). Production has increased dramatically since 1980, when 362 t were produced: in 2006, 6500 t of *Crassostrea gigas* were produced.

Ireland also reports some brackish water introductions. The zebra mussel *Dreissena polymorpha* is still expanding its range in Ireland and has been recorded now in 57 lakes. *Chelicorophium curvispinum* is associated with zebra mussel druses, and its abundance increased on the Shannon navigation and has also been recorded in Upper Lough Erne.

Caprella mutica was recorded in abundance associated with a fish farm in Betraghboy Bay on the west coast of Ireland in July 2003, but following some changes at the farm, it was not found in October 2003. The records note that both sexes were present in the wild and animals up to species 34 mm long are common. It was also recorded as abundant in Dublin Bay on the east coast of Ireland in April 2005, and subsequent surveys have confirmed that its range now is from the south coast of Ireland along the east coast to Carlingford Lough.

The serpulid worm *Ficopomatus enigmaticus* fouls the hulls of craft and structures within the Kilrush lagoon on the Shannon Estuary. The population was first recorded in 1998 and the local population there is currently moderately abundant but not

known to form reefs anywhere in Ireland. Subsequent surveys have identified the species in Arklow Harbour on the east coast.

The tunicate *Styela clava*, originally recorded in Cork Harbour in 1972, has recently extended its range and is found at low density in Dublin Bay and along Ireland's southwest coast in Dingle and Tralee bays.

In an estuary north of Dublin in October 2005, a growth form of *Didemnum* sp. (currently identified as *D. vexillum*) was overgrowing fouling on marina pontoons and heavily fouled leisure craft. In June 2006, the same species was found nearby in a marina in Carlingford Lough, northwest Ireland. Sheet-like growth was covering mussels, and long, pendulous growths up to ~60 cm were hanging from the hulls of craft and pontoons. The tunicate bears a strong resemblance to populations in the Rade de Brest and Le Havre, and in Dutch waters. *Didemnum vexillum,* of a similar growth form, is known from the east and west coasts of North America and from New Zealand.

The southern hemisphere tunicate *Corella eumyota* was found for the first time in Ireland at Cork Harbour in 2005. Subsequently it has been described from a range of marinas (four locations) that encompass the entire country.

In 2006, at least five Chinese mitten crabs *Eriocheir sinensis* were found in a ca. 20 km stretch of the Waterford Estuary in southeastern Ireland.

Surveys have identified two further species not previously described in Ireland, the amphipod *Corophium insidiosum* from Belfast Lough and the colonial tunicate *Botrylloides violaceus* from the Irish Sea.

UK (2003–2007)

Deliberate releases of Pacific oysters for cultivation continue at a level similar to that in previous years. A survey in Devon in 2006 found substantial wild populations at sites along the River Yealm, where aquaculture of the species has taken place since its introduction in 1965. The greatest abundance of individuals was at the site closest to the local oyster farm. There was a noticeable decrease in abundance from estuarine sites to the open coast, suggesting that local aquaculture was the source of recruitment. Pacific oysters were also recorded around Plymouth, although there has never been commercial production of the species in the surrounding estuaries. The site supporting the greatest number of individuals is a marina where the only space available was the structure holding the visitors' pontoon, and *Crassostrea gigas* appears to have optimized this space. The Pacific oyster is also reported to be recruiting naturally in the estuary of the River Thames, and individuals have been recorded as far from the Thames as Folkestone, Kent, where a single animal was found attached to a boulder at mid-tide level. Annual production of market-sized Pacific oysters is ~1000 t.

The valuable Manila clam *Ruditapes philippinarum* fishery in Poole Harbour is managed to produce around 400 t per year. There have been reports of a few Manila clams in Langstone Harbour and larger numbers along the northern coast of Kent, where there is a hatchery rearing the species. It is not known if either population is self-sustaining. The Langstone record can probably be related to residual animals from farming activity there previously. There are also reports of the species in Southampton Water, possibly from spawning of the Poole Harbour population, but no reports of recruitment elsewhere. There are just two other farm sites for the species in the UK, and these produce about 30 t annually.

Hatcheries for producing and rearing seed of ormers (*Haliotis tuberculata*) have been established in southwestern England. These are currently on a small scale and have not flourished. The industry may develop as imports of seed from French hatcheries are gradually allowed under the 2006 aquatic animal health regulations that came into force in 2008.

In addition, ~900 t of live Canadian/American lobsters are bought into the UK each year. A 90 mm female *Homarus americanus* was caught offshore of Felixstowe, Suffolk, on 2 July 2004. This is the first UK report of the species in the wild for two years. In 2006, too, there was a single report of a large American lobster caught by a fisher in the English Channel near Bournemouth, Dorset, apparently the first that fisher said that he had caught for more than 30 years.

Eusarsiella (= *Sarsiella*) *zostericola*, an alien ostracod that preys on copepods, has also been documented. The UK Environment Agency found seven individuals in a Joint Nature Conservation Committee (JNCC) Day grab sample at Mucking Flats on the Thames tideway. Other samples may also yield more. Anecdotally, the species was recorded previously at Kingsnorth Power station in 1984, but it was first recorded in the UK in 1975. It is quite a distinctive species, large enough to be retained on the 0.5 and 1 mm meshes commonly used. The UK Environment Agency is keen to determine its geographic distribution and monitor whether its range in the UK is increasing.

The Japanese colonial sea squirt *Perophora japonica*, reported from the Fleet lagoon in the report for the 2002 ICES WGITMO and originally recorded in Plymouth, was found in Milford Haven for the first time in 2002, the first record for Wales.

An alien crustacean species is currently colonizing the sea lochs of western Scotland; the skeleton shrimp *Caprella mutica* is a caprellid amphipod originating in Northeast Asia. It was discovered and positively identified on the Scottish west coast in 2002, and scientists at the Scottish Association for Marine Science (SAMS) are investigating just how much of an impact the skeleton shrimp is having on native species. Dense populations are generally found associated with artificial structures such as mooring ropes, aquaculture activities, harbours/marinas, and boat hulls. The year of introduction is unknown, but various reports suggest that the species has been present on the Scottish west coast since the early 1990s. Possible introduction and dispersion vectors are aquaculture, ballast water, and hull fouling. It is likely that it presence in the UK is attributable to multiple introductions, probably via different vectors, rather than a single introduction event. Little is known about its biology or ecology locally, or its potential impact on UK marine systems. It is also reported from Wales (Anglesey), the south coast of England (Poole Harbour, Empress Dock Southampton) and west of Ireland (Betraghboy Bay, Connemara). Subsequent studies by SAMS have established that it is widespread on the Scottish west coast, on mussel lines, probably by aquaculture or hull fouling noted within 30 km of port in the Shetlands, in England (Southampton Harbour, 2003) less than 10 km from the port, associated with shipping, and in Harwich Harbour (2004) within 10 km of port, brought by shipping, and in Wales on mooring lines, probably by hull fouling/recreational boats, within 20 km of port. Although some of these instances are pre-2005, this is the first time the species has been formally recorded. *Caprella mutica* displaces the native caprellids *Caprella linearis* and *Pseudoprotella* spp. from artificial structures at relatively low densities in aquarium trials.

Several species were most closely monitored by the Marine Aliens Project (www.marlin.ac.uk/marine_aliens): (i) as of 2007, *Caprella mutica* had still only been

found on artificial structures; (ii) already documented *Styela clava* and *Perophora japonica* ranges do not appear to have spread; (iii) *Corella eumyota* (a tunicate) has been reported along the south coast of England; and (iv) slipper limpets *(Crepidula fornicata)* were found in the Menai Strait (Wales) in 2007, most likely introduced with mussel seed. Subsequent attempts to eradicate the last species from that location appear to have been successful, but in 2002 it had already spread as far north as the Isle of Cumbrae.

The Chinese mitten crab *Eriocheir sinensis* has now extended its range around the UK, appearing in two Yorkshire Rivers in northeast England. It burrows extensively into the river banks around the Humber and its estuary, and gradually destroys flood defences, raising the threat of flooding in the adjacent low-lying areas. There are also claims that the crab is attacking marine life, including some targeted by the Humber fishery. From 1997 to1999, it spread along the coast at a rate of 448 km per year – nearly six times the average spread of 78 km per year between 1976 and1999. In rivers, the increased spread from 1995 to1998 was 49 km per year, around three times the average spread of 16 km per year from 1973 to 1998. The mitten crab is now thought to have the potential to establish itself in all major UK estuaries within a few years. However, there have been reports of a liver fluke epidemic in the Chinese community in London who have consumed raw mitten crabs caught in the Thames. The crab is a carrier for cysts of this pathogenic parasite. A study of crabs in the Thames failed to detect the parasite, probably because a secondary host is not present. A feasibility study on developing a fishery for the species in the Thames has now been commissioned. Chinese mitten crabs have anecdotally been reported on the intake screens of Shoreham Power Station, situated on the River Adur, Sussex (southern England), and have reached the River Dee (Wales), suggesting a clockwise extension around the UK.

An alien prawn species, *Palaemon macrodactylus*, has been discovered in the Orwell Estuary, Suffolk. It originates from northeast Asia and was probably introduced accidentally, likely via shipping. It has also been introduced into western North America and, recently, continental Europe. It was first recorded in the UK in December 2001. The prawns are locally abundant in the Orwell. There are also a few records from the Stour Estuary (Essex/Suffolk), but no ecological effects are yet apparent. There is the possibility of competition with native prawns or predation on young, but no measurable decline in other species has been recorded to date.

A full-grown (15–17 cm) live tiger prawn (penaeid, possibly *Penaeus japonicus*) was caught in 35 fathoms of water off Start Point (western English Channel) in January 2007. There is anecdotal evidence of previous records, probably of the same species. The prawn is farmed in France.

The UK Environment Agency has recently identified (confirmed by a consultant) the polychaete *Marenzelleria viridis* at Woolwich in the Thames. As far as is known, this is the first record of the species for the Thames, but it has been described as invasive, and there are accounts that it constitutes ~90% of the fauna present in the Baltic.

There are many problems associated with zebra mussels, *Dreissena polymorpha*, in English waterworks. Questionnaires and manual surveys conducted between 2001 and 2003 revealed that >30 water-treatment works in England suffered problems associated with zebra mussels, and hundreds of tonnes of mussels are removed each year from raw water intakes, pipelines, and reservoirs. Problems have increased in the period covered by this report, however, owing to an expansion of their range around England and Wales and the cessation of chemical treatment at the intakes of

many treatment facilities during the 1990s. In 2006, the zebra mussel was recorded at Monks Pool in Johnstown, the first confirmed sighting in North Wales. Anglers are being encouraged to wash all equipment, including nets, with disinfectant to help prevent the spread of this invasive organism.

In terms of freshwater invasions, there were five records of non-native signal crayfish (*Pacifastacus leniusculus*) extending their range into new areas of the UK in 2006. These are likely to have been the result of transfers by people ignorant of the laws designed to prevent such movements. There were also three incidences of non-native crayfish turning up in the ornamental fish trade.

Sweden (2003–2007)

The comb jelly *Mnemiopsis leidyi* was recorded outside Tjärnö (58°52'N 11°06'E) at the northern part of the Swedish Skagerrak coast from mid-September to November 2006. The large size of the population indicates that the species had arrived before 2006. It might have benefited from the unusually warm water, perhaps in combination with less competition from other scyphomedusae living deeper in the water column. During the summer of 2007 the species was extremely abundant all along the Swedish west coast, also in very shallow waters. Parasitic larvae of a sea anemone were foundinfesting the comb jellies in the southern Skagerrak area, the same parasites also.

As noted in previous reports, American lobsters *Homarus americanus* were introduced in unknown quantities from the USA and Canada, and oysters were imported from several sources. However, then there had been no confirmed records of wild American lobsters in Sweden.

A fisher from a village ca. 30 km south of Göteborg on the west coast claimed to have seen fertile females of Chinese mitten crab, *Eriocheir sinensis,* and that the numbers of specimens caught is increasing (the salinity in the area is ~20–25 psu).

Competition between two co-occurring copepods *Acartia tonsa* (an introduced species) and *A. clausi* over a wide salinity range (2–33 psu and 16–33 psu, respectively) has been studied experimentally in Sweden. For *A. tonsa*, the energy partitioning between ingestion, production, and respiration was relatively constant, with small differences in gross growth efficiency and cost of growth. In contrast, *A. clausi* exhibited significantly reduced ingestion and gross growth efficiency, and a highly elevated cost of growth at salinity ≤ 20 psu. These results contribute to the understanding of distribution patterns of the two species along salinity gradients, which would allow the dominance of *A. tonsa* at low salinities, although its greater energetic requirement and feeding activity subjects it to greater predation pressure than the competing *A. clausi*.

One very large (>20 cm) *Crassostrea gigas* was found in northern Bohuslän in 2004 and brought to the adjacent Tjärnö Marine Biological Station for examination. In the early 1970s, a few Pacific oysters were introduced and cultivated in Sweden, just south of Strömstad in Bohuslän, close to the area, so it has been assumed that this animal was a survivor from the original batch, thus indicating that it may live longer than 30 years. No surveys of oysters have been performed in Sweden, but if this oyster should become established on the Swedish west coast, there is concern for its impact on the ecosystem. In the summer of 2007 large numbers of the Japanese oyster, *Crassostrea gigas*, < 1 year old, were reported from the Swedish west coast within an area almost 300 km long, from close to the Norwegian border and down to the city of Falkenberg (ca 65°54'N 12°30'E), province of Halland. In the north, densities were

>400 ind. m^{-2}, while being less dense further south (Susanne Lindegarth, Univ. of Gothenburg, pers. comm.). Although some specimens from Wales had been introduced during 1973–1976, it is believed these young oysters originate from newly dispersed spat from populations in Denmark or Germany, probably having had good growth conditions due to the mild winter and spring 2007. Since they were found within such a long distance of the coast, it is less likely they came from the old introduction. One record at the Tjärnö Marine Biological Laboratory (58°52'N 11°06'E) was from a boat motor, which had been hanging in the water since October 2006, thus these specimens were younger than 1 year.

Norway (2003–2004, 2006–2007)

No signs of further migration northwards of the slipper limpet *Crepidula fornicata* from the Kvitsøy area (59°02'N 05°15'E) have been reported.

In 2003, six confirmed and a few unconfirmed (i.e. not identified formally) records of the American lobster *Homarus americanus* were received bringing the total numbers of confirmed Norwegian cases to 17 between 2000 and 2006. Five large males were found in the vicinity of Ålesund, and one female was found close to the southern cape of Norway (near Farsund). Seven small (below sexual maturity) animals alleged to be hybrids between American lobsters and European lobsters were later confirmed to be the European *Homarus gammarus*, but in the process, it was shown that physiological variations within both species are sufficiently large to create overlap in certain characteristics. Thorough genetic analysis seems to be the best way to distinguish between the two species.

During the 2005 lobster pot fishery, some 14 lobsters with suspect characteristics were collected in several parts of southern Norway. Eight were confirmed to be the American lobster, and two of them were females carrying fertilized eggs. Intensive efforts to capture more of them were initiated at that hotspot near Bergen (60°19'N 05°10'E), but no additional specimens were captured. Several of those captured had rubber bands on their claws, so it is appropriate to note that (at least) 156 shipments of American lobsters from Canada, totalling 57 t, took place during 2005. In 2006, of 11 suspected lobsters, three American lobsters were found in Norwegian waters in 2006, two from Ålesund, and one from Kristiansand.

The snow crab *Chionoecetes opilio* has become fairly common in 2005 bottom trawls made in the eastern Barents Sea/Goose Bank area, and an increasing number of young juveniles have been reported caught. The stock of that species has been estimated to number some 500 000–1 000 000 on Goose Bank (70–75°N 35–45°E) in the Russian EEZ. They are taken sporadically along the coast of Finnmark County, but their main population is still concentrated in the eastern Barents Sea.

In 2006, Norway reported that the red king crab *Paralithodes camtschaticus* had continued its westward and southward spread and that there were indications too of a northward spread towards Spitsbergen. One red king crab was collected at 64°40'N 11°00'E, well south of the Lofoten archipelago, but it is believed to have been a released animal. Suspected migrating crabs have been caught close to Tromsø (at 70°N 19°30'E), and several single animals (likely translocated anthropogenically) have been taken farther south; southwestward expansion of the stock is now clear.

The Pacific oyster *Crassostrea gigas* has previously been cultured in enclosed ponds in Norway (although the practice is now illegal). Scientists conducted a survey in the vicinity of one facility and removed young oysters at Espevik (59°54'N 05°40'E) in

2006. Another two Pacific oysters were collected near Kragerø (58°52'N 09°00'E), and future eradication effort is planned.

The alien comb jelly *Mnemiopsis leidyi* continued its spread into Norwegian waters after its discovery in the Netherlands, Germany, and Sweden. Large numbers of adults were found in the "coastal current" from the Oslofjord area, outside the Skagerrak, and off Bergen.

The gammarid *Caprella mutica* is now found from Hidra (58°09'N 06°39'E) to the vicinity of Tromsø (69°42'N 19°01'E; Vim Vader, University of Tromsø, pers. comm.).

Denmark

No national reports were submitted by Denmark, but according to the Swedish national reports, an unknown quantity of *Perna* sp. was imported to Denmark from Sweden in 2000. Also, the Belgian national report states that the giant chironomid *Telmatogeton japonicus* was found in Denmark in 2002 on the towers of windmills of the offshore windmill park Horns Rev.

Germany (2003–2007)

Since the 1980s, an oyster farm has been operating on the island of Sylt in the Wadden Sea, and culture activities have resulted in the establishment of the Pacific oyster *Crassostrea gigas* (for which seed is generally imported from France) in the Wadden Sea outside the farm. As there is not much hard substratum in the German Wadden Sea on which to settle, beds of the native mussel *Mytilus edulis* became the initial foothold for oyster spat, and *C. gigas* continues to spread south and to compete with *M. edulis* for habitat and food. At several sites, the oysters are increasingly overgrowing the mussel beds.

The import from various European countries and North America of live crustaceans (*Nephrops norvegicus*, *Homarus gammarus*, *H. americanus*, *Callinectes sapidus*, and *Cancer pagurus*) for human consumption has continued in unknown quantities.

In the early 1990s, some 60 years after its initial documentation in German rivers, the Chinese mitten crab (*Eriocheir sinensis*) started to become abundant again, although from the end of the 1990s, its population density was again on the decline. However, records in the central Baltic Sea (Poland to the Gulf of Finland) reveal increased abundance since 2000.

Caprella mutica was first recorded from the German North Sea coast in 2004 and seems to be well established there (Schrey and Buschbaum, 2006). A single *Palaemon macrodactylus* was found on the North Sea coast near Bremerhaven 2007 (González-Ortegón *et al*., 2007).

Germany notes too that although the gastropod *Rapana venosa* has been recorded in the southwestern North Sea, there have as yet been no records from Germany. There is concern that this predatory snail may negatively impact native bivalves, including those used for aquaculture purposes.

The Asian shore crab *Hemigrapsus takanoi (*initially and erroneously identified as *Hemigrapsus pencillatus*) was predicted to invade German waters by the mid-1990s, based on records from Belgium and the Netherlands indicating eastward spread into the German Bight. *Hemigrapsus takanoi* may be a sibling form of *H. penicillatus* that is also known to compete with larger decapods. Indeed, the first record of *H. takanoi* in Europe was in 1993 during the German shipping study of hull-fouling samples of a commercial vessel in Bremerhaven. In 1994, it was found in the Bay of Biscay

(France), in 1996 in Spain, and in 1997 at Le Havre (France). Dutch records reported its presence in 2000 in the Oosterschelde estuary, and later also from the Westerschelde. In 2007, it was recorded for the first time in German waters along the coast of the southwestern Wadden Sea. Other studies in 2007 also documented its presence along with *H. sanguineus* in the area. A new German record of *Hemigrapsus* cf. *penicillatus* was documented later for 2007 at Büsum (north of the Elbe River estuary) and at the German Wadden Sea island of Amrum, indicating northward spread in the Wadden Sea.

Pachygrapsus marmoratus was found in the German Wadden Sea at Lüttmoorsiel, Nordstrand, on 29 September 2006, on a bed of blue mussels. The record is not considered to be a species introduction, but rather a range extension that may have been supported by the unusual warm temperatures that year. The species may also have reached the area with an anomalous water inflow from the Atlantic.

The Netherlands (2006)

In 2005, a comprehensive summary report of non-indigenous marine and estuarine plant and animal species recorded from the Netherlands was published. Three species were added to the list of introduced species in the Netherlands: *Palaemon macrodactylus*, *Rapana venosa*, and *Neogobius melanostomus*.

Didemnum sp. ("*lahillei*" in Dutch literature), herafter known as *Didemnum vexillum* (= *Didemnum* sp. or *D. lahillei*) has been present in the Dutch Oosterschelde estuary since 1991. It was rare until 1998, after which it expanded dramatically and overgrew almost all hard substrata, including organisms such as algae, plants, bivalves, hydroids, sponges, sea anemones, and other ascidians. It is hypothesized that *Didemnum vexillum* could not expand its populations earlier than 1998 because of the minimum water temperature of −2°C in 1996 and 1997. After 1997, however, the minimum water temperature remained at about 4°C, likely warm enough for the didemnid to survive. In the USA, *D. vexillum* does live in areas where the water temperature drops below −2°C, but it regresses at temperatures of 4–6°C.

The Pacific oyster *Crassostrea gigas* is still spreading throughout the Wadden Sea, and its spread and interaction with native shellfish species are being studied.

Belgium (2003–2007)

Several non-indigenous species such as *Crassostrea gigas*, *Ensis directus*, *Crepidula fornicata*, and *Austrominius* (= *Elminius) modestus* constitute important, and in some cases even dominant, parts of the Belgian marine fauna. Their success in Belgium is likely attributable to the alterations made by man to the environment, chiefly through beam trawling and the construction of artificial hard substrata. In man-made environments such as harbours, the overall presence of non-indigenous species is even more obvious.

Mytilopsis leucophaeata (= *Congeria cochleata*) is present in Antwerp Harbour, causing a nuisance by obstructing the intakes at some chemical plants. However, following a drop in salinity there, *Dreissena polymorpha* has started to replace it. *Cordylophora caspia*, a brackish water ponto-Caspian hydroid, is another species that causes nuisances at the same locations, and the University of Gent is currently seeking a possible biological control of the problems caused by these species.

An adult male *Callinectes sapidus* was taken in November 2002 off Oostende, and again in 2006 more records of the species from the Belgian coast were documented. Between 28 July and 4 October, at least seven specimens were brought in by coastal

shrimp fishers; all were females and several of them were carrying eggs. Subsequent anecdotal evidence revealed that catches of this conspicuous and aggressive crab were not uncommon. *Callinectes sapidus*, like the *Eriocheir sinensis* Chinese mitten crab, is a migratory species that spawns in salt water, raising the question of the origin of the specimens taken and whether there might exist a small, but established resident population, for example in one of the ports or estuaries along the southern coast of the North Sea.

Caprella mutica was first recorded in 1998, and is now established on several of the buoys marking the entrance to the Zeebrügge harbour and in Zeebrügge marina. In April 2002, it was recorded on a buoy at the entrance to Oostende harbour, indicating spread, possibly via ship fouling (*C. mutica* has no free-living larvae) between the two harbours. The species is now recorded annually.

As in earlier years, *Ficopomatus enigmaticus* was abundant in Oostende harbour in 2005, forming reef-like structures on submerged substrata.

The cosmopolitan barnacle *Megabalanus tintinnabulum* was recorded in 1998 for the first time in the southern North Sea, on buoys off the Belgian coast. As then, specimens are now found annually in low numbers on buoys off the Belgian coast. *Megabalanus coccopoma* was apparently present on buoys off the Dutch coast in 1976 and 1977 but never formally identified, but during a survey of 56 buoys off the Belgian coast between 1997 and 1999, it was recorded several times. Again in 2003, it was recorded on a buoy off the Belgian coast. *Megabalanus coccopoma* was originally described from the central American Pacific coast by Darwin in 1854. However, the Indo-Pacific species, *M. rosa*, described in 1917 by Pilsbry, might be the same species. Studies are ongoing to investigate the true identity of *M. rosa*. If *M. rosa* is proven to be a junior synonym of *M. coccopoma*, this would shed more light on the origin and spread of *M. coccopoma*, i.e. Indo-Pacific origin of the species might be possible. It is clear, however, that both warm-water non-native species of *Megabalanus* took advantage of the warm summer of 2003 to spread north, but have since become well established in the southern North Sea, although not in great abundance.

The bryozoan *Tricellaria inopinata* was first observed in 2000 in the marinas of Oostende and Blankenberge. During 2001, it was not recorded at those locations, but it was found in Zeebrügge marina. All these observations were of isolated specimens on pontoons, but in November 2002, many colonies were present on the hull of a yacht lying in Nieuwpoort marina. The species is still present and now apparently also spreading. Rather surprisingly, though, the species was recorded in September 2001 on several objects and on a branch of *Fucus vesiculosus* stranded on the Belgian coast, together with other species of southern origin, possibly further indication of the establishment and spread of the species in the English Channel.

Although actively sought, *Hemigrapsus* spp. was not recorded from Belgium in 2002. However, in 2003, *Hemigrapsus penicillatus* (now identified as *H. takanoi*) was discovered along the coasts of northern France and Belgium, and along the borders of the River Scheldt. It proved to be widespread and common, mainly in harbours. Subsequently, the species has been sought at various locations along the Belgian and northern French coast and along the left bank of the River Scheldt. It was found at various sheltered locations along the coasts of Zeeuws-Vlaanderen (the Netherlands), Belgium, and northern France (Nord and Pas-de-Calais). The southernmost finding was at Calais in France, and it was absent at Boulogne. The crab has been found upstream on the left bank of the River Scheldt as far as the nature reserve known as "Verdronken land van Saeftinge". It is not found in the Belgian part of the Scheldt (Prosperha-

ven, Lillo Fort, and Doel), but it is abundant in habitats such as harbours, living among reefs holding Pacific oysters *Crassostrea gigas*. *Hemigrapsus takanoi* occupies the same niche as the indigenous (young) green crab *Carcinus maenas*. Along the eastern Belgian coast, the species has been discovered on groynes, exposed habitats, though it is doubtful whether the crab will be able to develop stable populations at such locations. At Oostende, Zeebrügge, and Dunkerque, it was also present in non-tidal inner biotopes. Its abundance and the many locations at which *H. takanoi* (= *penicillatus*) has been found since summer 2003 is surprising because in previous years it was not reported at many of them (though routinely sought). Its sudden discovery in large numbers during 2003 indicates that it might have already been present in the area for a few years prior to its detection. It is assumed that it was introduced mainly via ship traffic (coastal trade and yachts) originating in the Dutch Delta area. Locally, it could have dispersed by natural means, i.e. via larvae in the water column. On the other hand it is not impossible that its introduction at Dunkerque originates from the French Atlantic coast or the population in the English Channel harbour of Le Havre, where there is a thriving population. The species continued to be reported from various locations during 2004, including on groynes in the vicinity of Oostende, an open-shore habitat. During 2006, several were trawled off Oostende, indicating that the species is now no longer restricted to littoral artificial substrata.

Although *Hemigrapsus sanguineus* was specifically sought during surveys, it was not recorded until 2005. In July 2006, two adults were found at Knokke Heist, but subsequent surveys have revealed no further specimens. However, in August and September 2006, *H. sanguineus* was recorded at Nieuwpoort. There appears to be a small population existing between the stones of the saltwater spray zone of the groynes at Nieuwpoort Beach and along the hard banks of the River IJzer near the marina.

Notable during 2004 was the first discovery in the southern North Sea of the Asian shrimp *Palaemon macrodactylus*. This Asian shrimp was first identified at Zeebrügge, where it was fished on 12 June 2004 between the epiflora and epifauna of the pontoons of the marina. It is another introduction from the temperate Northwest Pacific. It proved subsequently to have become established in several suitable habitats. Additionally, a single sample collected in November 1999 from Walsoorden (Westerschelde estuary) was also found to contain some aberrant *Palaemon* specimens that proved to be *P. macrodactylus*. Clearly the species is present at several localities along the Dutch and Belgian coasts, including the Westerschelde estuary, but has not been found yet at the northern French ports of Calais and Dunkerque. Although it is now present in the sluice dock of Oostende (a port basin known to harbour many introduced species), it is worth mentioning that it was not found there in 1996, 1998, or 1999. *Palaemon macrodactylus* was probably introduced to Belgium and the Netherlands via ballast water and not by shellfish importation. All water bodies where the species has been identified are characterized by intensive intercontinental and regional ship traffic. The species was also recorded in 2005.

The giant chironomid *Telmatogeton japonicus* has been identified from buoys off the Belgian coast; it is common on all offshore buoys, even remote ones. It lives in the splash zone, i.e. the vertical zone of the buoy, above the algae zone. The species is present during most of the year and is apparently the only chironomid on the buoys. It can live on ships' hulls and is probably transported around the world in that manner. Other European records are from Denmark (2002 on the towers of windmills of the offshore windmill park Horns Rev), the Netherlands (several localities), Iceland, Ireland, Norway, Poland, and Germany.

In 2005, the invasive predatory mollusc *Rapana venosa* was found twice in the southern North Sea. Although not in Belgian waters *per se*, one of the findings was very close to Belgian waters. An alert campaign has been initiated.

A few specimens and egg capsules of the American oyster drill *Urosalpinx cinerea* have been found at Gorishoek in the Oosterschelde, an area of shellfish culture in the Netherlands, probably introduced with imported shellfish from southeastern England.

A vast population of the estuarine bivalve *Rangia cuneata* is present in the port of Antwerp, a new addition to the European brackish water fauna. After the first record of a few small individuals in August 2005, it was encountered frequently in the pipes of the cooling water system of an industrial plant from February 2006 on. However, it must have been introduced several years before its first discovery, because it has been found too at Verrebroekdok, a large container dock with a Ro-Ro terminal in Antwerp harbour. During a survey in May 2007, living specimens of several year classes were found (Kerckhof, unpublished). Being at least six years old, the records indicate that the species colonized the dock soon after its opening in 2000, though only when it became a nuisance at certain industrial plants was its presence formally recorded. It has also been found in the Netherlands in the Noordzee Kanaal and the Kanaal Gent-Terneuzen. Before the Belgian records, *R. cuneata* was only known from the Gulf of Mexico and the Atlantic coast of North America.

Mytilopsis leucophaeata (= *Congeria cochleata*) has long been present at Antwerp, causing a nuisance by obstructing the water intakes of some chemical plants. The comb jelly *Mnemiopsis leidyi* was discovered in August 2007 in Zeebrügge harbour, although its presence in the vicinity at the time was already known (Dumoulin, 2007). Subsequent to its initial detection, it has also been identified in Oostende harbour and several times too from beach strandings, indicating widespread presence in coastal waters, until at least November.

France (2003–2007)

Large populations of the benthic foraminiferan *Quinqueloculina carinatastriata* were reported for the first time from intertidal mudflats of the French Atlantic coast (Marennes-Oléron Bay and Ile de Ré) on 2 June 2004. The species was previously described from the Adriatic and Tyrrhenian seas (central Mediterranean Sea) and reported from the eastern Mediterranean and Red seas, as well as tropical and subtropical regions. Living specimens were found in 14 out of 32 samples. The large population of *Q. carinatastriata* (2500 living individuals in 50 cm^3 of sediment at Les Traires) shows that the species has found favourable conditions for its growth and reproduction along the French Atlantic coast. Maximum abundance in September suggests reproduction during summer, when water and surface sediments at low tide are warmest, reflecting the origin of the species in warmer climates, which seems to corroborate Mediterranean and/or tropical–subtropical origin. A survey of available literature to trace records of the species in muddy shallow habitats along the western coasts of Europe and Africa reveals that the species has not been recorded in the western Mediterranean Sea and is unknown in the eastern Atlantic Ocean from the Ivory Coast to Denmark, including the UK. Marennes-Oléron Bay is Europe's largest area of production of the Pacific oyster, which was introduced during the 1970s. The nearest major seaport handling international cargo is La Rochelle–LaPallice, north of Marennes-Oléron Bay and east of the Ile de Ré. Shellfish industries and ballast water discharged from ships have both led to numerous human-mediated dispersals non-indigenous species, supporting the hypothesis that the species has been introduced

accidentally outside its natural range as a probable consequence of mariculture and/or shipping activities. This is the first report of a successful introduction of non-indigenous benthic foraminiferan to the Atlantic coast of Europe.

The Pacific oyster *Crassostrea gigas* remains the key invertebrate for imports and exports in the French aquaculture industry. Oysters were imported initially from Ireland, the UK, Spain, Portugal, Denmark, and the Netherlands, and were exported to Italy, Belgium, Germany, Spain, Russia, Ireland, and the Netherlands.

In 2003, the venerid *Austrovenus stutchburyi*, native to New Zealand, was observed on piles of rubbish associated with the oyster cultures in Vendée, south of the Loire River on the Atlantic coast. Hundreds of animals were recorded, dead but with putrid flesh. Their origin is unknown.

Ocinebrellus inornatus was recorded in 2003 for the first time in the bay of Mont St Michel (northern Brittany). It was probably introduced with oysters brought in from elsewhere.

A blue crab (*Callinectes sapidus*) was caught by a fisher 5 miles from Courseulles-sur-Mer (Calvados, Normandy) in September 2003. It was a male 90 mm long with a carapace 200 mm wide. There are other records of the species since it was caught for the first time in 1975 in the Bay of the Seine. It was probably introduced with ballast water into Le Havre, where it would have found good conditions for settlement in water warmed by the outfall from a power station behind the port. Only males have been caught along the coast of Normandy.

A Chinese mitten crab *Eriocheir sinensis* was taken in the Charente estuary by a sport-fisher at the end of October 2003. It was a male with a carapace of ~65 mm. The species was first recorded along the French Atlantic coast in 1954, in the Gironde estuary, where it was caught along with the native green crab *Carcinus maenas* (André, 1954). Since then, it has been recorded rarely, though this recent capture could reflect the spread of the species.

Dredging was carried out in May 2004 along with industrial suction barges in an attempt to eradicate the invasive slipper limpet *Crepidula fornicata*. The biomass of the species was assessed in Cancale Bay (northern Brittany near the bay of Mont St Michel). Initial results showed that, following the very high recruitment of 2003, the species had expanded in the area, possibly jeopardizing the local shellfish industry.

Another study investigated the history of *Cyclope neritea* settlement and expansion along the French Atlantic coast. A new population was observed in the Bay of Morlaix (western English Channel) in spring 2003, which probably represents the then northern limit along the French coast.

A lobster fisher from Asnelles (Normandy) caught an American lobster (*Homarus americanus*) in a lobster pot in 2003.

Giant scallop *Placopecten magellanicus* seed was transferred from the Magdalen Islands in Canada to St Pierre et Miquelon in France (south of Newfoundland, Gulf of St Lawrence,) for aquaculture several times during the period covered by this report.

Since 1997, 13 adult whelks *Rapana venosa* had been formally identified in southern Brittany. The (likely) vector for introduction was the transfer of the Manila clam *Venerupis* (= *Ruditapes*) *philippinarum* from the Adriatic Sea (Italy) into southern Brittany, the *R. venosa* being used to ballast clam bags. In 2002, two *R. venosa* were found in the raceway of a shellfish farm in the Vendée area, south of the Loire, a farm that previously imported Manila clams from Italy. There is no evidence that the species was

released into the open sea, however. Five *R. venosa* were collected in southern Brittany (Morbihan) during 2003 and four in 2004 in the same area. In 2005, an adult whelk of 682 g wet weight was caught in Anse du Pô in the Bay of Quiberon (southern Brittany) close to the area where *R. venosa* had been collected previously. Two more were caught in the same bay in 2006. Although now clearly established, the small number of whelks being captured probably indicates limited consequence of its introduction.

A male Japanese prawn *Penaeus (= Marsupenaeus) japonicus* 19 cm long was caught in the Bay of Quiberon (southern Brittany) in May 2005. The species was introduced for farming in France in 1969 and until recently has been cultured in Mediterranean lagoons and in natural saltwater ponds along the French Atlantic coast. A farm at Plouharnel (southern Brittany), close to the Bay of Quiberon, produced the species in the 1990s, but production stopped in 2003. Occasional likely escapees from the farm ponds have been taken since the early 1990s in the Bay of Biscay and in the English Channel, but it is not known whether or not the species has become permanently established.

Hemigrapsus sanguineus was reported in summer 2006 near Luc sur Mer (Normandy) and in northern France (Pas de Calais), with ballast water the suspected vector for introduction.

Several individuals of the oriental shrimp *Palaemon macrodactylus* were reported from two estuaries along the French Atlantic coast, the Gironde and the Adour, in August 2006 and September 2006, respectively. Analyses of samples collected previously in the Gironde estuary then revealed one specimen taken in 1998 and several in 1999 and 2000, so the species has clearly been present since at least 1998. Ballast water is suspected to have been the vector for introduction. Several ovigerous females were caught, indicating possible establishment of an exotic population. The species clearly can compete with local shrimp populations and hence reduce the native species abundance. In 2007, *P. macrodactylus* was caught in the Charente estuary.

Spain (2005–2007)

At the 2006 meeting of WGITMO, reference was made to a study undertaken to collect records and review information on the introduction of marine fauna and flora to Spain. Currently, 131 species of marine organisms have been identified as non-native. Most are crustaceans, molluscs, and macroalgae.

In 2002, the mollusc *Xenostrobus secures* was found to have become established in the Rio de Vigo (42°13'34''N 08°48'29''E; Pascual *et al.*, 2010; Garci *et al*., 2007). In 2006, five new species were reported as first records from the Atlantic coast of Spain (Table 4.1). The blue crab *Callinectes sapidus* was found in the Seville region (37°23´07''N 06°00´03''E), but just one was found near Gijón (43°33'42''N 05°45'40''E). Three crustaceans taken at Guipuzcoa (43°19'40''N 02°04'24''E) were subsequently identified as the Asian shore crab *Hemigrapsus takanoi*, *Hexapleomer robusta*, and *Hyale spinidactila*. The tunicate *Corella eumyota* was also found at Guipuzcoa.

Callinectes sapidus was first found < 2002 in the Guadalquivir Estuary (southwestern Spain) and in 2004 in northern Spain at El Musel, Gijón, N Spain.

In Andalusia, a programme to control invasive species was initiated in 2001. During the programme, 571 *Eriocheir sinensis* Chinese mitten crabs were collected in the Guadalquivir River at Seville.

In 2007, there were two new species records for the Atlantic coast of Spain: *Rapana venosa* at Cambados, and *Crepipatella dilatata* at Mulle Aldán (the latter had been rec-

orded frequently since 2005 (Collin *et al.*, 2009). *Crepidula fornicata* has been reported in Galacia since 1977 (Rolan, 1983; Rolan *et al.*, 1985 in Blanchard, 1997).

Table 4.1. Records of non-native species found along the Atlantic and Mediterranean coasts of Spain by 2006. Asterisks indicate that the date of first report may be earlier. Two dates mean that the species was reported in the literature on the earlier date, but only appeared later in the national report. Several species had not been reported previously and are included in the summary for 2003–2007 as first records to ICES.

Taxon	Year of first record	Location of first record	Possible vectors	Invasion status
Mollusca				
Rapana venosa	2007	Spain, Atlantic coast		
Venerupis (= *Ruditapes*) *philippinarum*	1980	Spain, Atlantic coast	Aquaculture	Established
Crassostrea gigas	1877; 1960s–70s	Cádiz, N and SW Spain, Atlantic coast	Aquaculture	Established
Gibbula albida	1985	Galicia, NW Spain, Atlantic coast	Aquaculture	Established
Tritia (= *Cyclope*) *neritea*	1900–1910	N and SW Spain, Atlantic coast	With aquaculture	Established
Crepipatella dilata	2007	N Spain, Atlantic coast	Mussel aquaculture	Established
Crepidula fornicata	1977; 1978	Galicia, Asturias, N and NW Spain, Atlantic coast		Established
Xenostrobus secures		Rio de Vigo, Spain, Atlantic coast		established
Crustacea				
Austrominius modestus	1955	Bay of Betanzos, Galicia, NW Spain, Atlantic coast		Established
Rhithropanopeus harisii	1990	Guadalquivir Estuary, SW Spain, Atlantic coast		
Eriocheir sinensis	1997	Guadalquivir estuary, SW Spain, Atlantic coast	Ballast water; hull fouling	Established
Callinectes sapidus	< 2002 2004	Guadalquivir Estuary, SW Spain, Atlantic coast Gijón, N Spain, Atlantic coast		
Hemigrapsus takanoi (was identified as H. penicillatus)	1996	Laredo, N Spain, Atlantic coast		Spreading
Hexapleomera robusta	1996	Gipuzkoa, N Spain, Atlantic coast	Hull fouling	Spreading

Taxon	Year of first record	Location of first record	Possible vectors	Invasion status
Hyale spinidactyla	1992	Gipuzkoa, N Spain, Atlantic coast	Hull fouling or ballast water	Established
Scyllarus posteli	1982	Cádiz, SW Spain, Atlantic coast		Established
Chordata				
Corella eumyota	2003	Ria de Vigo, Galicia, NW Spain, Atlantic coast		

4.3.2 Baltic Sea coasts (inside the Kattegat, Sound, and Belts)

Sweden (2003–2007)

According to surveys in 2002 and 2003, *Cercopagis pengoi*, a predatory water flea, is present along the Swedish east coast from Gävle (north) to the northern part of Öland (south) and in the open northern Baltic proper (Landsort Deep, Gotland Deep). However, the distribution is patchy and densities are generally low (10–100 ind. m^{-3}). Moreover, in Himmarfjärden Bay, a station where monitoring data for the previous six years are available, *C. pengoi* abundances at the peak of development decreased from 200–400 ind. m^{-3} in 1997 to 20–30 ind. m^{-3} in 2002. Fish diet analyses show that *C. pengoi* is consumed readily by herring and sprat, within their size ranges commonly found during August and September, i.e. 5–15 cm for sprat and 5–25 cm for herring. Large fish exhibit clear positive selectivity for *C. pengoi*. As suggested by diet analyses and stable isotope studies, the trophic position of herring has changed since the invasion of *C. pengoi*.

Surveys in the Gulf of Bothnia in 2004 revealed *C. pengoi* along the Swedish east coast in the Baltic proper and in the Bothnian Sea, but at varying and often low abundances. At that time, there were still no reports of its presence in freshwater ecosystems anywhere in Scandinavia. During 2005, field and experimental studies were conducted to assess changes in body size and fecundity (including also embryos carried by parthenogenetic females and their subsequent growth), and results on the individual growth rate of *C. pengoi* revealed direct selective predation on the cladoceran. These changes were observed within 2–3 generations and they could not be attributed to temperature fluctuations; however, the extent to which availability of prey (i.e. herbivorous zooplankton) for *C. pengoi* contributed to the observed patterns of growth and fecundity remained unclear. The results did suggest, though, that fish predation may strongly impact *C. pengoi* abundance and population structure, and possibly cause cascading effects of *C. pengoi* predation on herbivorous zooplankton, thus mediating the effects of this newcomer on the ecosystem.

In the Gulf of Bothnia, the polychaete *Marenzelleria*, at that time still referred to as *M.* cf. *viridis*, was reported in the national reports for 2003 and 2004 and has been found from the very innermost part of Bothnian Bay at Råneфjärden (about 30 km north of Luleå) to Öregrund in the south Bothnian Sea. It was found during several of the monitoring programmes along the Swedish east and south coasts, and in Öresund and Skälderviken. However, it was not recorded in samples taken from the Swedish west coast. Currently, it is not known if the findings from the Öresund area belong to the true *M. viridis*, which has been introduced to the European Atlantic coasts, or should be named *M. neglecta*, following a revision of this genus. In 2005, *Marenzelleria*

was recorded only from a single site in the Helsingborg area, at relatively low abundance, whereas a year earlier it had been found in four different areas. In the Bothnian Sea, ~1000 ind. m^{-2} were recorded. In the southern Bothnian Sea, off the nuclear power plant at Forsmark, Uppland province, *Marenzelleria* was first recorded in 1997, and in 2004 it constituted 55% of the total number of individuals at a station 16 m deep, and 77% at a station 41 m deep, where it also made up 32% of the biomass. It is not known to which species it belongs, though, following the revision by Sikorski and Bick (2004).

Single records of the Chinese mitten crab, *Eriocheir sinensis,* turn up in Sweden occasionally and, in summer 2002, a large female was found in a river in Skåne, southern Sweden (other single captures are probably made but not reported). There are no reports of mass occurrence of the species. Thereafter, single Chinese mitten crabs have been reported caught by fishers virtually every year (e.g. at Södertälje, Lake Mälaren, in June 2005, and one as far north as the Norrfällsviken Gulf, Bothnian Sea). However, there is anecdotal information that commercial fishers in Lake Mälaren net 20–30 mitten crabs each day in the fishing season. In 2006, many more Chinese mitten crabs were recorded in Lake Vänern than previously. One fisher operating in the lake caught some 300 crabs, and from other parts of the same lake (the largest in Sweden) catches have been reported as far away as Glafsfjorden. Some crabs were caught in the lake in earlier years, but not as many as in 2006.

Finland (2003–2007)

In 2003 in the Gulf of Finland, a new mussel species was found in the cooling water discharge area of the nuclear power plant of Loviisa (eastern Gulf of Finland). The mussel was identified as Conrad's false mussel, *Mytilopsis leucophaeata*, which is known to be a serious biofouler.

The North American amphipod *Gammarus tigrinus* was recorded in August 2003 at the Port of Hamina on the southeastern coast of Finland, and from the Turku area in southwest Finland. Before this, *G. tigrinus* had become established in the inland waters of central Europe from the 1950s and had spread along the southern coast of the Baltic Sea right up to the Vistula Lagoon. A probable transport vector for *G. tigrinus* to the Gulf of Finland is the ballast water of ships. By 2006, it was common along the whole Finnish coast.

The decapod *Palaemon elegans* was found at Tvärminne, the entrance to the Gulf of Finland. The species has been recorded in the southwestern and southern Baltic up to the Gulf of Gdańsk.

The Chinese mitten crab *Eriocheir sinensis* was first reported from Finland's southeastern Lake District in 1998 and has become more frequent during the current reporting period.

No new species of invertebrate were recorded in Finnish waters in 2006, but both *Gammarus tigrinus* and *Mytilopsis leucophaeata* distribution was expanding.

Estonia (2003–2006)

The hydromedusa *Maeotias marginata*, native to the Ponto-Caspian region, was first found in Estonian waters (Väinameri Archipelago, western Estonia) in 1999. Its presence was confirmed in 2002 when two specimens were caught at one sampling site.

Since the invasion of the predatory cladoceran *Cercopagis pengoi* in Pärnu Bay in 1991, the zooplankton community is likely to be regulated by that introduced species rather

than by phytoplankton dynamics. The negative relationship between the density of zooplankton and herring larvae in the 1990s suggests that the major shift in the zooplankton community attributable to *C. pengoi* resulted in food limitation of herring larvae. It was confirmed by Laboratory experimentation (hatching resting eggs and studies on newly released young) confirmed *C. pengoi* as the only species of *Cercopagis* in the Gulf of Riga (Simm *et al.*, 2006).

The gammarid *Gammarus tigrinus* was observed for the first time along the Estonian coast (Kõiguste Bay, northern Gulf of Riga) in 2003, when a mesocosm experiment was being conducted. In 2003, it was not found at traditional benthic stations although the bay was monitored intensively throughout the ice-free season. In 2004, it occupied the whole area of Kõiguste Bay, and by 2005 it was already dominating local benthic invertebrate communities (Kotta *et al.*, 2006).

Annual catches of the Chinese mitten crab *Eriocheir sinensis* were substantially higher in 2002–2005 than in the period 1991–2001. Catches peaked during the months of May/June and October/November (Ojaveer *et al.*, 2007).

The amphipod *Chelicorophium curvispinum* was observed for the first time along the Estonian coast in 2005. This invasive species was found while monitoring phytobenthic communities in the eastern Gulf of Finland and is the northernmost documented location of the species in the Baltic Sea. Together with juvenile gammarids, *C. curvispinum* dominated the invertebrate fauna in the samples.

Poland (2004, 2006, 2007)

Palaemon elegans (Rathke, 1837; Decapoda) was found in 2002 and 2003 in the coastal zone of the Gulf of Gdańsk, near ports and piers, and in the so-called Dead Vistula (one of the branches of the Vistula flowing through the city of Gdańsk). Females with eggs and young specimens were observed.

Obesogammarus crassus (Amphipoda) is a Ponto-Caspian newcomer to the River Odra estuary. The species was recorded only recently in Polish waters, in the Vistula Lagoon and the Dead Vistula in 1998. *Pontogammarus robustoides* (Amphipoda) is another Ponto-Caspian species that has been recorded in the Vistula Estuary since the late 1990s and in the Odra Estuary from Pomeranian Bay to the Szczecin Lagoon and downstream Odra south of Szczecin. *Dikerogammarus haemobaphes* (Amphipoda), yet another Ponto-Caspian species, was first recorded in 1996 in a reservoir on the River Vistula. In 1999, it was present in the mid- and downstream sections of the River Odra, and by 2001 and 2002, it had spread into the upper section of the river and the Szczecin Lagoon. *Dikerogammarus villosus* (Amphipoda), another Ponto-Caspian species, had reached the River Odra by 2001, whereafter it rapidly spread both up- and downstream, reaching the Baltic coast (Szczecin Lagoon). *Chaetogammarus ischnus* (Amphipoda) a species of Caspian and Black seas origin, was recorded in the River Vistula as long ago as 1928, but since the 1990s, it has been found in the River Odra, and in 2002 it was caught in the Odra Estuary.

Chelicorophium curvispinum (Amphipoda), yet another species of Ponto-Caspian origin, is now included in the common fauna of the River Odra system. It was first recorded in Szczecin Lagoon at the beginning of the 20th century.

The freshwater shrimp *Atyaephyra desmaresti* (Decapoda) is well known to aquarists; it originates in the Mediterranean Sea, but is now found in the Odra Estuary.

Hemimysis anomala (Mysidacea) is a euryhaline mysid of Ponto-Caspian origin, which by2002 had reached the Baltic Sea in the Odra Estuary.

Gammarus tigrinus (Amphipoda) is native to northeastern North America, but since the late 1980s it has been common in the Odra Estuary and since the late 1990s in the Vistula Estuary. It was found along the coast of Puck Bay (0.4. m deep) in summer 2001 and September 2002.

Orconectes limosus (Decapoda) has also appeared along the Polish coast. It was introduced into the River Odra drainage basin at the end of the 19th century, and has been reported from the Odra Estuary since at least the 1930s; one specimen was found in the coastal zone of the Baltic Sea, near Władysławowo, and it is also found in the Vistula Lagoon.

Chinese mitten crabs *Eriocheir sinensis* have become more common in polish waters in recent years. Since the 1940s single large crabs have been caught annually (especially in the Odra Estuary) and 186 crabs were captured in Lake Dąbie in August 1998. In the past few years, however, it has been caught in increasing numbers in the Gulf of Gdańsk, mainly near the ports of Hel and Kuźnica, on both the open-sea and Puck Bay sides of the Gulf in both shallow coastal waters and deeper.

Specimens of *Rhithropanopeus harrisii* (= *Rhithropanopeus harissi tridentatus*) were collected monthly from May to October 2001 from the Dead Vistula River. Of the 220 collected, 57% were males and 43% were females. Females with eggs on the pleopods were present throughout June, July, and August. The depth where they were found was ~1.5 m and the salinity varied between 1 and 2 psu.

Cercopagis pengoi, a predatory cladoceran, is native to the Ponto-Caspian area and was recorded for the first time in the Baltic Sea in the Gulf of Riga and the open Gulf of Finland in 1992. The species had never been recorded in the Gulf of Gdańsk prior to 1999. In the shallow coastal area of the western part of the Gulf of Gdańsk the species was recorded on 30 July 1999 at densities of 1369 ind. m^{-3} and on 5 August 1999 at densities of 421 ind. m^{-3}, when the water temperature was at its maximum, in excess of 21.7°C and 23.9°C, respectively. It seems that the *C. pengoi* population in the Baltic Sea is more abundant in sheltered locations and that its size depends to a large extent on weather conditions.

*Marenzelleria viridis (*Verill, 1873*;* Spionidae) is a new polychaete species, which along with *Ocenebra inornata* (= *Ocinebrellus inornata*) was found in samples collected from inshore Pomeranian Bay, the river Świna, and the littoral in the eastern part of Szczecin Lagoon during 1991–1998 (de Montadoudouin and Sauriau, 2000).

In May 2005, 24 specimens of the semi-terrestrial beach flea *Platorchestia platensis* (Amphipoda) were found beneath stones and debris wedges within a stone coastal defence structure on the southern shore of the Hel Peninsula at Kuźnica (Puck Bay). It has a cosmopolitan distribution, occurring worldwide in supralittoral environments.

Mnemiopsis leidyi's (Ctenophora) native habitats are temperate to subtropical estuaries along the Atlantic coast of North and South America, where it is found in an extremely wide range of environmental conditions (winter low and summer high temperatures of 2°C and 32°C, respectively, and with salinities ranging from < 2 to 38 psu; Purcell *et al*., 2001). On 3 October 2007, the first individuals of *M. leidyi* (about 10) were observed and collected by a diver in the coastal zone of the Gulf of Gdańsk at a depth of 1.5 m (water temperature 14°C, salinity 7 psu). Subsequently, they were observed by divers in Gulf waters from the surface to a depth of 42 m (total length 1.8–8.0 cm).

In summer 2006, unusual amphipods, *Dyopedos monacanthus*, were noticed at five deep-water stations over the Słupsk Furrow, currently the easternmost limit of the species' range in the Baltic Sea.

Germany

A comprehensive summary report of introduced aquatic species in German waters was published in 2006.

In 2004, the cladoceran *Cercopagis pengoi* was recorded from German waters in the Pomeranian Bay region (Baltic Sea), the first record from German coastal waters.

In summer 2006, the invasive ctenophore *Mnemiopsis leidyi* was first recorded in the western Baltic. Its abundance increased from < 30 ind. m^{-3} in mid-October to >90 ind. m^{-3} in late November 2006. Its occurrence in the Baltic Sea was regarded as a matter of great concern because it is assumed to have contributed to the decline in fish harvest in the Black Sea. The species was also found in 2006 in the North Sea, and it was assumed that it had been present in the region for years, but had been overlooked.

4.3.3 Mediterranean Sea

Spain

At the 2006 meeting of WGITMO, reference was made to a study undertaken to collect records and review information about the introduction of marine fauna and flora to Spain. Currently, 131 species of marine organisms have been identified as non-native to Spain. Most of these are crustacean, molluscs and macroalgae. Although many of the species were reported before the time-frame of this report, they are included as the first records for ICES (Table 4.2).

In 2007, the polychaete *Branchiomma luctuosum* were found to have become established in Valencia Poer, Cullera, Vinoaroz, and Portixol Port.

Table 4.2. Reports of non-native species for Mediterranean Spain from the 2006 national report.

Taxon	Year of first record	Location of first record	Possible introduction vector	Invasion status
Polychaeta				
Branchiomma luctuosum		Spain, Mediterranean		Established
Mollusca				
Venerupis (= *Ruditapes*) *philippinarum*	1980	Catalonia (NE Spain) and Andalusia (S Spain)	Aquaculture	Established
Crepidula aculeata	1973	Alicante harbour, E Spain		
Fulvia fragilis	1991	Mediterranean Sea		Infrequent
Chlamys lischkey	1985	Alborán Sea, SE Spain		Local record
Dreissena polymorpha	2001	Ebro estuary, E Spain	Hull fouling of recreational boats	Spreading

Taxon	Year of first record	Location of first record	Possible introduction vector	Invasion status
Crustacea				
Percnon gibbesi	1999	Balearic Islands		
Cryptosoma cristatum	1987	Alboran Sea, SE Spain		
Calappa pelii	1991	Chafarinas Islands, SE Spain		

Italy (Guest status, 2003–2007)

The main invertebrate species introduced to Italian waters are the bivalves *Crassostrea gigas* and *Venerupis philippinarum* (= *Ruditapes philippinarum*), both for fisheries purposes. Italy is the fifth largest producer of molluscs in the world, mainly through its culture and harvesting of Manila clam *V. philippinarum*. Introduction of that species into Venice Lagoon in 1983 evolved into rapid colonization and subsequent expansion during the 1990s. After that demographic explosion, a number of environmental, biological, operational, social, and political problems emerged, including collapse of prices, increase in illegal vessels, collection in forbidden areas, trading without health certification, availability and collection of seed. The total harvest was 4500 t in 1993 and 40 000 t in 1996; in recent years it has remained stable around the latter figure. A heavy mortality was experienced in 2001, concomitant with a bloom of picocyanobacters. By 2004, a heated debate was underway on the management of the culture and fisheries for the species. Fisher organizations pressed the government for full unrestricted permits to translocate stocks and seed on the ground where the species was introduced into European waters more than 30 years ago, with the understanding that the species was already "naturalized".

In all, some 2200 fishers (legal and illegal) operate in Venice Lagoon on some 16 000 ha of potential grounds; ~3000 ha have been subjected to regulated exploitation, and a further 1200 ha have been requested by fish farmers. Collecting in the central basin, in which lies the urban centre of Venice, is forbidden for sanitary reasons; the species is very common there, and there is a nursery west of Venice, raising concern about safety of the product generally. The proliferation and spread of Manila clams in the Lagoon has brought about significant changes in the benthic communities, where the non-indigenous species has supplanted native species such as *Ruditapes decussatus*. The native clam population was already declining when the Manila clam was introduced, probably because the native species was already overexploited. The introduction of the Manila clam in other lagoons of the northern Adriatic, namely Marano (about 1800 t year^{-1}), Caleri, Scardovari (10 000 t), and Goro (9000 t), was followed by organization of the fishers into cooperatives clearly interested in rational management of the resource, with regulated seeding and harvesting operations. Benthic fluxes of material influenced by bivalves have been studied in Goro Lagoon (the delta of the River Po). Manila clams are also collected in small lagoons in the Lazio, Puglia, and Sardinia regions. More recent localities for *V. philippinarum* collection include Ancona harbour, the coastal muddy sand along the nearby coast of Senigallia, and the brackish environment of Pialassa Baiona (Emilia Romagna region). In 2002, Italy reported that Manila clams had been released into the brackish coastal Lake Fusaro near Naples.

In 2001, Italy reported that the crayfish *Penaeus japonicus*, as well as *Penaeus monodon* and *Litopenaeus vannamei* (= *Penaeus vannamei*), were being reared in ponds using

semi-intensive systems, but only once to date have they been recorded in open habitat. *Penaeus monodon* introduction was carefully planned under controlled and restrictive conditions for semi-intensive rearing in ponds. Its introduction has underscored the risk of introducing pathogenic agents such as *Baculovirus*. The Office of International Epizooties (OIE) must be notified if larvae and postlarvae escape from ponds. Fertilized eggs were preferred for importation to reduce the risk of disease.

Of molluscs, the Indo-Pacific bivalve *Theora lubrica* was found in Leghorn in 2001; it has since then colonized a few stations inside the harbour, forming a large population.

Several individuals of *Aplysia dactylomela* (Gastropoda, Opisthobranchia, Aplysiomorpha) were found in 2003 at Lampedusa Island, off Sicily. The species is circumtropical in distribution, but until now it has not been recorded in Europe beyond the Canary Islands and Cape Verde Islands.

Anadara transversa (= *demiri*) is found as an epibiont on other molluscs in the Adriatic and has entered Venice Lagoon. It appears to have gained full status as a component of the Adriatic Sea coastal benthic community despite, its recent first entry, in the early 2000s.

Taranto is a new location for *Arcuatula* (= *Musculista*) *senhousia*, adding to the already long list of alien species for that locality. It is widely distributed in the Adriatic, and its effects on the benthic communities have been studied in the Sacca di Goro. Predation by crabs, which show a preference for this Asian mussel, might contribute to the control of mats in the habitat.

From 2002 to 2005, Italy reported numerous *Mercenaria mercenaria* clams in the brackish embayment of Goro, in the Po River delta region, probably introduced with *Venerupis philippinarum* seed.

Further records of *Melibe viridis* (syn. *Melibe fimbriata*) have been reported from Sicily and in the northwestern Ionian Sea. It can definitively be considered a resident species in the opisthobranch fauna of the semi-enclosed bays of Taranto, where many were observed during diurnal foraging activity and associated with anaspidean species such as the native *Aplysia depilans* and the Lessepsian immigrant *Bursatella leachii* (Carriglio *et al*., 2004).

The whelk *Rapana venosa* (Mollusca Gastropoda) has been known in the northern Adriatic since 1973. It is already widespread along the northern Adriatic coast (including Venice Lagoon), on the Italian and Slovenian sides. One specimen has also been found near Elba Island in the Tyrrhenian Sea. It is believed that it was introduced with oyster imports. Density peaks are around Cesenatico (Emilia Romagna coast).

In 2006 *Novafabricia* sp. cf. *N. infratorquata* was reported from Otranto (southern Adriatic) (Licciano and Giangrande, 2006).

A new alien decapod pilumnid *Actumnus globulus* has also been reported recently from the Mediterranean Sea. It was collected in 1978 off Punta Ala, Tuscany (Tyrrhenian Sea), but has only recently been formally identified. From the same sample, another alien crustacean, *Menaethius monoceros*, known from the Indo-Pacific, was described in 2003. Both species may have been ship-borne arrivals because they were found near a port frequented by coastal vessels.

An isopod species belonging to the genus *Mesanthura*, known from tropical areas and new for the Mediterranean, was found in Salerno harbour (Tyrrhenian Sea, southern Italy); it is probably *M. romulea*.

A single adult male Chinese mitten crab *Eriocheir sinensis* (Crustacea, Decapoda Grapsidae) was caught in Venice Lagoon in May 2005 and sent live to the Venice Fish Market Veterinary Service. Passive transport of larvae in ballast water is one potential pathway of introduction, but in this case the import of live material is most likely: living Chinese mitten crabs imported from the UK were sold in the local fish market in 2003.

The eastern Pacific isopod *Paracerceis sculpta* has been recorded in the Gulf of Olbia, Sardinia.

The copepod *Acartia (Acanthacartia) tonsa* has replaced the congeneric species *A. margalefi* and *A. latisetosa* in the inner parts of northern Adriatic lagoons. In 2004, *A. tonsa* was observed in Venice Lagoon, the Sacca di Scardovari, and the Laguna di Caleri. In Venice Lagoon, detailed observations have been made covering both tidal and seasonal cycles. The arrival of *A. tonsa* may have caused the disappearance of the previously abundant *A. margalefi*. As reported before, the planktonic copepod *Acartia clausi* has been the most widespread acartiid species in the Mediterranean Sea for many years, whereas *A. tonsa*, a species only recently introduced, is less common and is found in brackish waters and confined environments. The latter became the dominant species of the planktonic copepod component in lagoons of the northern Adriatic, leading to a gradual decrease of congeneric autochthonous species. Temperature and salinity do not appear to play a decisive role in the spatial distribution of these two species.

The hydroid *Clytia hummelincki* was recorded for the first time in Calabria in 1996. It has been found too in the Adriatic Sea (Tremiti islands, Croatia), in Sardinia, and in the islands of the Pontine archipelago. At present, it is widespread along the Apulian coast. Two surveys carried out in 2003 and 2004 along the coast of the Salento Peninsula revealed that the species inhabits a belt between 0.5 and 1 m deep in sea urchin barrens and in areas damaged by date mussel fisheries.

In 2002, during a survey for control and detection of non-indigenous species in Venice Lagoon, the decapod *Rhithropanopeus harrisii* was found in two inner areas characterized by mean annual salinity < 24 psu. *Rhithropanopeus harrisii* is frequently caught on Asian mussel *Arcualata senhousia* beds in Goro Lagoon, beds that are common inside Leghorn harbour, expanding its Tyrrhenian distribution. Asian mussels, already present in the northern Adriatic, Taranto Gulf, and off northern Sardinia, have been found too along the southern coast of Sardinia, inside Cagliari harbour. It was previously known from a basin used for rearing *Penaeus japonicus* in the Po River delta.

The American mud crab *Dyspanopeus sayi* has established a population in the North Adriatic brackish environment of the Valli di Comacchio, where it has been observed feeding on Asian mussels.

Caprella scaura, an Asian amphipod collected for the first time in 1994 in Venice Lagoon, was also recently reported as abundant in Ravenna harbour.

The subtropical crab *Percnon gibbesi*, already known from Sicily, rapidly expanded northwards and was recorded at the islands of Ischia and Procida and along the coast of Campania at Gaeta, reaching the central Tyrrhenian Sea. *Percnon gibbesi* has also expanded to new localities in Sicily. Data on the structure, bathymetric distribution,

microhabitat preference, and diet of a newly recorded population in a marine protected area in northwestern Sicily demonstrate that it is well adapted to its new habitat. Its success has been related to reproductive characteristics and to its strictly herbivorous feeding habits.

The distribution of *Branchiomma luctuosum*, *Microcosmus squamiger* (= *Microcosmus exasperatus*), and *Arcualata senhousia* has been described in the sea inlets facing the town of Taranto. *Microcosmus squamiger* was also found in the harbour of Salerno (Tyrrhenian Sea).

The non-indigenous ascidian *Distaplia bermudensis*, known from the western Atlantic, was found for the first time in 2000 near Taranto (Ionian Sea, southern Italy), where a large population of colonies was already established.

The stolidobranch ascidian *Polyandrocarpa zorritensis* was detected, for the third time in the Mediterranean, in Taranto harbour. Colonies develop vigorously on all hard substrata in shallow water, and now represent one of the most important elements of the local fouling community. The morphology of the larva and a vascular budding mechanism of replication similar to that known for the Botryllinae, were observed for the first time.

Cerithium scabridum is expanding on the western shores of Sicily; it builds up large populations in some locations, but they generally disappear after a year or so, as reported in previous national Italian reports.

The brackish water hydrozoan *Cordylophora caspia*, previously known from the northern Adriatic, has been recorded in the "Palude del Capitano," a small pond along the Apulian Ionian coast (Denitto *et al*., 2006).

The symbiotic scleractinian coral *Oculina patagonica* is known from water3–10 m deep, in several locations in the Mediterranean Sea. Along the Ligurian coast, where unusually high temperatures have been recorded, colonies collected from Albissola (W Liguria and E Liguria) were used for experimentation. A test was designed to measure the growth and photosynthesis of corals maintained at 20°C and 26–28°C (Metalpa *et al*., 2006). The results indicate that during warm summers, *O. patagonica* may suffer less than *C. caespitosa*, which is endemic to the Mediterranean.

Croatia (Guest status, 2007)

More than 127 specimens of the bivalve mollusc *Idas simpsoni* were collected from the skull of a fin whale *Balaenoptera physalus*, the first record of *I. simpsoni* in the Adriatic Sea.

Ficopomatus enigmaticus (Polychaeta, Serpulidae) was recorded for the first time in the Bay of Šibenik (central Adriatic) in 2006. A possible vector for introduction is ships transporting stone from central Dalmatia.

The first record of blue crab *Callinectes sapidus* in the southern part of the eastern Adriatic was made at the mouth of Neretva River and Mali Ston Bay.

4.3.4 Western Atlantic coasts

Northwestern Atlantic coast

Canada (2003–2007)

Although a number of activities and introductions have been described in Canadian national reports, they are primarily updates on issues reported in previous years. No significant new releases or planned introductions were reported for 2003–2007.

In the Maritime Region (Prince Edward Island, New Brunswick, and Nova Scotia) limited activities are undertaken by private and provincial (New Brunswick and Prince Edward Island) shellfish hatcheries with giant sea scallops (enhancement), and soft- and hard-shell clams (enhancement).

Mercenaria mercenaria, and *Placopecten magellanicus* were intentionally imported from the USA, and *Haliotis rufescens* was imported from Iceland.

The first report of the green crab *Carcinus maenas* in Canadian waters (Atlantic seaboard) was from Passamaquoddy Bay in July 1951, where it quickly colonized the Bay of Fundy. In 1954, one specimen was found at Wedgeport, Nova Scotia, the first Canadian sighting outside the Bay of Fundy. The spread of green crabs along the Atlantic coast of Nova Scotia is not well documented, but they were first observed in St Georges Bay at the eastern end of the southern Gulf of St Lawrence in 1995. The first report in Prince Edward Island, in early autumn 1998, was described as a "heavy concentration" in some bays at the eastern end of the island. The rate of dispersal has been rapid, with annual range expansions exceeding 100 km. The green crab was reported in Prince Edward Island in 1997. Since then the species has spread, and it is now well established in all estuaries in the eastern portion of the province. In 2000, green crabs were found in Hillsborough River. An isolated sighting in Malpeque Bay, Prince Edward Island, in November 2000, apparently has not resulted in establishment of a viable population. Green crabs continue to spread in the southern Gulf of St Lawrence; in 2002, the distribution on the mainland expanded to Port Elgin, New Brunswick. In 2004 green crabs were reported in the lagoon of the Grand Entrée of Magdalen Islands, but none were found there in 2005. Its presence in the Cape Borden area was confirmed in 2005, and it is likely that the species will continue to expand its presence in those waters. The green crab was found in Newfoundland in 2007, probably arriving by ship. The green crab, *Carcinus maenas*, was detected in Placentia Bay, Newfoundland, in August 2007. The origin is unknown but it is suspected to be related to commercial shipping activity. Biological characteristics of sampled animals indicate colonization, reproduction, and establishment of populations. Control/mitigation planning was scheduled to start in March 2008.

Studies on the caprellid *Caprella mutica*, a new species detected for the first time in 2003 in the Baie des Chaleurs and in 2005 at the Magdalen Island Archipelago, are identifying the impact of this new species on mussel culture. *Caprella mutica* has been identified on natural reefs and artificial structures in estuaries of the east end of Prince Edward Island. Archived samples revealed its presence back to 2000. There were noticeable increases in 2002 and 2003 in the southeastern Prince Edward Island estuaries.

Chinese mitten crabs *Eriocheir sinensis*, including one female, were found in the St Lawrence estuary in 2006.

Since the identification of the presence of the clubbed tunicate *Styela clava* on mussel leases at Prince Edward Island, three more tunicates have been confirmed as estab-

lished there. The golden star tunicate *Botryllus schlosseri* was transferred to the province in 2001, the violet tunicate *Botrylloides violaceus* in 2004, and the vase tunicate *Ciona intestinalis* in 2004. All four species compete with mussel culture in waters in which they are established, adding costs to production, harvesting, and processing. Managing the spread and impact of each species has been a collaborative effort between the aquaculture industry and the provincial and federal governments. Regulating the movement of bivalves into, out of, and within waters infested with one or more species has been successful in slowing the spread of tunicates between water bodies. The clubbed tunicate is well established in the Murray River, St Mary's Bay, and Montague and Brudenell Rivers. It is also present in the Cardigan River, but at lesser densities. The population density in March Water, a portion of Malpeque Bay, increased notably in 2005. The species was confirmed as present in Darnley Basin in 2005, but in low numbers. The presence of clubbed tunicates in Orwell River is now suspect, with no animals being detected in routine surveys. The vase tunicate is currently restricted to the Montague and Brudenell River estuaries and St Mary's Bay. Numbers in those waters were particularly high and troublesome to the mussel industry in 2005. Since its identification in St Peters Bay, the golden star tunicate was confirmed as present in the Cardigan River and St Mary's Bay in 2005. The species has also been recorded in Savage Harbour since 2004. Population densities increased in St Peters Bay and Savage Harbour in 2005. The violet tunicate is well established in Savage Harbour and Cape Borden, and was detected in five new estuaries in 2005. These included the Cardigan River, the Brudenell River, St Peters Bay, Rustico Bay, and March Water. As a result of their ability to reproduce sexually and asexually, both violet and golden star tunicates will prove more difficult to control than the solitary clubbed and vase tunicates, which only reproduce sexually. Nova Scotia and Newfoundland/Labrador monitor for tunicates and other alien invasive species. Violet and golden star tunicates were found on the south coast of Newfoundland at single locations in 2007, but the vector is unknown. At Prince Edward Island, no new species were detected in 2007, but all four non-indigenous tunicate species continue to spread within Island waters.

The bryozoan *Membranipora membranacea* was discovered in the Baie des Chaleurs in 2006, on kelp produced for aquaculture experiments that were completely decimated. The species was also found on wild kelp around the experimental site. The long-term impact of this bryozoan on wild populations is unknown.

USA

In 2003, the Virginia Seafood Council implemented a plan to grow up to one million oysters among ten specific commercial shellfish operations in lower Chesapeake Bay. The plan called for the use of triploid oysters, and was reviewed twice by a review panel of the Chesapeake Bay Program and a committee of the National Research Council (NRC). The planned introduction was highly controversial, owing to the desire to revive a once-productive native oyster fishery in the Chesapeake and the potential risks associated with use of a non-native species. The NRC report highlighted considerable uncertainties about the potential impacts of the non-native oyster, and called for limited trials with significant research investment to address critical knowledge gaps (to evaluate risks). The decision and legal authority to proceed resided with the state of Virginia. Field trials, using triploid oysters, began in summer 2003; any oysters used in such trials were monitored over time and removed prior to reaching maturity. Both the use of triploid oysters and monitoring were intended to reduce the chances of establishment, although the NRC report pointed out that some oysters would revert to diploid with the risk of establishment.

Crassostrea ariakensis, the Suminoe oyster, was used in a research project in Roanoke and Pamilico Sounds, North Carolina, where it was released accidentally in 2004. The introduction of *C. ariakensis* into tidal waters of Chesapeake Bay was approved and implemented in 2004, when 800 000 oysters were deployed. These were removed in February 2005 from the test sites. Of 7600 oysters tested, four had the ability to reproduce, but the odds were purported to be low (no number given) that fertile oysters were in close enough proximity to reproduce. The Virginia Seafood Council was given approval to continue to grow sterile oysters at ten sites in mesh bags inside submerged cages, following protocols similar to the earlier experiment. The oysters were triploids and deemed to be free of parasites. However, environmental groups expressed concern that they may cause problems in the ecosystems beyond competition with native oysters. In addition, although *C. ariakensis* appears not to be susceptible to disease, it is not tolerant of pollution, and especially low oxygen. In 2006 it was reported that the US Army Corps of Engineers was preparing an environmental impact statement for a proposed introduction of *C. ariakensis* into tidal waters of Maryland and Virginia, to establish a naturalized, reproducing, and self-sustaining population of this oyster species.

Didemnum sp. (now *D. vexillum*) was first identified in 2000, during a survey in Massachusetts. Upon examination of archived samples, *D. vexillum* was present in Boothbay Harbor, Maine, in 1993 and the Damariscotta River, Maine, in 1988. The species is abundant and growing aggressively along both the Pacific and Atlantic coasts of the USA, and common in both shallow and deep water in the northeastern USA. The current range is much greater than reported in earlier years. Species identification was unknown and previous species names that were assigned (e.g. *D. lahillei*, *D.* sp. A) are not being used in the USA, although species nomenclature in New Zealand assigned different species names to organisms from Georges Bank and New Zealand. The nomenclature currently accepted, based on molecular studies, is *D. vexillum*. *Didemnum vexillum*'s geographic origin is unknown, although molecular studies indicate that 18S is similar in organisms collected from the Atlantic and Pacific coasts, Japan, and New Zealand. However, additional molecular studies are being conducted to confirm or refute that these are the same species.

Didemnum vexillum reportedly covered 70–90% of a 75 km^2 area in Georges Bank prime Atlantic scallop and groundfishing area in 2002. By 2005–2006, the area affected was ~200 km^2. Georges Bank is approximately 200 nautical miles offshore and 50–70 m deep, so this is one of the first reports of an introduced species in an area near the continental shelf break. Commercial vessel traffic and fishing vessels traverse and visit the area. A workshop on ascidians held at Woods Hole, Massachusetts in April–2005 highlighted ongoing research on *D. vexillum* and other introduced ascidians. New reports of the species include Cobscook Bay, Maine, Strong Island, Osterville, Massachusetts, Woods Hole Iselin Dock, Massachusetts, Fort Point, New Hampshire, and Beavertail Point, Rhode Island. In 2007, it was reported that *Didemnum* sp. was expanding its range on Georges Bank. At some of the sites surveyed sites, *D. vexillum* covered 50–75% of the gravel substrata, approximately doubling the amount of coverage recorded in 2005–2006. It was also found in Mission Bay, San Diego.

The isopod *Synidotea laevidorsalis*, native to the western Indo-Pacific, was collected in New York City harbour at South Street Seaport in 2003, and in 2002 it was found on fouling plates in lower Chesapeake Bay. On the Pacific coast, it is known from San Francisco Bay (since 1897) and from Willapa Bay, Washington. It was first found on the east coast in 1998 at Charleston, South Carolina, and in 1999 in Delaware Bay.

Synidotea laevidorsalis is likely to be present in other North American east coast estuaries, and has also been collected on the Atlantic coasts of France and Spain.

A single specimen of *Metacarcinus magister* (= *Cancer magister*) (Dungeness crab) was reported caught in the Atlantic Ocean off Gloucester, Massachusetts, in 2007. This specimen was apparently discarded or had escaped from a live seafood market. There are no other reports of this crab from the Atlantic.

In 2007, Chinese mitten crabs *Eriocheir sinensis* were caught in the Patapsco River, near Baltimore, on upper Chesapeake Bay. This was the first known collection of this invasive crab on the US Atlantic coast, although the species had been collected several times in the Great Lakes and tidal St Lawrence River, and once in Louisiana.

The amphipod *Caprella mutica* was reported in Massachusetts and Rhode Island from surveys conducted in 2000. It species was recorded in samples during a 2003 rapid assessment survey in locations from Portland, Maine, to Mystic, Connecticut. It can be very abundant locally.

In 2002, *Alcyonidium* sp., a new bryozoan was observed growing on aquaculture fish pens near the Isle of Shoals and the Coast Guard Pier in New Castle off the coast of New Hampshire. The invading bryozoan, tentatively identified as an *Alcyonidium* sp., seems to be established in New Hampshire, but recently has been preyed upon by a native nudibranch, leaving only small fragmented colonies over winter, so its establishment over the long term needs to be verified. The species was identified from Massachusetts to Maine in subsequent years.

Southwestern Atlantic coast

USA

The spotted jellyfish *Phyllorhiza punctata* was reported for the first time along the Atlantic coast of Florida, a range extension from the Gulf of Mexico. It was found in the Indian River lagoon in 2001. In 2007, *Phyllorhiza punctata* (Australian spotted jellyfish) appeared for the first time in Galveston Bay, Texas, and in July it extended its range about 200 km north to Guana Lake, a lagoon near Augustine Inlet, Florida.

The orange cup coral *Tubastrea coccinea*, a native Indo-Pacific coral, first appeared in the Caribbean in 1943, probably transported on ship fouling. It gradually expanded its range north into the Gulf of Mexico, reaching oil platforms off Texas and Louisiana by 1991. By 2002, it had invaded the Flower Garden Banks National Marine Sanctuary off Texas, an important deep-water reef, and had also been collected on shipwrecks off the east coast of Florida.

Stramonita haemostoma floridana (Southern Oyster Drill, Florida Rock Shell) is a subspecies of the amphi-Atlantic *S. haemostoma* and native to the Northwest Atlantic, south of Cape Hatteras. Since 1955, it has been known from Atlantic coastal bays (Hog Island Bay, Chincoteague Bay) in Maryland and Virginia, where it may have been introduced with planted oysters. In 2005 and 2006, two small collections of this snail were made in Chesapeake Bay proper, in the James and York Rivers, Virginia. Molecular analysis indicated that these animals originated from Atlantic coast populations, not from Europe or the Gulf of Mexico (Harding and Harasewych, 2007). The coastal currents between Cape Hatteras and the mouth of Chesapeake Bay are variable, but tend to flow south, so anthropogenic movement with fisheries or shipping may be more likely than natural dispersal. The occurrence of established populations in Chesapeake Bay has not been established.

Two serpulid polychaetes, *Ficopomatus ushakovi* and *Hydroides diramphus*, were found at several sites in Texas during surveys in 2001.

The Indo-Pacific oyster *Hyotissa hyotis* is often misidentified as the native Atlantic oyster, *H. mcgintyi*. However, *H. hyotis* differs in shell colour and attains a much larger size. During a molecular study of *H. mcgintyi*, two oyster specimens found near Marathon Key, Florida, in 2003 proved almost identical to specimens of *H. hyotis* from Guam. Earlier records of *'H. hyotis'* in western Atlantic waters refer to *H. mcgintyi*. Several specimens of true *H. hyotis* have been collected in Florida, but established populations have not been confirmed. Hull fouling and ballast water are possible vectors for the transport of this oyster.

The range for the green mussel *Perna viridis* has increased; it can be found now from Titusville north to Jacksonville (about 210 km). This is an expansion of its range from the first report of its introduction in Tampa Bay, Florida (Gulf of Mexico coast), and it continues to expand its range northwards. In 2003, it was collected for the first time in Georgia waters, along the entire coast of the state, from St Simons Island north to the Savannah River. In October 2006, it was collected for the first time in South Carolina waters, in Charleston harbour and surrounding waters.

The Charru mussel *Mytella charruana* was first collected near a power plant in Jacksonville, Florida, in 1986, but the population hen seemed to disappear. It was later collected in 2004 in Mosquito Lagoon near Titusville, Florida. The mussel is a native of the east coast of South America. It was also found "growing heavily on floating docks" on the Medway River, flowing into St Catherines Sound, Georgia.

Charybdis helleri, the Asian swimming crab native to the Indo-Pacific, was reported in 2004 to extend its range from Sarasota Bay, Florida, on the Gulf of Mexico north to Core Sound, North Carolina, about 50 miles south of Cape Hatteras.

The eastern Pacific titan acorn barnacle *Megabalanus coccopoma*, native from the Gulf of California to Peru, had colonized Brazil by 1961, and has been collected from 2001 through 2004 at several locations in the Gulf of Mexico (Florida, Texas, and Louisiana), although established populations were not found. Between 2005 and 2007, it was collected at numerous Atlantic coast locations from Fort Pierce, in the Indian River Lagoon, Florida, north to Beaufort, North Carolina (US Geological Survey Center for Aquatic Resource Studies). The Beaufort specimen was a single barnacle on a buoy, but populations have now established at least as far north as Wilmington, North Carolina (USGS Center for Aquatic Resource Studies, 2007).

Four Indo-Pacific bryozoans introduced to estuaries of the southeastern United States (*Celleporaria pilaefera*, *Electra bengalensis*, *Hippoporina indica*, *Sinoflustra annae*) were identified during fouling plate studies and taxonomic studies, starting in 2001, conducted by the SERC Marine Invasions Group. *Hippoporina indica* was the most widespread, occurring in eight of the estuaries sampled, from Norfolk, Virginia, in Chesapeake Bay, to Corpus Christi, Texas. This species had not been reported previously from the Atlantic. *Electra bengalensis* was found in the St Johns River estuary, Jacksonville, and the Indian River lagoon, both in Florida, and is previously known from Hawaii, the Pacific entrance to the Panama Canal, and West Africa. *Sinoflustra annae* and *Celleporaria pilaefera* were found only in the St Johns Estuary. Two of these species, *E. bengalensis* and *S. annae*, are characteristic of brackish water, and possibly could survive transport through the Panama Canal as adults, but also belong to families with long-lived planktrophic larvae, so have potential for ballast-water transport. The other two species seem to be confined to more-saline locations, and their mode of development is unknown (McCann *et al*., 2007).

Penaeus monodon, the Asian tiger shrimp, is reared widely in aquaculture operations around the world. In 1988, large numbers escaped from a rearing operation in South Carolina. About 1000 were captured from North Carolina to Florida that year (USGS Center for Aquatic Resource Studies), but no reproduction was documented. In 2006 and 2007, several more were caught on the Atlantic and Gulf coasts of the US, in Pamlico Sound, North Carolina (five specimens in 2006, one in 2007), near Beaufort, South Carolina (one in 2007), near Mobile Bay (one in 2006), and in Vermillion Bay, Louisiana (one in 2007). These captures probably represent occasional escapes from aquaculture.

4.3.5 Eastern Pacific coasts

Canada

As in previous years, the British Columbia shellfish industry imported seed for the main aquaculture species: *Venerupis* (= *Ruditapes*) *philippinarum*, *Crassostrea gigas*, and *Mytilus galloprovincialis* and *M. edulis*. Lesser quantities of seed for *C. sikamea*, *C. virginica*, *Ostrea edulis*, and the purple-hinge scallop, *Crassodoma gigantea*, were also imported. With the exception of the scallops, which are grown in nets, these molluscs are used primarily for beach-seeding and grow-out on open-water structures. All imports originate from health-certified facilities.

In 2007, *Crassostrea gigas* was reproducing in the wild. It is assumed that *V. philippinarum* will spread northwards.

In British Columbia, varnish clams *Nuttalia obscurata* have now expanded their range. If the species proves to be tolerant of colder water, it may become widespread on British Columbia's central coast. There is now a small, successful commercial fishery for the species.

As reported in 2003, illegal introductions of lobsters (likely *Homarus americanus*) led to the finding of a large lobster in Vancouver Harbour. This species was outplanted intentionally in a British Columbia inlet several decades ago, but did not become established.

Green crabs, *Carcinus maenas*, were first reported in Canada around 2002. In British Columbia there were only single or limited numbers of individuals detected, and there is no indication that they spread from one area to another. A single male green crab was found during 2002, but it died in an experimental holding tank in November 2003. Many of the findings are reported from the west coast of Vancouver Island. In 2006, trap surveys for *Carcinus maenas* were completed on the west coast of Vancouver Island and in Desolation Sound, Discovery Passage, and Johnstone Strait. A total of 388 green crabs was collected from beaches in Barkley, Clayoquot, Nootka, and Kyuquot Sounds, and Esperanza Inlet. No green crabs were found on the east side of Vancouver Island. Length frequencies suggested at least three year classes present, which indicates local recruitment. These populations could serve as sources of larvae that could result in continued northward expansion of green crabs in British Columbia in years of strong northward current transport. Populations increased during 2007.

Green mussels (*Musculista senhousia*) were recorded at two new localities. They have been reported from several localities in the Strait of Georgia since the 1990s; the new records in 2006 suggest that the species' range is continuing to expand in British Columbia.

European flat oysters (*Ostrea edulis*) were collected attached to hard substratum in Useless Inlet and Joes Bay in Barkley Sound; this is the first confirmation of successful reproduction and settlement in British Columbia. The species is cultured in British Columbia, and collection of unattached single oysters in Esperanza Inlet in 2006 were traced back to deliberate stocking in 1991 and subsequent human-mediated movement of adult oysters.

A previously unreported population of the Japanese oyster drill *Ocinebrellus inornatus* was discovered on the west coast of Vancouver Island. The drills may have been established for some time, because this is also a site of early Pacific oyster introductions, reported in 2006.

Japanese mudflat snails (*Batillaria attramentaria*) were found at two new localities, both of which have long histories of Pacific oyster (*Crassostrea gigas*) culture.

For the first time, the New Zealand mud snail *Potamopyrgus antipodarum* was reported in British Columbia in 2007, at a single location on the west coast of Vancouver Island.

The snail *Littorina littorea* was reported from two Pacific coast locations in 2002 and 2003. A population of ~250 mature individuals was found in rocky rip-rap of San Francisco Bay. They were mature snails of a single size class, occurring along a 25 m stretch of shore. All the individuals found were removed in an attempt to eradicate the population. A second population has been reported from Anaheim Bay, California, but no details are available yet.

USA (2003–2007)

In 2006, species exported and identified as live/fresh included the geoduck clam, other clams, conch, cuttlefish, molluscs, octopus, scallops, sea urchin, and squid (with *Loligo* identified as one species). Mussels are listed as live/fresh and either farmed or wild. Under the category of live/fresh/salted/brined exports are crabs; under the category of live/fresh/dried/salted/brined exports are crustaceans, lobsters, rock lobsters, and shrimp; and under the category of live/fresh/frozen/dried/salted/brined exports are oysters. The only exported species reported in 2006 that had no description of its condition, but is presumed to have been live, is oyster seed.

Several non-native molluscs are grown along the Pacific coast, including the oyster *Crassostrea gigas*, mussel *Mytilus galloprovincialis*, and clam *Ruditapes* (= *Tapes*) *philippinarum*. Along the Atlantic coast, the oyster *Ostrea edulis* continues to be cultured at several sites. Detailed information about the scale of aquaculture for these species, and possible movement of aquaculture products regionally, nationally, and internationally, remains elusive.

Didemnum vexillum has been reported from the west coast at several locations in California and Washington. An unsuccessful eradication effort was undertaken in Friday Harbor, Washington area. The species has been found offshore in approximately 45–65 m of water throughout the area surveyed and may cover more than 67 m², representing about a tenfold increase in a single year. In areas where it has been recorded, *D. vexillum* may cover up to 75% of the bottom cobble area.

The colonial tunicate *Perophora japonica* was found for the first time in Humboldt Bay, California, in 2003. It has not been reported from other US waters, but has colonized European waters, where it was first collected off Brittany in 1982. In the East Pacific and East Atlantic, hull fouling is the probable mode of introduction.

Orthione griffenis is a bopyrid isopod that inhabits the gill chambers of burrowing mud shrimps of the genus *Upogebia*. It is apparently native to Japan, and was first collected in US waters in 1985. It now infests *U. pugettensis* from Santa Barbara, California, north to British Columbia. In Oregon estuaries, up to 80% of the shrimps are infected and rendered incapable of reproduction. Mud shrimps are important as a suspension-feeder and as food for a wide range of fish and shorebirds. Impacts of this parasite on the abundance of mud shrimp abundances are currently being studied. Ballast water is considered to be the likeliest vector for introduction.

In 2004, *Hydroides diramphus* was reported in San Diego Bay, California, during two independent surveys.

Clymenella torquata was abundant in Samish Bay, Washington, where it interferes with the culture of the Pacific oyster *Crassostrea gigas*.

In July 2007, in the upper reaches of the Coos Bay estuary, Oregon, high densities (thousands per m^3) of a very small (~5 mm) unidentified snail were observed. At one site, the snail co-existed with *Potamopyrgus antipodarum*, the New Zealand mud snail. The snail was later identified as *Assiminea parasitologica*, a brackish water snail native to southern Japan and Korea. Sampling was planned for 2008 to determine whether this snail occurred in other west coast estuaries. The genus includes snails with direct development and with planktonic larval development, so that the mode of transport is unclear.

In 1999, two unidentified types of small (~5 mm) hydrobiid snails were collected in Suisun Bay, a brackish water portion of the inner San Francisco Bay estuary. One was identified as *Littoridinops monroensis*, previously known from brackish and coastal freshwater habitats in the southeastern USA (Maryland–Mississippi), and clearly an introduction. Molecular analyses indicated close affinity with US east coast populations. Ballast-water sediment was suggested as a vector for the species, which lacks a planktonic stage. The date of introduction of this easily overlooked species is unknown. The other species, *Tryonia porrecta*, is native to interior basins of the southwestern USA and was considered cryptogenic in California (Hershler *et al*., 2007).

Molgula ficus, a solitary tunicate found in southern California harbours, had been previously identified as the native *M. verrucifera*, but it was subsequently found to be different from open-coast forms that more clearly fit the original description. The harbour form has now been identified as *M. ficus*, an Indo-Pacific species. It was first collected in San Diego Bay in 1994, but now ranges north to Port Hueneme and is present at a single location in San Francisco Bay. This tunicate has also been reported from Chile (Lambert, 2007).

In August 2006, 256 specimens of an unidentified exotic oyster were found in San Francisco Bay, on the eastern shore of South Bay, from Dumbarton Point to Coyote Slough. The oysters were collected in an eradication attempt, because they are considered a threat to restoration of the native *Ostrea conchaphila* (the olympic oyster). The exotic oysters did not look like typical *Crassostrea gigas* and genetic studies were commenced to determine their identity. One empty shell of a large *Crassostrea* was found on a fouling plate in the Bay in 2004 (San Francisco Chronicle, 2006; USGS Center for Aquatic Resource Studies, 2007). Since 2000, settlement of unidentified *Crassostrea* oysters has also been observed in southern California embayments, from Tijuana Estuary to Los Angeles Long Beach Harbour. These oysters are probably established in some embayments, and efforts at genetic identification are in progress.

4.3.6 Great Lakes (freshwater)

A new invader to the Great Lakes in 2005 is the sideswimmer *Gammarus tigrinus*, which has been documented in all five Great Lakes.

The Chinese mitten crab *Eriocheir sinensis* was first recorded in Canada in 1965 in the Detroit River, near Windsor, and then in 1973 in Lake Erie. At that time its presence did not raise much concern among biologists because the Great Lakes do not offer the saltwater environment that the species requires for reproduction. Conversely, off the California coast in San Francisco Bay, where conditions are similar to those of the St Lawrence estuary, the species has installed itself permanently, causing irreversible negative impacts. In 2004 a single 40 g female adult mitten crab was found in the St Lawrence estuary. This is the first identification in the lower St Lawrence River where the species might have access to salt water and hence potential for establishment. Additional specimens were found in 2005 and 2006. The vector for this apparently healthy specimen is thought to be transoceanic shipping traffic in the area. Should the species become established in the lower St Lawrence, and the potential exists, other tributaries in the region would be at risk of invasion. The environmental and economic impact of such a scenario is unknown, but work has begun to identify the origin of the Chinese mitten crabs found in the St Lawrence through genetic studies. Additional records of the mitten crab have since become known, highlighting the concern about this invasive species.

Over the entire reporting period, *Dreissena polymorpha* was reported to continue spreading westwards.

4.3.7 Pacific Ocean

Australia (Affiliate status, 2004, 2007)

In total, 223 invertebrate species are currently recognized as introduced (118) or cryptogenic (105) in Australian waters. The vast majority of these are not considered to be pests of national concern (i.e. causing significant social, economic or environmental degradation). Species identified as pest species of national concern are documented below.

Crassostrea gigas has now been confirmed as prevalent throughout most estuaries in New South Wales, including Port Kembla, Sydney, Botany Bay, and Newcastle. All these ports have been surveyed, but on each occasion the survey apparently failed to detect its presence. The Pacific oyster was first introduced into New South Wales in 1967, and by 1973 had been recorded in several estuaries (and ports) in that state, as far north as Port Stephans. Oyster spat continue to be exported from Tasmanian hatcheries to South Australian oyster leases (e.g. Coffin Bay). Initial expectations were that salinity levels in South Australian embayments (>36 psu) were too high to permit oyster settlement. In 1990 and 1992, however, naturalized spat falls were observed in Franklin Harbour and Murat Bay. Isolated feral populations are now scattered across South Australia, but are much less extensive than their Tasmanian counterparts. It is unclear whether the Australian national translocation policy or the ICES Code of Practice are applied to these introductions.

Another single live individual of the Asian green mussel *Perna viridis* was discovered in 2007 on a pylon of a floating dock structure. It was further detected during an inspection on a dredge vessel at Dampier Port, Western Australia, in November 2006. In response to the detection, the vessel was sent to Singapore where fouling was removed by heat treatment and physical removal.

In November 2006, three specimens of the New Zealand greenlipped mussel *Perna canalicula* were found on a vessel in dry dock. Survey work is being undertaken at Port Kembla and Westernport to determine the status of the species there.

In July 2006, visual surveys of seven foreign fishing vessels (FFVs) conducted by divers had detected blackstriped mussel (*Mytilopsis sallei*) and Asian green mussel. The FFVs were apprehended and escorted to Darwin Harbour to have the hulls treated to kill the mussels.

There was a significant range expansion of the seastar *Asterias amurensis* in 2004. In January 2004, about 30 northern Pacific seastars were discovered by community groups at Inverloch, a small tidal inlet situated some 100 km southeast of Port Phillip Bay. The discovery of the seastar there represents the first occurrence on the open coastline of the Australian mainland (i.e. outside Port Phillip Bay). All the seastars were removed by hand, but over the following months (January–March), small numbers (3–10) continued to be discovered at low tide trapped in rock pools at the mouth of Inverloch Inlet.

No change has been reported in the distribution of the Asian clam *Corbula gibba*, the mussel *Musculista senhousia*, the European green crab *Carcinus maenas*, or the polychaete *Sabella spallanzanii*, all non-indigenous to the area.

The East Asian dove snail *Mitrella bicincta* was established at various sites in New South Wales, having been introduced in the 1960s, but only recently reported.

New Zealand (Affiliate status, 2003, 2004)

In all, 148 species are reported to have been introduced to New Zealand accidentally, nearly 70% thought to have been introduced as hull-fouling organisms. Invertebrate species of concern are described in the text below.

The swimming crab *Charybdis japonica*, a native of Japan, Korea, and Malaysia, was first discovered in New Zealand in 2000. It is currently distributed in estuarine areas east of Auckland on the North Island. The crab is already well established. Eradication or containment is not considered feasible, and recent reports indicate that it is expanding into new estuaries, although it appears that this may be by natural dispersal rather than human-mediated.

The corophiid amphipod *Paracorophium brisbanensis* was identified from Tauranga Harbour in 2002. This species was previously recorded only from the eastern coast of Australia, and was probably introduced to New Zealand by shipping. No new information is available.

The cancrid crab *Cancer gibbulosus* was identified from Wellington Harbour in 2002. The species was previously recorded only from the China Sea and was probably introduced to New Zealand by shipping. It is currently only known from within the harbour. Again, no new information is available.

In October 2001, an undescribed species of *Didemnum* was reported in large quantities from wharf piles in Whangamata Harbour in the Bay of Plenty. The same species was subsequently discovered covering a barge transferred from Whangamata to the Marlborough Sounds (New Zealand's primary marine farming region). This species has since been formally described as *Didemnum vexillum* and thought to be native to New Zealand, but continuing controversy exists between taxonomists. The recent discovery of the same didemnid on Georges Bank, Massachusetts, USA, has created controversy about its status in New Zealand. A critical review of molecular and morphological evidence is necessary to prevent further negative publicity. Although it is

clear that the Georges Bank population is new, its relation to the New Zealand population is currently undetermined and cannot aid in determining the status of the New Zealand population without further work.

The bryozoan *Biflustra grandicella* was identified from Golden Bay (NW South Island) in 2003 and originally misidentified as *B. savignii*. It was previously recorded only from the China Sea and was probably introduced to New Zealand by shipping as hull-fouling. It is currently distributed widely within the bay and appears to have been aided in its spread by scallop dredges. Its density is significant in some areas, fouling the scallop dredges with >2 crates (1 m^3) of material. It grows extremely fast and appears not to be fouled by epibiotic species. A contract is underway to determine the extent of fouling, epibiotic condition, and association with disturbance.

Table 4.3. First records of non-indigenous species (invertebrate taxa) 2003–2007 worldwide, including uncertain introductions and excluding species in containment. Asterisks indicate that the date of first report may be earlier. Two dates means that the species was reported in the literature on the earlier date, but only appeared later in the national report. Some species were reported during 2003–2007 although the first record was earlier. Species are arranged by taxa, alphabetically within taxa, and by region, similar to the approach used elsewhere in this report. Information is taken from national reports and abstracts in ICES WGITMO and ICES/IOC/IMO SGBOSV meeting reports. Species such as *Ensis directus*, *Crepidula fornicata*, and *Austrominius* (= *Eliminius*) *modestus* have been present in many European countries for years, but are fully documented here. *Crassostrea gigas* also has been present, but it is spreading and reproducing in the wild, so is included.

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Protists							
Quinqueloculina carinatastriata	2004	France	Widespread	Unknown	Shipping	East Africa	Foraminifera
Cnidarians: anthozoans							
Maeotias marginata	1999	Estonia	Established	Unknown	Unknown	Black Sea	Hydromedusae
Oculina patagonica	2007	Italy	Several localized locations, associated with warm waters	Unknown	Unknown	Southwest Atlantic	Coral
Phyllorhiza punctata	2001–2007	Gulf of Mexico	Spreading	Predation	Adjacent waters	Caribbean	Coral
Tubastrea coccinea	1991, 2002–2005	USA, Florida	From Gulf of Mexico to Florida	Unknown	Unknown	Indo-Pacific	Coral
Cnidarians: hydrozoans							
Cordylophora caspia	Unknown	Belgium	Established	Obstructs pipes	Fouling	Ponto-Caspian area	Hydrozoan
Cordylophora caspia	2007	Italy	Unknown	Unknown	Fouling	Ponto-Caspian area	Hydrozoan

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Clytia hummelincki	1996, 2003–2004*	Italy	Associated with date mussels	Unknown	Unknown	Eastern and western Atlantic, subtropical	Hydrozoan
Ctenophores							
Mnemiopsis leidyi	2006–2007	Norway	Established	Predation, foodwebs	Ballast water	Northwest Atlantic	Ctenophore
Mnemiopsis leidyi	2006	Sweden	Established	Predation, foodwebs	Ballast water	Northwest Atlantic	Ctenophore
Mnemiopsis leidyi	2007	Belgium	Established	Predation, foodwebs	Adjacent seas	Northwest Atlantic	Ctenophore
Mnemiopsis leidyi	2006–2007	Germany, Baltic Sea	Established	Predation, foodwebs	Ballast water	Northwest Atlantic	Ctenophore
Mnemiopsis leidyi	2007	Poland	Established	Predation, foodwebs	Ballast water	Northwest Atlantic	Ctenophore
Animals: polychaetes							
Branchiomma luctuosum	2005	Italy	Few locations	Unknown	Unknown	Red Sea	Polychaete
Branchiomma luctuosum	2005–2007	Spain, Mediterranean	Common	Unknown	Unknown	Red Sea	Polychaete
Clymenella torquata	2005	USA, west coast	Locally abundant	Interfering with aquaculture	Unknown	Northwest Atlantic	Polychaete
Ficopomatus enigmaticus	< 2002–2007	Belgium	Spreading	Unknown	Fouling organism	Southwest Pacific, Indian Ocean	Polychaete

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Ficopomatus enigmaticus	1998, 2004*	Ireland	Locally abundant	Competition with fouling organisms	Hull-fouling	Southwest Pacific, Indian Ocean	Polychaete
Ficopomatus enigmaticus	2006	Croatia	New record	Competition with fouling organisms	Hull-fouling stones	Southwest Pacific, Indian Ocean	Polychaete
Hydroides diramphus	2004	USA, west coast and Texas	New record, localized	Unknown	Unknown	Mediterranean, Adriatic	Polychaete
Marenzelleria viridis	< 2004	UK, River Thames	Common	Competition	Unknown	Northwestern Atlantic	Polychaete
Marenzelleria arctica	2004; 2005	Sweden (Baltic)	Spreading	Competition with amphipod	Unknown	Northern Russian coast, Arctic Ocean	Polychaete
Marenzelleria viridis	1990s, 2004*	Poland	Established	Competition	Unknown	Northwestern Atlantic	Polychaete
Marenzelleria neglect sp. nov.	2003–2007	Sweden (Baltic)	Spreading	Unknown	Unknown	Northwestern Atlantic	Polychaete
Novafabricia posidoniae or *Novafabricia* sp. cf. *N. infratorquata*	2006	Italy	Localized locations	Unknown	Unknown	Northwest Atlantic, Caribbean	Polychaete
Molluscs: gastropods							
Assiminea parasitologica	2007	Oregon, USA	Unknown	Unknown	Unknown	Japan and Korea	Gastropod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Batillaria attramentaria	2005	Canada, west coast	Spreading	Competition	Aquaculture	Japan	Gastropod
Cerithium scabridum	2003, 2005	Italy	Appears to disappear by 2005	Unknown	Unknown	Eastern Pacific	Gastropod
Crepipatella dilatata	2005	Spain, NE Atlantic	Common	Unknown	Unknown	South America	Gastropod
Crepidula aculeata	1973	Spain, Mediterranean	Unknown	Unknown	Unknown	Cosmopolitan in subtropics	Gastropod
Crepidula fornicata	< 2002, 2007	UK, Wales	Spreading	Competition	Aquaculture, mussel seed	Northwest Atlantic	Gastropod
Crepidula fornicata	2003	Norway	Not spreading northwards	Competition	Aquaculture, mussel seed	Northwest Atlantic	Gastropod
Crepidula fornicata	?, 2004	Belgium	Widespread	Competition	Aquaculture, mussel seed	Northwest Atlantic	Gastropod
Crepidula fornicata	?, 2004	France	Spreading, initiated eradication campaign	Competition	Aquaculture, mussel seed	Northwest Atlantic	Gastropod
Crepidula fornicata	1997	Spain	Unknown	Unknown	Aquaculture, fouling	Northwest Atlantic	Gastropod
Gibbula albida	1981–1984, 2005*	Spain	Widespread	Unknown	Unknown	Mediterranean	Gastropod
Gibbula adansoni	< 1992, 2005*	Spain	Widespread	Aquaculture	Unknown	Mediterranean	Gastropod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Haliotis discus hannai	< 2003–2004	Ireland	Localized aquaculture	Deliberate	Unknown	Mediterranean	Gastropod
Haliotis tuberculata	< 2003–2004	Ireland	Localized aquaculture	Deliberate	Unknown	Mediterannean	Gastropod
Haliotis tuberculata	< 2006*	UK	Localized aquaculture	Deliberate, may end in 2008	Unknown	Mediterranean	Gastropod
Littorina littorea	2003	USA, Pacific	Two regions	Attempt to eradicate	Unknown	East Atlantic	Gastropod
Littoridinops monroensis	< 1996, 2005*	USA Pacific, California	Spreading	Unknown	Ballast	Northwest Atlantic, Gulf of Mexico	Gastropod
Mitrella bicincta	1960, 2007*	Australia	Established	Unknown	Unknown	Indo-Pacific	Gastropod
Ocinebrellus inornatus	< 2003	Canada, west coast	Established	Shellfish aquaculture	Oyster shipments	Northwest Pacific	Gastropod
Ocinebrellus inornatus	2003	France, North Brittany	Established	Shellfish aquaculture	Oyster shipments	Northwest Pacific	Gastropod
Potamopyrgus antipodarum	2007	British Columbia, Canada	Localized	Unknown	Unknown	Southwest Pacific, New Zealand	Gastropod
Rapana venosa	2005–2007	Belgium	Single record	Predation	Clam shipments	Northwest Pacific, then Mediterranean	Gastropod
Rapana venosa	2005	The Netherlands	Single record	Predation	Clam shipments	Northwest Pacific, then Mediterranean	Gastropod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Rapana venosa	2003–2005	France, south Brittany	Few	Predation	Clam shipments	Northwest Pacific, then Mediterranean	Gastropod
Rapana venosa	2007	Spain, Atlantic	Present	Predation	Clam shipments	Northwest Pacific, then Mediterranean	Gastropod
Rapana venosa	2004	Italy	Locally abundant	Predation	Clam shipments	Northwest Pacific, then Mediterranean	Gastropod
Stramonita haemostoma floridana	2007	Chesapeake Bay, USA	Spreading	Oyster predation	Fishing, secondary boat traffic	Northwest Atlantic, south of North Carolina	Gastropod
Tryonia porrecta	2006	USA, Pacific, California	Established	Unknown	Unknown	Southwest US interior basins	Gastropod
Urosalpinx cinera	2007	Belgium	New record, few individuals, not established	Predations	Aquaculture	Northwest Atlantic	Gastropod
Molluscs: opisthobranchs							
Aplysia dactylomela	2003–2004	Italy	Localized locations	Unknown	Unknown	Circumtropical	Opisthobranch
Melibe viridis (= *fimbriata*)	1991 (2004)	Italy	Localized	Competition	Lessepsian	Indo-Pacific	Opisthobranch
Tritia (= *Cyclope) neritea*	2003	France	Expanding	Unknown	Aquaculture, human mediated	Mediterranean, Black Sea, subtropical Atlantic	Opisthobranch

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Tritia (= Cyclope) neritea	< 1991	Spain	Unknown	Unknown	Aquaculture, human mediated	Mediterranean, Black Sea, sub-tropical Atlantic	Opisthobranch
Molluscs: bivalves							
Anadara demiri	2001–2007	Italy	Abundant	Unknown	Unknown	Cosmopolitan	Bivalve
Austrovenus stuchburyi	2003	France	Discarded oyster shells	Unknown	Aquaculture	New Zealand	Bivalve
Chlamys lischkey	1985	Spain, Mediterranean	Unknown	Unknown	Unknown	Southwest Atlantic	Bivalve
Crassostrea ariakensis	2004	US, Chesapeake Bay	Localized	Competition with native oyster	Deliberate	Northwest Pacific	Bivalve
Crassostrea gigas	2007	Norway	Localized, not established	Competition with mussels	Escapee/ dispersal; now illegal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	2006–2007	Sweden, west coast	Spreading	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	1980, 2003–2007*	Germany	Spreading south	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Crassostrea gigas	2003–2007	Belgium	Spreading south, early reproduction	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	2005	The Netherlands	Dominant invader	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	< 2006*	UK	Spreading	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	Unknown	France	Dominant invader	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	1980, 2007*	Ireland	Scattered wild populations in northern areas	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	2005*	Spain, Atlantic	Unknown	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Crassostrea gigas	< 2005*	Spain , Mediterranean	Unknown	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlanticast Atlantic	Bivalve
Crassostrea gigas	< 2005*	Italy	Dominant species	Competition with native species,	Aquacuture/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	2007	British Columbia, Canada	Localized, wild set	Competition with mussels	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Crassostrea gigas	1967, 2004	Australia	Spreading, reproducing in the wild	Competition with native species	Escapee/ dispersal	Northwest Pacific, then Northeast Atlantic	Bivalve
Fulvia fragilis	< 2003	Spain, Mediterranean	Unknown	Unknown	Lessepsian	Indian Ocean and Red Sea	Bivalve
Driessena polymorpha	< 2003	Ireland	Spreading	Competes with native species	Shipping	Ponto-Caspian	Freshwater bivalve
Driessena polymorpha	< 2001	UK	Spreading	Competes with native species, clogs pipes	Shipping	Ponto-Caspian	Freshwater bivalve

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Driessena polymorpha	1980s	USA	Spreading, crossed the conti-nental divide	Competes with native species, clogs pipes	Shipping	Ponto-Caspian	Freshwater bivalve
Driessena polymorpha	< 2001	Belgium	Spreading, moved into areas of low salinity	Competes with native species, clogs pipes	Shipping	Ponto-Caspian	Freshwater bivalve
Hyotissa hyotis	2003–2005	USA, Florida	Not established	Unknown	Unknown	Indo-Pacific	Bivalve
Idas simpsoni	2006	Croatia	Skull of whale	Unknown	Unknown	East Atlantic	Bivalve
Mercenaria mercenaria	2004	Italy	Localized	Unknown	Aquaculture	Northwest Atlantic	Bivalve
Mytella charruana	2004	USA, Florida	First record 1986,disapppeare d, new record	Unknown	Unknown	South America	Bivalve
Mytilopsis leucophaeata	2005–2007	Belgium	Localized	Clogs pipes, fouling organism	Shipping	Northwest Atlantic	Bivalve
Mytilopsis leucophaeata	2003	Finland, Gulf of Finland	Localized	Clogs pipes, fouling organism	Shipping	Northwestern Atlantic	Bivalve
Mytilopsis sallei	2007	Australia	On vessels	Unknown	Unknown	West Indies, south Atlantic	Bivalve
Nuttalia obscurata	2003	Canada west coast	Establsihed	Unknown	Unknown	Northwest Pacific	Bivalve
Ostrea edulis	2006	Canada, west coast	Spreading	Competition	Aquaculture escapee	East Atlantic	Bivalve

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Perna canalicula	2007	Australia	3 specimens	Competition with native species	Escapee	New Zealand	Bivalve
Perna viridis	< 2004–2007	USA, Florida to North Carolina	Spreading	Competition	Unknown	Indo-Pacific	Bivalve
Perna viridis	2007	Australia	On vessels	Competition	Shellfish aquaculture	Indo-Pacific	Bivalve
Rangia cuneata	2000, 2005*–2007	Belgium	Spreading	Clogs pipes	Netherlands waters	Gulf of Mexico	Bivalve
Theora lubrica	2001	Italy	Locally abundant	Unknown	Unknown	Indo-Pacific	Bivalve
Venerupis (= *Ruditapes*) *philippinarum*	2003–2006	Ireland	Localized aquaculture	Unknown	Aquaculture	Northwest Pacific, then Northeast Pacific	Bivalve
Venerupis (= *Ruditapes*) *philippinarum*	2006	UK	Localized aquaculture	Unknown	Aquaculture	Northwest Pacific, then Northeast Pacific	Bivalve
Venerupis (= *Ruditapes*) *philippinarum*	2005*	Spain	Unknown	Unknown	Aquaculture	Northwest Pacific, then Northeast Pacific	Bivalve
Venerupis (= *Ruditapes*) *philippinarum*	2005*	Italy	Dominant biomass	Outcompetes native molluscs	Aquaculture	Northwest Pacific, then Northeast Pacifi	Bivalve

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Xenostrobus (= *Limnoperna*) *securis*	2005	Spain	Present	Unknown	Unknown	Indo-Pacific, Australia and New Zealand	Bivalve
Arthropod: insects							
Telmatogeton japonicus	2004–2007	Belgium	Limited to buoys	Unknown	Shipping/ hulls, Iceland?	Japan	Chironimid
Arthropods: crustaceans: cladocerans and ostracods							
Acartia tonsa	Mid-1930s	Sweden	Established	Competition with native species	Ballast, shipping	North America Pacific	Cladoceran
Acartia tonsa	2004	Italy	Established	Compeiton with native species	Ballast, shipping	Northwest Atlantic and Indo-Pacific	Cladoceran
Cercopagis pengoi	2004	Germany, Baltic Sea	Established	Ecosystem impact, predation	Shipping, second-ary boating	Ponto-Caspian area	Cladoceran
Cercopagis pengoi	1997; 2002–2004	Sweden, east coast	Low abundance	Ecosystem impact	From adjacent seas	Ponto-Caspian area	Cladoceran
Cercopagis pengoi	1999, 2003	Poland	Abundant	Ecosystem impact	Unknown	Ponto-Caspian area	Cladoceran
Cercopagis pengoi	< 2005	Estonia	Unknown	Ecosystem impact	Unknown	Ponto-Caspian area	Cladoceran
Eusarsiella (= *Sarsiella*) *zostericola*	1975, 2005*	UK	Near power plant, two estuaries, poor dispersion	Unknown	Oyster aquaculture	Northwest Atlantic	Ostracod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Arthropods: crustaceans: cirripedes							
Balanus improvisus	1900	Spain	Unknown	Unknown	Unknown	Northwest Atlantic	Cirripedes
Austrominius (= *Elminius*) *modestus*	Unknown	Spain	Rare	Competition	Shipping	Southwest Pacific	Barnacle
Megabalanus coccopoma	1976–2006–2007	Belgium	Established, spreading	Competition	Shipping	Southeast Pacific	Barnacle
Megabalanus coccopoma	2004–2007	North Carolina to Florida, USA	Established, spreading	Competition	Shipping	Southeast Pacific	Barnacle
Megabalanus tintinnabulum	< 2006–2007	Belgium	Established, spreading	Competition	Shipping	Southeast Pacific	Barnacle
Megabalanus tulipiformis	~1958, 2005*	Spain	Established, spreading	Competition	Shipping	Eastern Atlantic	Barnacle
Arthropods: crustaceans: amphipods							
Caprella mutica	2007	Norway	Established	Competition/ predation	Aquaculture, ballast water and hull-fouling	Northwest Pacific	Amphipod
Caprella mutica	< 2002–2007	UK, Scotland	Spreading	Competition/ predation	Aquaculture, ballast water, and hull-fouling	Northwest Pacific	Amphipod
Caprella mutica	2003–2007	Ireland	Spreading	Competition/ predation	Shipping	Northwest Pacific	Amphipod
Caprella mutica	1998	Belgium	Established	Competition/ predation	Shipping	Northwest Pacific	Amphipod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Caprella mutica	2004	Germany	Established	Competition/ predation	Shipping	Northwest Pacific	Amphipod
Caprella mutica	2000, 2003–2005*	Canada, Québec	Spreading	Competition/ predation	Unknown	Northwest Pacific	Amphipod
Caprella mutica	2000–2007	US (Maine to Long Island Sound)	Spreading	Competition/ predation	Unknown	Northwest Pacific	Amphipod
Caprella scaura	1994, 2005*	Italy	Abundant locally, spreading	Predation	Unknown	Western Pacific	Amphipod
Chelicorophium curvispinum	< 2003–2007	Ireland	Common	Unknown	Unknown	Ponto-Caspian	Brackish water amphipod
Chelicorophium curvispinum	2005	Estonia	Common	Unknown	Unknown	Ponto-Caspian	Brackish water amphipod
Chelicorophium curvispinum	1900ws, 2004*	Poland	Established	Unknown	Unknown	Ponto-Caspian	Brackish water amphipod
Chaetogammarus ischnus	1928, 2004*	Poland	Spreading	Unknown	Unknown	Caspian	Brackish water amphipod
Dikerogammarus haemobaphes	1999, 2004*	Poland	Spreading by 2000–2001	Unknown	Unknown	Ponto-Caspian	Brackish water amphipod
Dikerogammarus villosus	2001, 2004*	Poland	Spreading	Unknown	Unknown	Ponto-Caspian	Brackish water amphipod
Dyopedos monacanthus	2007	Poland	Local record	Unknown	Unknown	North Atlantic	Amphipod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Gammarus tigrinus	2003	Estonia, northern Gulf of Riga	established	Competition	Ballast water	North America	Freshwater amphipod
Gammarus tigrinus	2003	Finland	Established	Competition	Unknown	North America	Freshwater amphipod
Gammarus tigrinus	(1990s), 2003	Poland	Spreading	Competition	From adjacent seas	North America	Freshwater amphipod
Gammarus tigrinus	2005	Canada, Great Lakes	Widespread	Competition	Unknown	North America	Freshwater amphipod
Gammarus tigrinus	2005	USA , Great Lakes	Widespread	Competition	Unknown	North America	Freshwater amphipod
Monocorophium (= *Corophium*) *insidiosum*	2005	Ireland	New record	Mudflat occupier	Unknown	Unknown	Amphipod
Obesogammarus crassus	1998, 2004*	Poland	Unknown	Unknown	Unknown	Ponto-Caspian	Freshwater amphipod
Paracorophium brisbanensis	2003	New Zealand	Unknown	Unknown	Unknown	Indo-Pacific, Australia	Amphipod
Platorchestia platensis	2005	Poland	Unknown	Unknown	Unknown	Cosmopolitan	Supralittoral amphipod
Pontogammarus robustoides	1990, 2004*	Poland	Unknown	Unknown	Unknown	Ponto-Caspian	Freshwater amphipod
Serejohyale (= Hyale) spinidactila	2006	Spain	Present	Unknown	Unknown	Tropical Atlantic	Amphipod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Arthropods: crustaceans: isopods							
Mesanthura romulea	2005	Italy	Localized	Unknown	Shipping, vessels	Australia	Isopod
Orthione griffenis	1985, 2006	USA, west coast	Established, spreading	Alters foodweb (reproduction of shrimps that are prey for birds)	Ballast water	Northwest Pacific, Japan?	Isopod
Paracerceis sculpta	2004	Italy	Local record	Unknown	Unknown	Pacific	Isopod
Synidotea laevidorsalis	2003	USA, Long Island Sound	Northern range	Unknown	Expansion from south	Indo-West Pacific	Isopod
Arthropods: crustaceans: malacostracans							
Atyaephrya desmaresti	No date	Poland	Established	Unknown	Aquaria	Mediterranean	Freshwater shrimp
Hemimysis anomala	2002	Poland	Spreading	Unknown	Unknown	Ponto-Caspian	Brackish water mysid
Hexapleomera robusta	2006	Spain	Present	Unkonwn	Unknown	Atlantic and E Pacific	Tanaid
Merhippolyte ancistrota	1980, 2005*	Spain, Mediterranean	Unknown	Unknown	Unknown	Tropical or subtropical Atlantic	Shrimp
Litopenaeus (= *Penaeus*) *vannamei*	2001	Italy	Rare outside ponds	Competition	Shellfish aquaculture	East Pacific, subtropical	Shrimp
Palaemon elegans	2003	Finland	New record	Unknown	Unknown	Mediterranean	Decapod
Palaemon elegans	2004	Poland	New record	Unknown	Unknown	Mediterranean	Decapod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Palaemon macrodactylus	2004	UK	Abundant	Competition with local shrimp	Shipping, ballast water	Northeast Asia	Shrimp
Palaemon macrodactylus	1998, 2006*–2007	France, Atlantic	Common	Competition with local shrimp	Ballast water	Northeast Asia	Shrimp
Palaemon macrodactylus	2004–2007	Belgium, Zeebrügge marina	Established	Competition with local shrimp	Ballast water	Northeast Asia	Shrimp
Palaemon macrodactylus	2005	The Netherlands	Established	Competition with local shrimp	Ballast water	Northeast Asia	Shrimp
Palaemon macrodactylus	2004	Germany	Single record	Competition with local shrimp	Ballast water	Northeast Asia	Shrimp
Penaeus (*Marsupenaeus*) *japonicus*	2007	UK	Single record	Unknown	Shellfish aquaculture	Indo-Pacific, Red Sea	Shrimp
Penaeus (*Marsupenaeus*) *japonicus*	2005	France, Bay of Quiberon (South Brittany)	Single record	Unknown	Shellfish aquaculture	Indo-Pacific, Red Sea	Shrimp
Penaeus japonicus	< 2001	Italy	Rare outside ponds	Competition	Shellfish aquaculture	Indo-Pacific, Red Sea	Shrimp
Penaeus monodon	< 2001	Italy	Rare outside ponds	Competition	Shellfish aquaculture	Northwest Pacific	Shrimp
Penaeus monodon	2005–2007	North Carolina and South, USA	Few records	Competition	Shellfish aquaculture	Northwest Pacific	Shrimp
Processa macrodactyla	1980, 2005*	Spain, Mediterranean	Unknown	Unknown	Unknown	Atlantic?	Shrimp

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Arthropods: crustaceans: decapods							
Acantharctus (= *Scyllarus*) *posteli*	1982, 2005*	Spain, Mediterranean	Unknown	Unknown	Unknown	Western Atlantic	Decapod
Actumnus globulus	1978, 2003*	Italy	Localized	Unknown	Shipping, boats	Indo-Pacific	Decapod
Calappa pelii	1991, 2005*	Spain, Mediterranean	Unknown	Unknown	Unknown	Eastern Atlantic	Decapod
Arcuatula senhousia	2004	Italy	Spreading	Prey for crabs, competition	Unknown	Northwest Pacific	Bivalve
Arcuatula senhousia	2005	Canada, west coast	Spreading	Prey for crabs, competition	Unknown	Northwest Pacific	Bivalve
Callinectes sapidus	2002/2003–2007	Belgium	Single record, few specimens some with eggs	Predation	Unknown	Northwest Atlantic	Decapod
Callinectes sapidus	2003	France	Few	Predation, foodwebs	Unknown	Northwest Atlantic	Decapod
Callinectes sapidus	2005	Spain, Guadalquivir Estuary	Several records	Predation	Unknown	Northwest Atlantic	Decapod
Callinectes sapidus	2006	Croatia	New record	Predation	Unknown	Northwest Atlantic	Decapod
Carcinus maenas	2004	Canada, Québec, Magdalen Islands	New record	Predation/ aquaculture	Unknown	Europe	Decapod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Carcinus maenas	2007	Newfoundland, Canada	Spreading	Predation/ aquaculture	Commercial traffic	Europe	Decapod
Carcinus maenas	2006–2007	British Columbia, Canada	Spreading	Predation/ aquaculture	Commercial traffic	Europe	Decapod
Charybdis helleri	2004	USA, Gulf of Mexico, North Carolina	Spreading	Unknown	Unknown	Indo-Pacific	Decapod
Chionoecetes opilio	< 2003–2007	Norway, Barents Sea	Spreading in the north	Unknown	Ballast water	Northwest Atlantic and Pacific	Decapod
Dyspanopeus sayi	< 2004	Italy	Local record	Predation	Unknown	Northwest Atlantic	Decapod
Eriocheir sinensis	1976; 2003–2007*	UK	Spreading	Herbivory, predation, erosion	Ballast water, hull fouling	Northwest Pacific	Decapod
Eriocheir sinensis	1932; 2003	Sweden, west coast, 2003 first record of egg-carrying female	Established	Herbivory, predation, erosion	Shipping	Northwest Pacific	Decapod
Eriocheir sinensis	Unknown	Belgium	Established	Herbivory, predation, erosion	Shipping	Northwest Pacific	Decapod
Eriocheir sinensis	1912, 2003–2007	Germany	Established; after 60 years becoming abundant	Herbivory, predation, erosion	Shipping	Northwest Pacific	Decapod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Eriocheir sinensis	2003	France	Single record	Herbivory, predation, erosion	Ballast water, hull-fouling	Northwest Pacific	Decapod
Eriocheir sinensis	2006	Ireland	New record	Herbivory, predation, erosion	Ballast water, hull-fouling	Northwest Pacific	Decapod
Eriocheir sinensis	2006	Spain	>500	Herbivory, predation, erosion	Ballast water, hull-fouling	Northwest Pacific	Decapod
Eriocheir sinensis	1930s	Finland	Increasing in number	Unknown	B Spreading from nearby country allast water, hull-fouling	Northwest Pacific	Decapod
Eriocheir sinensis	1940s	Poland	Increasing in number	Unknown	Spreading from nearby country	Northwest Pacific	Decapod
Eriocheir sinensis	1930	Estonia	Elevated abundance	Unknown	Spreading from nearby country	Northwest Pacific	Decapod
Eriocheir sinensis	2004	Canada, St Lawrence estuary	Single record	Herbivory, predation, erosion	Shipping	Northwest Pacific	Decapod
Eriocheir sinensis	2001	Spain, Mediterranean	Unknown	Herbivory, predation, erosion	Ballast water, hull-fouling	Northwest Pacific	Decapod
Eriocheir sinensis	2006	Italy	Single record	Herbivory, predation, erosion	Ballast water, hull-fouling	Northwest Pacific	Decapod
Hemigrapsus sanguineus	2007	Germany, Wadden Sea	New record	Competition, predation	Shipping, dispersal	Northwest Pacific	Decapod
Hemigrapsus sanguineus	2006–2007	Belgium	New record	Competition, predation	Shipping, dispersal	Northwest Pacific	Decapod

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Hemigrapsus sanguineus	2006	France	New record	Competition, predation	Shipping, dispersal	Northwest Pacific	Decapod
Hemigrapsus takanoi (= *penicillatus*)	2007	Germany, Wadden Sea	New record	Competition, predation	Shipping, dispersal	Northwest Pacific	Decapod
Hemigrapsus takanoi (= *penicillatus*)	2003–2007	Belgium	Established	Competition, predation	Shipping, dispersal	Northwest Pacific	Decapod
*Hemigrapsus takano*i (= *penicillatus*)	1994, 2005–2006*	Spain, Bay of Biscay	Several locations	Unknown	Shipping, dispersal	Northwest Pacific	Decapod
Homarus americanus	2000–2007	Norway	75 total, a few egg-bearing females	Competition, hybridization	Deliberate	Northwest America	Decapod
Homarus americanus	2003	France	Few	Hybridization	Import for direct human consumption	Northwest America	Decapod
Homarus americanus	2004, 2006	UK	Few	Hybridization	Import for direct human consumption	Northwest America	Decapod
Menaethius monoceros	2003	Italy	New record	Unknown	Shipping	Indo-Pacific	Decapod
Metacarcinus (= *Cancer*) *magister*	2007	USA, Atlantic	Few records	Unknown, claws with bands, males	Discards from cruise ships	East Pacific	Decapod
Orconectes limosus	1930s, 2004*	Poland	Established	Unknown	Unknown	North America	Freshwater crayfish

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Pacifastacus leniusculus	2006	UK	Spreading	Competition	Release, aquarium trade	North and southwestern USA	Freshwater crayfish
Paralithodes camtschaticus	2003–2007	Norway	Spreading in southern Barents Sea	No observed effects	Deliberate	Northern Pacific, Japan	Decapod
Percnon gibbesi	1999	Spain, Mediterranean	Unknown	Unknown	Unknown	South Pacific and South Atlantic	Decapod
Percnon gibbesi	2004	Italy	Expanding north from Sicily	Unknown	Unknown	South Pacific and South Atlantic	Decapod
Rhithropanopeus harrisii	Unknown	Belgium	Established	Unknown	Unknown	Northwest Atlantic	Decapod
Rhithropanopeus harrisii	2001, 2004*	Poland	Spreading	Unknown	Unknown	Northwest Atlantic	Decapod
Rhithropanopeus harrisii	2001, 2005–2007*	Spain, Mediterranean	Unknown	Unknown	Unknown	Northwest Atlantic	Decapod
Rhithropanopeus harrisii	2005	Italy	Abundant locally	Unknown	Unknown	Northwest Atlantic	Decapod
Ectoprocts/bryozoans							
Celleporaria pilaefera	2006	USA, southwestern Atlantic	Established	Unknown	Unknown	Red Sea	Bryozoan

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Electra bengalensis	2006	USA, southwestern Atlantic	Established	Unknown	Unknown	West Africa and India	Bryozoan
Hippoporina indica	2006	USA, southwestern Atlantic	Rare	Unknown	Unknown	India	Bryozoan
Membranipora membranacea	2005	Canada	Spreading	Destroyed kelp aquaculture	Unknown	Pacific	Bryozoan
Sinoflustra annae	2006	USA, southwestern Atlantic	Established	Competition	Unknown	India	Bryozoan
Tricellaria inopinata	2000–2001	Belgium	Spreading	Competition	Unknown	Northeast Atlantic	Bryozoan
Echinoderms							
Coccinasterias tenuispina	2000, 2005*	Spain, Bay of Biscay	Spreading	Unknown	Unknown	Unknown	Echinoderm
Diadema antillarum	2005*	Spain, Mediterranean	Unknown	Unknown	Unknown	Subtropical Atlantic	Echinoderm
Asterias amurensis	< 2004*	Australia	Expanding range	Predation	Ballast water	East Pacific	Echinoderm
Hemichordates: tunicates							
Botrylloides violaceus	2004*	Ireland	New record	Fouling/shellfish aquaculture	Vessel traffic/processing	Northwest Atlantic	Tunicate
Botrylloides violaceus	2004–2007	Canada, Prince Edward Island	Spreading	Fouling/shellfish aquaculture	Vessel traffic/processing	Northwest Atlantic	Tunicate

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Botrylloides violaceus	2007	Canada, Newfoundland	Spreading	Fouling/shellfish aquaculture	Commercial traffic	Europe	Tunicate
Botryllus schlosseri	2001–2007	Canada, Prince Edward Island, Magdalen Islands, Quebéc	Spreading	Fouling/shellfish aquaculture	Shipping/processing	Europe	Tunicate
Botryllus schlosseri	2007	Canada, Newfoundland	Spreading	Fouling/shellfish aquaculture	Commercial traffic	Europe	Tunicate
Ciona intestinalis	2003–2007	Canada, Prince Edward Island, Magdalen Islands, Québec	Spreading	Shellfish aquaculture	Vessel traffic/processing	NW Atlantic (USA)	Tunicate
Corella eumyota	2005	Ireland	New record, four locations	Unknown	Unknown	Southern hemisphere	Tunicate
Corella eumyota	< 2007	UK	Not expanding	Unknown	Unknown	Southern hemisphere	Tunicate
Corella eumyota	2006	Spain	New record	Unknown	Unknown	Southern hemisphere	Tunicate
Didemnum vexillum	2005–2007	Ireland	Spreading	Shellfish aquaculture, ecosystem impacts	Aquaculture, secondary boat traffic	Northwest Pacific, Japan?	Tunicate
Didemnum vexillum	1991, 2005	The Netherlands	Began spreading after 1998	Shellfish aquaculture, ecosystem impacts	Aquaculture, secondary boat traffic	Northwest Pacific, Japan?	Tunicate

Genus and species/category	Year of first record	Country	Status	Impacts	Vector	Country of origin	Taxonomic group
Didemnum vexillum	1990s, 2000–2007	USA, Maine to New York City (Long Island Sound)	First report 2000, spreading, present 200 miles offshore at 70 m	Shellfish aquaculture, ecosystem impacts	Aquaculture, secondary boat traffic	Northwest Pacific, Japan?	Tunicate
Didemnum vexillum	2003	USA, west coast	Widespread	Shellfish aquaculture, ecosystem impacts	Aquaculture, secondary boat traffic	Northwest Pacific, Japan?	Tunicate
Distaplia bermudensis	2000	Italy	Abundant locally	Unknown	Unknown	Western Atlantic	Tunicate
Microcosmus squamiger	2005	Italy	Few locations	Fouling	Unknown	Australia	Tunicate
Perophora japonica	2002	UK	Localized, spreading	Unknown	Hull-fouling	East Pacific	Tunicate
Perophora japonica	2003	USA, Humboldt Bay, California	Localized	Unknown	Hull-fouling	East Pacific	Tunicate
Polyandrocarpa zorritensis	2004	Italy	Recorded in three locations	Fouling organism	Unknown	Eastern Pacific	Tunicate
Styela clava	2007	UK	Increasing population in southern UK	Impacts aquaculture	Unknown	Northwest Pacific	Tunicate
Styela clava	1972, 2005*	Ireland	Localized until 2005, spreading	Unknown	Unknown	Northwest Pacific	Tunicate
Styela clava	No date	Canada, Prince Edward Island	Spreading	Unknown	Unknown	Northwest Pacific	Tunicate

5 Introduction and transfer of finfish

Malin Werner

5.1 Introduction

This chapter, which covers finfish introductions, is a summary of the national reports submitted between 2003 and 2007. Those national reports provide more detailed information, especially on export and import numbers. Both marine and freshwater fish are considered here.

A review of past introductions of non-native fish in 17 countries of Europe and North America (Copp *et al*., 2005b) found that the USA (93) and France (35) top the list for intentional fish introductions, followed by the Czech Republic, Russia, Romania, Austria, and Spain (27 to 21), with all other countries (including the UK) having 10–20 intentional introductions, and Germany the only country to have had fewer than ten introductions.

Of concern is the release of fish from private aquaria, which is quite common in some areas (Arthington *et al*., 1999; McDowall, 2004; Semmens *et al*., 2004; Copp *et al*., 2005b; Rixon *et al*., 2005; Duggan *et al*., 2006). Species such as sterlet, *Acipenser ruthenus*, have been imported to Germany, Spain, and the UK mainly for ornamental purposes and have started to find their way into the wild (Copp *et al*., 2005a, 2006a; Zięba *et al*., 2010). Sturgeons are increasingly placed in garden ponds (Britton and Davies, 2006a), but on reaching a size too large to suit their facilities, they are not always killed, and are often released into natural water bodies.

Porcupine fish are popular in the marine aquarium trade, and whereas most species grow to maximum lengths of about 30–50 cm, *Diodon hystrix* can grow to >90 cm. As such, porcupine fish are capable of outgrowing home aquaria, and this increases the risk that they may be released to the wild, such as reported for the coast of eastern England (Ellis, 2006).

Commonly sold, moved, and cultured fish species reported here are *Salmo salar*, *Salvelinus alpinus*, *Salmo trutta trutta*, *Oncorhynchus mykiss*, *Cyprinus carpio*, *Anguilla anguilla*, *Acipenser ruthenus*, sturgeon species such as *Acipenser baeri*, and many ornamental fish for the aquarium trade (see FishBase online for common names). Some are mentioned below, but the use of common names may vary between countries, so Latin names are used as in the annual national reports.

5.2 Laws and regulations

The ICES Code of Practice on the Introductions and Transfers of Marine Organisms was published in 2005 (ICES, 2005c).

Canada

Canada's National Code of Introductions and Transfers of Aquatic Organisms was reported in 2004 to have been adopted. The 2005 Federal Budget allocated $10 million (CAD) over five years to address aquatic invasive species, with activities to focus on research, monitoring, risk assessment, and outreach.

Estonia

A new Nature Conservation Act was submitted to Parliament on 21 April 2004 and came into force on 1 May 2004. In the Act, alien species are considered in paragraphs

57 and 58, and it is stated that the release of living specimens of alien species, and the planting and sowing of alien plant species into nature is prohibited.

Finland

According to the statute of the Ministry of Agriculture and Forestry (157/2005) the use of fresh, frozen, and ensiled wild marine fish for food for aquaculture fish is banned because of virus risk.

New Zealand

The most recent amendment to the Biosecurity Act in 2003 explicitly stated the obligation of all individuals in New Zealand to report organisms that they suspect as not belonging to an area or region. Although the target audience for this amendment was the scientific community, its implications are profound. Education and awareness materials were developed for biosecurity in all environments, with a single point of reporting in the Ministry of Agriculture and Forestry (MAF).

Sweden

A regulation prescribing that salmon *S. salar* and sea trout *S. trutta trutta* stocked into the sea should have their adipose fin removed was enacted in 2003 (the Regulation on fishery SFS 2003:353, complementary directions FIFS 2003:34). The regulations concerning stocking of salmonids in rivers on the Swedish west coast free from the parasite *Gyrodactylus salaris* was sharpened, with stocking of salmonids downstream of the second fish migration barrier forbidden (complementary directions, FIFS 2003:34). Imported fish have to be proven free of contagious diseases and from a fish farm complying with the Swedish conditions of approval for fish farms occupied in stocking purposes (FIFS 2004:47).

UK

In 2002, the UK government, through the Environment Agency, banned the use of live bait in sport angling. This ban, which is expected to aid in controlling the spread of non-native fish species in waters of northern England, was subsequently complemented by the Animal Welfare Act 2006. This legislation includes a provision that prohibits the awarding of live animals as a prize to persons under the age of 16 years old, which means that fairground events may no longer award goldfish as a prize to young persons (who are deemed more likely to release them to the wild).

To complement the Import of Live Fish Act 1980 (ILFA), The Prohibition of Keeping or Release of Live Fish (Specified Species; Amendment; England) Order was enacted in 2003. Most important among these new measures is that they extended controls to the keeping of non-native species for commercial and private purposes (e.g. fish farmers, fish dealers, ornamental trade, and aquarists). Intended to be precautionary, these new measures provide a general presumption against the keeping or release of any new species, and a presumption against the release of any of the listed species to open waters.

New EU legislation on imports of live fish (2003/858/EC as amended by 2004/454/EC and 2004/914/EC) from third countries came into force in the UK in May 2004. This legislation should provide stricter controls on these imports.

5.3 Introduced finfish

Norway (2003, 2005–2007)

Import and export

There are substantial imports of live finfish for stocking, but for most species, stocking is in land-based systems, where the risk of escape is believed to be low. In the period 2003–2007 Norway imported salmon *S. salar* from the Faroes, halibut *Hippoglossus hippoglossus* fry from Iceland, halibut eggs from Denmark and Iceland, turbot *Scopthalmus maximus* from the UK, France, Spain, and Denmark, sea bass *Dicentrarchus labrax* from France, and sea bass fry from the USA. Aquarium species are imported from Sweden (origin unknown, but some from Australia), Denmark, and Malawi (likely to be cichlids). Other ornamental fish for aquaria are recorded as originating in South America and Russia, but apparently there is also substantial import from the Czech Republic and Singapore, neither of which are recorded in the official register. *Cyprinus carpio*, the common carp, is imported from Japan. Sheepshead minnow *Cyprinodon variegatus* is imported for scientific studies.

Sweden (see also Baltic coast; 2003–2007)

No reported finfish has accidentally reached the Swedish west coast, but an *Acipenser ruthenus*, which is not native to Sweden, was found in a tributary to the river Rönne (at Ängelholm, southern Sweden) upstream of a migration barrier, when a power plant owner cleaned the grille to the turbines. The fish was released after being photographed. It is assumed to have been released from an aquarium (Anon., 2004).

Two reports on introductions of fish in Swedish waters are now available in Swedish (Anon., 2003, 2004). The latter also includes, as an annex, a list of fish used in the aquarium trade.

A document listing all fish species in Sweden has seven introduced brackish water species and 15 introduced freshwater species; 18 species in all (four of them are both brackish and freshwater). Some may, however, be single records, whereas others are well established.

Import and export

Sweden imports many ornamental fish (mainly for the aquarium trade) from Singapore, the Czech Republic, Thailand, Israel, Brazil, Indonesia, Denmark, Colombia, Vietnam, Hong Kong, the Netherlands, India, Nigeria, Sri Lanka, China, Germany, Peru, USA, and Malaysia. Most are freshwater species, but some are marine, particularly from Indonesia and Sri Lanka. The koi carp *C. carpio* is imported from Israel, Japan, Thailand, and Denmark.

Sweden exports ornamental fish to Norway, Finland, Denmark, Germany, and Russia, and live fish for consumption to Denmark, the Netherlands, Germany, Finland, Belgium, Italy, Poland, and Hungary. Such fish are mainly European eel *A. anguilla*, *O. mykiss*, salmon, and carp.

Germany (2003–2007)

Several aquaculture facilities have been in operation for decades, using the warm-water effluent from power plants. Fish are cultured for the aquarium industry (ornamental species: koi carp, goldfish, and sterlet), human consumption (Asian carp, *Tilapia* spp.), and restocking (imported glass eels). The total annual production is ~250 t.

The Ponto-Caspian fish *Neogobius melanostomus*, known from the German Baltic coasts, was recently recorded in the wild in the Netherlands – the first record from the North Sea. It is assumed that the species may also be recorded from the German North Sea coast in the near future.

Import and export

Glass eels are imported from various countries (e.g. France, Italy, Ireland, the Netherlands, and Sweden) according to the ICES Code of Practice. With a weight of 25 g, the individuals are used for restocking German inland waters.

Several sturgeon species are imported from Russia by local farmers for small-scale culture, including the Siberian sturgeon *A. baeri*. Records of escapees continue, however, and the numbers recorded increase annually. There are also German sturgeon hatcheries that produce *A. baeri* juveniles to stock other farms inside Germany and elsewhere, though the number of juveniles exported is unknown. Several sturgeon species (some from the Far East) are sold in the aquarium trade for pet fish garden ponds, and judging from sale advertisements on the Internet, the number must be in the thousands. Many are released from the ponds once they reach a certain size. *Acipenser oxyrinchus* (egg, larvae, and juveniles) were imported from Canada.

The continuous reproduction and import of live sturgeon species for aquaculture and the aquarium trade has resulted in increased availability of sturgeons on the market. As a consequence, the fish have been transferred into many open-water bodies of central and western Europe (Gessner *et al*., 1999; Arndt *et al*., 2000; Rochard *et al*., 2001). According to fishers, the number of sturgeon caught in natural water bodies far exceeds the numbers formally reported.

A project "Transfer of Atlantic sturgeon *Acipenser oxyrinchus* [note that this species is not the Atlantic sturgeon; Atlantic sturgeon is *A. sturio*] from North America for remediation efforts into Baltic Sea tributaries" was underway in 2004, but put on hold for some months in 2005. It is planned to follow the ICES Code of Practice on the Introductions and Transfers of Marine Organisms (2003 version) when importing fish from North America, likely the first application of the code in Germany. As the lifespan of sturgeons is relatively long, however, the code cannot be followed completely. Living juvenile sturgeon have been imported by air and placed in quarantine facilities in Germany before release into the environment.

Large quantities of marine, brackish water, and freshwater organisms were imported from South America, Southeast Asia, and other regions (intra-European trade) to serve the aquarium and hobby industry. Marine aquaria are becoming increasingly popular in Germany as the years pass (tens of thousands of Germans currently maintain marine aquaria alone). However, many underestimate the effort and cost of running a marine aquarium, and species are often discharged into the wild. Although mostly warm-water species are kept in aquaria, some may become established near the warm-water effluents of power plants. Germany is currently one of the top three importers of live display organisms, after the USA and Japan. Annually, more than six million fish are imported into Germany, mainly from the Philippines, Indonesia, Thailand, Singapore, and Hawaii.

Common carp have been imported live into Germany for many decades, mainly from Poland, Hungary, and the Czech Republic. They are also exported to Sweden.

Eggs of *S. alpinus* are imported from Canada and Finland, and *O. mykiss* are exported to Finland.

The Netherlands (2006)

In 2005 the Ponto-Caspian fish *N. melanostomus* was recorded in the Netherlands. The species seems to be well established, with several records in 2005.

An overview of non-indigenous marine and estuarine plant and animal species recorded from the Netherlands was provided by Wolff (2005). Exotic species from outside NW Europe and non-indigenous species from elsewhere in NW Europe are listed. Species suggested to be non-indigenous in the Netherlands but for which insufficient evidence can be found are discussed in the paper, based mainly on the literature, but supplemented by personal observations. The work is opened with an introduction describing the history of Dutch research on introduced species, the origin of the marine and estuarine flora and fauna of the Netherlands, natural and human-induced dispersal processes, and a summary of the geographic patterns of introduced species.

Import and export

Available data (from Statistics Netherlands, see www.cbs.nl) on live imports and transfers, and live exports to other countries, are grouped as "live or fresh fish", which includes both live and dead animals. Imports and exports to and from European countries are almost an order of magnitude larger than for other countries.

Belgium (2003–2007)

In 2002, a restocking project for sole *Solea solea* and turbot *Scophthalmus rhombus* was started by the Sea Fisheries department (CLO-SFD, Oostende), but it was stopped in 2005.

A private company, the N. V. Joosen-Luyckx Aqua Bio in Turnhout, is cultivating six species of sturgeon, mainly to produce caviar. The Siberian species *Acipenser baeri* is used, and in 2002, 150 kg of so-called Royal Belgian Caviar was successfully put on the market. Research is ongoing into the production of caviar from other species, e.g. *A. gueldenstaedti* and *A. ruthenus*. *Acipenser stellatus* and albino *A. ruthenus* are popular as ornamental species, but the latter is also used to produce white caviar. The fish grow to maturity in ponds, and the complete fish breeding cycle, from egg to mature fish, is followed in culture. There are also experiments ongoing with the American shovelnose *Scaphirhynchus platorynchus*, from the Mississippi basin.

Import and export

In Belgium there is a lot of uncontrolled import and export of a wide variety of marine and freshwater species for research, human consumption, aquaculture, and the aquarium trade. It is virtually impossible to obtain figures on quantities or origin.

France (2003–2007)

A few specimens of warm-water fish were observed along the Atlantic coast, likely related to the unusually warm weather in 2003. An oceanic puffer *Lagocephalus lagocephalus* was found, driven ashore, in the Bay of Quiberon, south Brittany, in mid-October 2003, but no additional data were available. An ocean sunfish *Mola mola* and a flying gurnard *Dactylopterus volitans* were found at the end of September along the coast of Morbiha.

Import and export

Detailed tables on fish imports and exports are available online in French at http://www.ofimer.fr.

UK (2003–2007)

A common theme to the UK national reports for 2003–2007 was the continued incidence of ornamental "pet fish" (aquarium and garden pond species) in both coastal and inland waters of the UK. Coastal and inland species recorded include porcupine fish *Diodon hystrix* from a beach in Norfolk in September 2005 (Ellis, 2006), *A. ruthenus* and sturgeon hybrids, usually with *A. baeiri* (Britton and Davies, 2006a), white catfish *Ameiurus catus* (Britton and Davies, 2006b), bighead carp *Hypophthalmichthys nobilis* (Britton and Davies, 2007), white sucker *Catostomus commersoni* (Copp *et al*., 2006b), and various varieties of goldfish *Carassius auratus* and common carp *C. carpio* (Copp *et al*., 2005b). Often referred to as the ornamental trade vector, releases of non-native fish via this introduction pathway are more likely to be a consequence of the human use of ornamental fish (Copp *et al*., 2005b) rather than the result of trade in these species *per se*. However, there is an unavoidable link between the frequency and intensity of ornamental fish imports and the incidence of non-native fish in the wild (Copp *et al*., 2007), which is an increasing trend (Copp *et al*., 2005b, 2006a).

Between 2003 and 2007, much research was undertaken on topmouth gudgeon *Pseudorasbora parva*, which is not only one of the most invasive species in Europe (Pinder *et al*., 2005), but also a healthy host of the rosette agent *Sphaerothecum destruens* (Gozlan *et al*., 2005), which is a threat to numerous native European species (R. E. Gozlan, pers. comm.). Successful eradications of *P. parva* have been undertaken using rotenone or drain-down and liming (Britton and Brazier, 2006; Britton *et al*., 2007), although in one case *P. parva* was extirpated by repeated removals of the small number of specimens present in the water body. Since 2003, an eastward expansion in southern England of sunbleak *Leucaspius delineatus* has been attributed to the translocation of live fish spawn on anglers' keepnets (Zięba *et al*., 2010).

The potential natural dispersal of introduced pikeperch *Sander lucioperca*, a salt-tolerant species (Brown *et al*., 2001), via 'salt bridges' to new, previously uninvaded, river systems (Brown *et al*., 2007) was examined first experimentally (Brown *et al*., 2007; Scott *et al*., 2007; Stakėnas *et al*., 2009), then by field studies using acoustic telemetry (Stakėnas *et al*., 2007). At no time during the 18-month field investigations were *S. lucioperca* observed in the saline tidal waters of the lower Thames (Stakėnas *et al*., 2007).

Import and export

The import and transfer of *O. mykiss* eggs far exceeded that of any other non-native species of live fish into the UK. The *O. mykiss* eggs came mainly from South Africa, as well as from other disease-free sources including Australia, Denmark, USA, France, and within the UK, the Isle of Man, and Northern Ireland. Live *A. anguilla* were imported for human consumption from Holland (mainly), France, and Spain. Imports of Atlantic salmon eggs into Scotland came mainly from Iceland and other EU member states, but also from Australia, the USA, and Norway. Scotland received *S. salar* parr and smolts from other EU member states, and *S. salar* ova were exported from Scotland to other EU member states, Chile, and the Faroe Islands. In Scotland, small numbers of eggs of *S. alpinus*, cod *Gadus morhua*, and brown trout *S. trutta trutta* were imported for aquaculture purposes.

Ireland (2003, 2005–2007)

The perch *Perca fluviatilis*, an exotic species, has been known in Ireland since the 19th century. There are plans for their cultivation in ponds (L. Watkins, pers. comm.)

Import and export

Ireland imports *O. mykiss* eggs from the Isle of Man, Denmark, England, and Northern Ireland, *O. mykiss* from Northern Ireland and Wales, *S. salar* eggs and juveniles from Scotland and Iceland, *S. trutta trutta* from Northern Ireland, *H. hippoglossus* from the Isle of Man, and *Psetta maxima* from France and the Isle of Man.

Ireland exports of *S. salar* eggs, juveniles, and adults to Scotland, England, Germany, Wales, Northern Ireland, Greece, France, and the Shetlands, *O. mykiss* to Scotland, *S. trutta trutta* to Northern Ireland, *C. auratus* Subunkin goldfish to Wales, England, and Jersey, and *Leuciscus idus* to Wales.

Aquarium species are imported from outside the EU, especially from Singapore, but also from other EU member states.

Spain (2006–2007)

No reports of fish species new to Spain have been reported since 2003, but a list of species reported as present is included in Table 5.1.

Table 5.1. First records of non-indigenous fish species found in Spain are listed, although none were reported in 2003–2007 national reports.

Species	Location	1st record	Native region	Invasion status	Reference	Vector
Acanthurus monroviae	Marbella, Alboran Sea (36°29'N 04°42'W)	1981	Atlantic: tropical western Africa from Morocco to Angola	Local record	Crespo *et al.* (1987)	Straits of Gibraltar
Carcharhinus altimus	Off Chafarinas Islands, Alboran sea (Mediterranean Sea; 35°12'N 02°26'W)	1983	In Pacific, Indian and Atlantic Ocean: from Florida to Venezuela and Senegal to Ghana	Frequent	Moreno and Hoyos (1983).	Straits of Gibraltar
Carcharhinus falciformis	Alboran Sea (Mediterranean Sea; SE Spain)	1987	Circumtropical	Rare	Moreno (1987)	Straits of Gibraltar
Dicologlossa hexophthalma *(= Microchirus (Zevaia) hexophthalmus)*	Off Port de la Selva, Mediterranean Sea (NE Spain; 42°20'16.81"N; 03°02'21.16"E)	1977	Eastern Atlantic from Portugal (Madeira) to Angola	Very rare	Matallanas (1984)	Straits of Gibraltar
Diodon eydouxii	Zahara de los Atunes, Cádiz (SW Spain; 36°08'N 05°50'W)	1975	Circumtropical	Local record	Crespo *et al.* (1987)	
Fistularia commersonii	Alboran Sea: Berenguel Bay (Almuñécar, Granada; 36º43´16.3N 03º44'14.3W) and in Herradura Bay (Almuñécar, Granada; 36º43'29.5N 03º44'15.3W)	2007	Indian and Pacific Ocean, central and South America	Local record	Sánchez-Tocino *et al.* (2007)	Lessepsian
Fistularia petimba	Linea de la Concepcion, Alboran Sea (36°10'N 05°20'W)	1996	Tropical oceans (Atlantic, Pacific, Indian)	Local record	Càrdenas *et al.* (1997)	Straits of Gibraltar

Species	Location	1st record	Native region	Invasion status	Reference	Vector
Fundulus heteroclitus heteroclitus	Gulf of Cádiz, Atlantic coast, Spain	1857	NW Atlantic	Established	Machado-Nunez (1857), cited by Fernández-Delgado, 1989b)	
Gambusia affinis	Caceres, Spain	1921	NW Atlantic	Introduced	Fernández-Delgado (1989a)	
Megalops atlanticus	Off coast Asturias, Atlantic coast (43°28'N 04°45'W)	2003	Tropical or subtropical Atlantic		Arronte *et al*. (2004)	
Psenes pellucidus	Palma Bay, Balearic Islands (Mediterranean Sea; 39°35'N 02°39'E)	1995	Tropical and temperate waters of Atlantic, Pacific and Indian Ocean)	Rare	Riera *et al*. (1995)	Straits of Gibraltar
Pseudupeneus prayensis	Off Nerja, Alboran Sea (36°44'N 03°53' W)	1981	Eastern Atlantic from Mauritania to Angola	Local record	Reina-Hervás (1987)	Straits of Gibraltar
Scorpaena stephanica	Off Blanes, Mediterranean Sea (41°36'N 02°49'E)	1977	Eastern Atlantic from Mauritania to Angola	Local record	Allué *et al*. (1981)	Straits of Gibraltar
Seriola fasciata	Balearic Islands (Mediterranean Sea)	1989	W Atlantic (Massachusetts, USA to Brazil), E Atlantic (Madeira, Canary Islands)	Rare	Massutí and Stefanescu (1993)	Straits of Gibraltar

5.3.1 Baltic coast (inside the Kattegat, Sound, and Belts) – Sweden, Finland, Estonia, Russian Federation, and Poland

Sweden (see also Eastern Atlantic; 2003–2007)

Most finfish released in Sweden are native species, especially smolt of Baltic salmon *S. salar*, sea trout *S. trutta trutta*, and pikeperch *S. lucioperca*, the latter also into Baltic bays. For compensatory purposes, fry of salmon and sea trout are stocked mainly in rivers running into the Baltic.

There are also annual releases of eel *A. anguilla*, imported from UK, Norway, Denmark, Germany, Belgium, as well as transfer of small adult eels from the Swedish west coast into the Baltic Sea. In freshwater, increasing numbers of rainbow trout and decreasing numbers of American brook charr are released to support the sport fishery. Carp and other cyprinid fish have also been introduced in freshwater to graze down excessive benthic vegetation.

Import

Salmon for consumption are imported from Denmark, Norway, USA, and France, rainbow trout from Denmark, and carp from Denmark and Germany.

Finland (2003–2007)

A round goby, *Neogobius melanostomus* (Pallas) was caught by an angler in the southwestern archipelago of Finland for the first time in February 2005, but none have been caught since.

In November 2005, several Prussian/gibel carp, *Carassius gibelio*, were caught off Helsinki, and for the first time identified to species. However, more observations came to light from the southern coast of Finland after that announcement in the media. It is believed that the Prussian carp has likely been in the waters off Helsinki since at least 2001, although there is ongoing debate as to whether the Prussian/gibel carp is a species in its own right (*C. gibelio*) or rather a subspecies of the goldfish (*C. auratus gibelio*).

In 2006, one starry sturgeon, *A. stellatus*, was caught off the western coast of Finland. Several of them have been caught since the first one was taken in 1999, and all have been considered to be escapees from Russian fish farms. In 2007, at least three Russian sturgeons, *Acipenser gueldenstaedtii*, were caught along the coast of Finland. Again, they were considered to be escapees from Russian fish farms.

Deliberate releases into the Baltic Sea (including rivers draining into the Baltic) were for fisheries and fish stock enhancement; they included newly hatched and older salmon (*S. salar*), newly hatched and older sea trout (*S. trutta trutta*), newly hatched and one-summer-old whitefish *Coregonus lavaretus*. In these introductions, meant to compensate for losses caused by river construction for power plant purposes, non-native fish were used, including salmon from the River Neva.

Veterinary authorities also allowed the import of European elvers *A. anguilla* for release in natural waters and for ongrowing at farms for human consumption.

Import and export

Sturgeon (*Acipenser sturio* and *A. baeri*) were imported from Italy, France, and Germany for ongrowing at farms and for human consumption. Perch and sander were imported from Sweden and rainbow trout from Denmark to the Åland Islands. Rainbow

trout *O. mykiss* were imported from Germany to the Finland archipelago, Denmark to the Åland Islands, and from Sweden to the archipelago and inland. Eels imported from Sweden (in quarantine) originated from the UK.

A. sturio eggs were imported from France in 2003 and Siberian sturgeon *A. baeri* from Italy in 2007 for culture purposes.

Sheatfish *Siluris glanis* were imported for ongrowing at farms and for human consumption, and tropical fish for the aquarium trade were also imported.

Rainbow trout *O. mykiss* juveniles and eggs and sperm were exported to Russia and Estonia, but also to Sweden and Austria. In addition, whitefish *C. lavaretus* juveniles were exported to Sweden (River Tornionjoki), and fertilized eggs of charr *S. alpinus*, brown trout *S. trutta fario* and greyling *Thymallus thymallus* to Austria (inland farms) and fertilized grayling eggs to Germany (inland farm). Rainbow trout eggs were exported to Chile for the first time in 2006.

Estonia (2003–2006)

In 2002, two new alien fish species were found in Estonian waters: bighead carp *Hypophthalmichthys molitrix* and round goby *Neogobius melanostomus*. The former is native to lowland rivers of the plains of northern China and also southern China. One fish was found in Pärnu Bay, NE Gulf of Riga in September 2002. The species had been imported into Latvia in the 1960s and up to now, two other records from the Gulf of Riga (near the river mouths of the Salaca and the Daugava) have been documented. The probable vector for invasion is migration from neighbouring areas/countries (e.g. Latvia). Bighead carp were again recorded in Pärnu Bay in 2005, most likely originating in this case from aquaculture. The ecological impact of the species is considered to be insignificant.

The round goby was recorded for the first time in 2002. The species is native to the Ponto-Caspian region and invaded the Baltic Sea in the early 1990s. One fish was found by a commercial fisher in Pärnu Bay, NE Gulf of Riga, in April 2002, but recent contact with leisure fishers operating in Muuga Harbour (Gulf of Finland) in 2005 suggest that the fish has further colonized northern and eastern parts of the Baltic Sea. According to fisher reports from the area, *N. melanostomus* is, although not abundant, relatively common in their catches. The wider ecological impact of the species along the coast of Estonia is considered to be low.

The gibel carp *C. gibelio* was deliberately introduced into fish ponds and small lakes of Estonia in 1948. The fish was first found in Estonian marine waters in 1985 in the Gulf of Riga. During recent years, however, the species has become invasive: the fish have colonized the whole Estonian coast and in some areas even dominates the biomass. At least one of the likely reasons is consecutive warm summers during the 1990s and the low abundance of predatory fish. In some shallow, sheltered areas the species can reproduce and thrive, but in more open coastal areas, only large adult specimens are caught. The ecological impact of the species is unknown.

Salmon *S. salar*, whitefish *C. lavaretus*, sea trout *S. trutta trutta*, pike *Esox lucius*, pikeperch *Stizostedion lucioperca*, and European eel *A. anguilla* have all been released deliberately in Estonian waters.

Import and export

Ornamental freshwater fish have been imported live into Estonia from China, the Czech Republic, Finland, Germany, Taiwan, Singapore, Thailand, the UK, Indonesia,

Latvia, and Thailand. Ornamental marine fish have been imported from Singapore and Indonesia, and unidentified fish from Sweden, Denmark, Finland, and Latvia (freshwater and marine).

Oncorhynchus apache and *O. chrysogaster* have been imported from Denmark, European eel from the UK and Italy, *Oncorhynchus* spp., *S. salar*, and *Hucho hucho* from Norway and carp from Latvia.

Live exports of unidentified and ornamental fish have been to Latvia, the Netherlands, Norway, the Russian Federation, the UK, the USA, and Sweden. Estonia has also exported live fish of unidentified species to countries such as Bahamas, Malta, St Vincent and the Grenadines, Antigua and Barbuda, Cyprus, Liberia, and Switzerland. Estonia also exported *O. apache* and *O. chrysogaster* to Cyprus.

Russian Federation (2004)

No reports of new fish species in Russia have been received.

Poland (2004, 2007)

Smolts and juveniles of the salmon *Salmo salar* and fry and juveniles of sea trout *S. trutta trutta* were released into the wild by Poland. Fry and juvenile whitefish *C. lavaretus* originating in the Pomeranian Bay were released into Puck Bay as part of a programme to reintroduce whitefish there, which has been in operation since 1991. Fry of whitefish were also released into Szczecin Lagoon to enhance the existing wild stock, and juvenile whitefish were released into Puck Bay and Reda River.

H. molitrix, *Aristichthys nobilis*, and *Ctenopharyngodon idella* were imported to Poland in the 1960s. They now occur in aquaculture and naturally (Guziur, 1991; Szczerbowski, 1993). Many individuals of these species were observed in the Odra Estuary near Szczecin in 1997, after floods; *C. idella* is a newcomer to the Gulf of Gdańsk (Skóra, 2000).

The sturgeon *A. gueldenstaedtii*, *A. baeri*, and *A. ruthenus* are used for aquaculture in Poland, but do occasionally escape. In the Gulf of Gdańsk and the Polish Baltic, these species are now non-indigenous members of the fish fauna (Skóra, 2000).

Salmo gairdneri is another newcomer to the Gulf of Gdańsk (Skóra, 2000), and the round goby *N. melanostomus* is a newcomer to the Polish part of the Baltic Sea (Skóra, 2000). Currently, round goby populations in Polish waters are found in the Gulf of Gdańsk and the Vistula Lagoon, and most probably also (recently) in the Szczecin Lagoon. As yet, however, there have been no reports of the species from the commercial fishery, but anglers do catch them. The biomass of the species in the Gulf of Gdańsk grows year on year, and in 2003, a preliminary biomass estimate for the species was >20 t. There is currently no fishery for round goby, but the species occasionally forms a large unwanted bycatch, especially in shallow-water fykenet catches. It has also become the basic food for cormorants since the mid-1990s, and herons also appear to feed extensively on the species.

The first record of the Ponto-Caspian racer goby *Neogobius gymnotrachelus* in Poland was made in 1995 in the River Bug. The species was subsequently found in Włocławski reservoir, where it constituted a vivid, abundant self-sustaining population (Kostrzewa and Grabowski, 2003). The species has now spread to the middle and lower sections of the Vistula River, as far down as Toruń (53°02'N 18°37'E; Grabowska and Grabowski, 2005).

Import and export

Sturgeon *A. baeri* eggs are imported into Poland from Russia, *S. salar* eggs from Latvia, and *O. mykiss* eggs from France, Spain, Denmark, and South Africa. *Lepomis gibbosus* and *Percottus glenii* arrived in Poland as freshwater ornamental fish.

Rainbow trout *O. mykiss* are exported to Germany.

5.3.2 Northwest Atlantic and Pacific coast of Canada and the USA

Canada (2003–2007)

Transfer of fish species within, to, and from Canada is common, so the information that follows is separated into regions (Pacific, Great Lakes, and Atlantic). The national reports provide more detail, however.

Pacific region

The recent illegal introductions of alien fish into water bodies within British Columbia have raised concerns. Although many of the introduced species are considered to be valuable sport and commercial fish in other parts of Canada, in British Columbia, yellow perch *Perca flavescens*, smallmouth bass *Micropterus dolomieui*, largemouth bass *Micropterus salmonides*, pumpkinseed *L. gibbosus*, walleye *Stizostedion vitreum*, black crappie *Pomoxis nigromaculatus*, brown bullhead *Ictaluris nubulosus*, carp *C. carpio*, and northern pike *E. lucius* are all considered to be alien invasives, competitors, and predators on native fish species.

Under the Canada–US Transboundary agreement, sockeye *Oncorhynchus nerka* fry were returned to northern British Columbia (Tahltan Lake, Tuya Lake, Tatsamenie Lake, and Trapper Lake) after initial incubation in an isolation unit at an Alaskan hatchery. The projects have to meet the requirements of the Canadian Fish Health Protection Regulations.

Atlantic salmon continue to be introduced into British Columbia for aquaculture and into the wild as a result of escapes from aquaculture facilities.

Imports and exports

Fishery administrators in British Columbia have received requests to import several marine species to be raised in closed circulation, land-based aquaculture facilities. The species under consideration include barramundi *Lates calcarifer*, cobia *Rachycentron canadum*, Florida pompano *Trachinotus carolinus*, and red drum *Sciaenops ocellatus*.

Freshwater species imported include white sturgeon *Acipenser transmontanus* for stock enhancement in the Columbia River drainage and for aquaculture, tilapia *Oreochromis niloticus* and *S. salar* for aquaculture and human consumption, and *O. mykiss* for bioassays and aquaculture. Bull trout *Salvelinus confluentus*, carp (koi only), Dolly Varden *Salvelinus malma*, and dace *Phoxinus* sp. have also been imported.

Aquaculture companies in British Columbia have been importing Atlantic salmon eggs from Iceland since 2004. Otherwise, the pattern of importation is expected to remain similar to previous years.

Arctic charr eggs were exported to China, France, Italy, Austria, Slovenia, England, Germany, Macedonia, Switzerland, and the USA.

Kelp greenling *Hexagrammos decagrammus*, striped perch *Embiotica lateralis*, pile perch *Rhachochilus vacca*, kelp perch *Brachyistius frenatus*, copper rockfish *Sebastes caurinus*, painted greenling *Oxylebius pictus*, ratfish *Hydrolagus collei*, and white-spotted green-

ling *Hexagrammos stelleri* were exported in the aquarium trade to France, red Irish lord *Hemilepidotus hemilepidotus* to France and Portugal, and tiger rockfish *Sebastes nigrocinctus*, black rockfish *Sebastes melanops*, and wolf eel *Anarrichthys ocellatus* to Holland and France. Also exported were cabezon *Scorpaenichthies marmoratus*, copper rockfish *Sebastes caurinus*, silverspot sculpin *Blepsias cirrhosus*, tidepool sculpin *Oligocottus maculosus*, mosshead warbonnet *Chirolophis nugatory*, and northern clingfish *Gobiesox meandricus*.

Within-region transfers

Oncorhynchus species (Chinook, coho, steelhead, rainbow, chum, pink, sockeye, kokanee), wolf eel, white sturgeon *Acipenser transmontanus*, sablefish *Anoplopoma fimbria*, halibut *Hippoglossus stenolepis*, eulachon *Thaleichthys pacificus*, koi carp *C. carpio*, and burbot *Lota lota* have been transferred within-region.

Great Lakes area (central and Arctic Region)

A grass carp *C. idella* was captured at the mouth of a river flowing into Toronto Harbour, Lake Ontario, in October 2003, but intensive surveys of the area by the state and provincial agencies failed to recover any additional specimens. It is believed, therefore, that this was an isolated incident resulting from an unauthorized release of a fish from one of the many live foodfish markets in the area. As far as can be determined, there have been no other deliberate or planned introductions of non-native species to natural waters in the central and Arctic region of the Great Lakes. Several non-native species of fish, including bighead and grass carp, are imported live into Canada in large numbers from aquaculture facilities in the southern USA; it is a growing industry in Canada. Concern centres, however, on the possibility that customers will buy and release live fish into the wild or that there may be accidental releases from transporters or wholesalers, or that non-native pathogens, parasites, and disease organisms might be released with untreated transit water. It has been estimated that >2 million kg of live freshwater fish are sold annually in the Greater Toronto market area alone. A multi-agency task force has been examining various options for eliminating the risk of introducing non-native species posed by this pathway.

Imports

Ontario reported imports of rainbow trout eggs (from Washington, USA) and *S. alpinus* eggs (from the Yukon).

Atlantic region (including Québec)

Non-intentional introductions

One brown bullhead (*Ictalurus nebulosus*), a species not native to the waters of Newfoundland and previously unreported, was angled from a natural water body in 2006. The implications of this are unknown, however, because no other individuals have been discovered.

In 2003, there was an increased incidence of Atlantic salmon smolts in the Magaguadavic watershed in New Brunswick. The fish were identified as hatchery stock that had escaped or were deliberately released into the watershed from facilities ashore. These are the only confirmed accidental releases documented in the area, however.

New Brunswick reported an accidental release of 55 000 Atlantic salmon smolts from a farm on Grand Manan Island in 2005.

Two reports of release of aquarium-trade species into the wild were investigated in Newfoundland. Ornamental species of carp (species undetermined) were seen at Janes Pond, Burin Peninsular, and on private property near Heart's Delight, Trinity Bay. The origin of the fish is currently unknown.

The tench *Tinca tinca* was first observed in 2001. Tench have now been captured in commercial fisheries in large numbers and in a range of sizes, indicating natural production in the Haut Richelieu area and possibly in Lake Champlain. The species was also found in a lake (Lac des Deux Montagnes), where they are thought to have been introduced by a former landowner. The species was extirpated in November in 2002.

Intentional introductions

In Québec, glass eels *Anguilla rostrata* were transferred from the Bay of Fundy to Lake Champlain in 2003. Spotted wolffish *Anarhichas minor* and Atlantic wolffish *A. lupus*, were released into the St Lawrence estuary in Québec in 2004. At Prince Edward Island (PEI), Atlantic salmon fry *S. salar* were released for enhancement of native stocks. In Newfoundland, fry of *S. fontinalis* were stocked into Star Lake as part of the Star Lake Fish Compensation Programme to compensate for loss of productive fish habitat associated with the Star Lake hydroelectricity generation project. Brook trout and ouananiche (landlocked *S. salar*) were transferred from three ponds in central Newfoundland to East Pond Brook and Harpoon Brook as part of a habitat compensation programme associated with a mine development project, and the Fish Friends Programme released wild Atlantic salmon fry into several rivers. In New Brunswick, Atlantic salmon and brook trout were released into several rivers for enhancement purposes, and in Nova Scotia, *S. fontinalis*, *O. mykiss*, and brown trout *S. trutta trutta* were released into several rivers as part of the spring stocking programme.

Exports, aquarium trade

Species exported to Spain included *Sebastes caurinus*, *Embiotoca lateralis*, and *H. decagrammus*, and to Portugal, *Anarrhichthys ocellatus*.

Imports

Québec imported spotted wolf eel *Anarhichas minor* eggs from Norway. New Brunswick imported Atlantic salmon from the USA, and cod *G. morhua* from the USA, both for aquaculture, and New Brunswick imported rainbow trout from Ontario for research purposes. Nova Scotia imported rainbow trout eggs (from Washington) and Atlantic cod (from Massachusetts) for aquaculture, and zebra fish *Danio rerio* (from Massachusetts and Oregon) to contained facilities for research.

Newfoundland and Labrador imported Atlantic salmon (from Washington, Prince Edward Island, and Nova Scotia), and rainbow trout triploid eggs and fingerlings (from Québec and Nova Scotia). Other species imported to land-based laboratories for research included male tilapia (from Ontario), genetically modified Atlantic salmon (from PEI), genetically modified rainbow trout (from PEI), and diploid rainbow trout (from Ontario).

Within-region and other domestic transfers

Atlantic salmon *S. salar*, speckled/brook trout *Salvelinus fontinalis*, *S. alpinus*, halibut *H. hippoglossus*, haddock *Melanogrammus aeglifinus*, cod *G. morhua*, Atlantic sturgeon *Acipenser oxyrhynchus*, shortnose sturgeon *A. brevirostrum*, Atlantic wolffish *Anarhichas lupus*, winter flounder *Pseudopleuronectes americanus*, rainbow trout *O. mykiss*,

brown trout *S. trutta trutta*, striped bass *Morone saxatilis*, and lake charr *Salvelinus namaycush* were all subjected to within-region transfer

Atlantic halibut *H. hippoglossus*, spotted wolffish *Anarhichas minor*, winter skate *Raja ocellat*, rainbow trout *O. mykiss*, Atlantic salmon *S. salar*, *S. alpinus*, brook trout *Salvelinus fontinalis*, lake whitefish, American eel, Atlantic whitefish, and Atlantic cod were all moved around domestically.

International exports from the whole of Canada

King salmon were exported to Italy, black cod to the UK, Atlantic salmon to Belgium, coho salmon to France and Germany, Atlantic sturgeon eggs and adults to Germany and Poland, Arctic charr eggs to Italy, Slovenia, France, Austria, Switzerland, England, Germany, and Macedonia, and Atlantic salmon eggs to Ireland.

USA (2003–2007)

Atlantic/Gulf coast

The red lionfish (*Pterois miles/volitans* complex Scorpaenidae) appears now to be well established from North Carolina to Florida, its range and abundance continuing to expand. By 2006, specimens were being captured as far north as Jamestown, Rhode Island, in Narragansett Bay, and the first records were reported from the Gulf of Mexico, at Treasure Island, Florida. It is a common aquarium fish that is associated with reefs in its native range in the Indo-Pacific, western Australia, and Malaysia to southern Japan, south to Lord Howe, and throughout Micronesia. It has been released deliberately from aquaria to the coast of Florida.

In June 2004, three orbiculate batfish *Platax orbicularis* were reported off Molasses Reef in the Florida Keys. Two of the three species were captured and taken to the Florida aquarium. In 2003 and 2004, Atlantic salmon *S. salar* were captured in Ketchikan, Alaska. They are believed to have been escapees from fish farms, and there is concern that they may be able to outcompete native species.

In December 2004, a peacock hind *Cephalopholis argus* was reported off Boca Raton, Florida.

Freshwater

Two introductions of predatory freshwater fish in US Atlantic coast rivers pose concerns for anadromous fish populations such as alewife and American shad *Alosa spp*. *Channa argus*, the northern snakehead, which is native to Asia, were caught in 2004 in both the Potomac and Delaware rivers, in the vicinities of Washington and Philadelphia, respectively, and are now established in both estuaries. *Pylodictus olivaris*, the flathead catfish, native to the Mississippi River and other Gulf of Mexico tributaries, was introduced to Atlantic watersheds in North Carolina and Virginia in the 1990s by state agencies. In 2002, this catfish was first caught in Pennsylvania tributaries of the Delaware River and, in 2004, it was caught in the Susquehanna River, the largest tributary of Chesapeake Bay. The flathead catfish is now established in both rivers, reaching tidal freshwaters in the states of Maryland, Pennsylvania, and New Jersey. Both *C. argus* and *P. olivaris* are large, top-level predators, with maximum sizes of 0.85 and 1.4 m, respectively. Extensive efforts are being made to restore populations of American shad *A. sapidissima* in these rivers, but restoration is threatened by the introduction of the predators to the freshwater migration and spawning areas of shad.

For both introduced species, the likeliest vector for introduction is illegal stocking by private individuals.

Pacific coast

Rhinogobius brunneus (species complex), an amphidromous goby native to East Asia (Russia and Japan to the Philippines), is established and reproducing in drainages of the Columbia River in Washington State. This goby was probably introduced to North America in ballast water, although websites indicate that it is sometimes kept as an aquarium fish. This introduction brings the total of Asian/Northwest Pacific gobies established on the US west coast to five. *Rhinogobius brunneus* is the first of these species to be found outside California.

Live imports and exports

It is extremely difficult to obtain data on the quantity of live imports from the US, although some data can be found on a National Oceanic and Atmospheric Administration website, http://www.st.nmfs.noaa.gov/.

No fish were reported as being imported live, although live eels from Bangladesh have been observed at markets.

5.3.3 Mediterranean Sea

Spain (2006–2007; also see Northeast Atlantic)

Spain's list of non-indigenous species is given in Table 5.1.

France (2003–2007)

No reports of fish species new to the French Mediterranean have been received.

Italy (guest status; 2003–2007)

An update of the Indo-Pacific and Atlantic immigrant fish in the Mediterranean has been published by Orsi Relini (2001), and must be supplemented by the more recent list of Golani *et al*. (2002) in the ICES atlas of exotic species.

The blue-spotted cornetfish *Fistularia commersonii* is a lessepsian species recorded for the first time in 2000 along the coast of Israel; subsequently, it has been found more widely in the eastern Mediterranean. The first *F. commersonii* in Italy was caught in the waters of Lampedusa in December 2002, and was followed by another 10 records (5 in Italian waters) from the Sicily Straits (Fiorentino *et al*., 2004; Azzurro *et al*., 2004b, 2004c). The first record from the western Mediterranean was in the Gulf of Castellamare in November 2003 (C. Pipitone, pers. comm.). In 2006, it was reported to be fairly common in the Sicily Straits, and was also caught along the southwestern shore of Sicily (Milazzo *et al*., 2006) and at other localities in the Tyrrhenian Sea (Micarelli *et al*., 2006). In 2006, it was found near Arbatax in Sardinia (Pais *et al*., 2007). That specimen hosted 58 species of parasite in its mouth and digestive tract alone. With the exception of the specific trematode *Allolepidapedon fistulariae*, all the other parasites found had already been reported in other hosts from the Mediterranean Sea.

Siganus luridus was recorded for the first time in Italy in 2005, from the Linosa and Lampedusa islands near Sicily (Azzurro and Andaloro, 2004; Azzurro *et al*., 2004a, 2004b). For the *S. luridus* found at Linosa in 2000, a lowering of the genetic diversity of the invading population was determined. Within the Mediterranean populations of Israel, Greece, and Italy, there was no pattern of regional separation, and mito-

chondrial diversity appeared to be preserved during the Linosa colonization, with no traces of founder events. *S. luridus* has been found also near Capo d'Orlando, along the northern coast of Sicily (Castriota and Andaloro, 2008). A study by Azzurro *et al*. (2006) indicated the population at Linosa to be reproductively active and suggested that self-maintaining populations were now present across the whole central Mediterranean.

One juvenile sandbar shark *Carcharhinus plumbeus* was recorded from the southern Tyrrhenian Sea. It was collected in an area of the Sicilian coast where trawling is banned except for scientific purposes (Consoli *et al*., 2004). It was subsequently found that the species had been known (Tortonese, 1956) from different locations along the Italian coasts since the 19th century.

From 1994 to 2002, 80 lesser amberjacks *Seriola fasciata* were caught in Sicilian waters, where the population is now well established. *S. fasciata* was recorded in 2002 for the first time in Sardinian waters, near Oristano (Andaloro *et al*., 2005). *Seriola carpenteri* has also established stable populations (Pizzicori *et al*., 2000). A third species, Almaco jack (*Seriola rivoliana*), has been found only occasionally, and was reported for the first time in the Mediterranean Sea in 2003 (Castriota *et al*., 2002, 2004).

One specimen of the lessepsian clupeid *Etrumeus teres* was caught off the island of Lampedusa, in the Sicily Straits, in 2005 (Falautano *et al*., 2006). The species is now well known in the eastern Mediterranean, as far as the islands of Rhodes and Cyprus.

The first record of the dwarf flathead, *Elates ransonnetii*, in the Mediterranean Sea was reported in October 2005, from the southern coast of the Gulf of Taranto (northwestern Ionian Sea). This species is commonly recorded from the Timor Sea off Australia to Papua New Guinea, and along the coast of Indonesia, Singapore, Thailand, South China, and the Philippines. It is also known from the coast of Burma to the Red Sea, and it may have entered the Mediterranean Sea through the Suez Canal (Mastrototaro *et al*., 2007).

An additional Mediterranean record of the smooth puffer *Sphoeroides pachygaster* was reported for the central Tyrrhenian Sea (Psomadakis *et al*., 2008).

Croatia (2007)

Because Croatian legislation is restrictive, no deliberate introductions have been recorded.

Two major vectors of introduction of non-indigenous species into the Adriatic Sea are (i) currents from the eastern Mediterranean through Otranto Strait along the eastern Adriatic coast, and (ii) ships (both ballast water and biofouling). Mariculture production does not play an important role in non-indigenous species introduction to Croatia, but planned farming growth in some parts of the Croatian coast may have a considerable impact on the appearance of non-native species in future.

Because Croatian ports are used mostly for import, ships entering from the Adriatic Sea carry cargo and not ballast water, so most non-indigenous species found along the eastern Adriatic are likely caused by hull-fouling carriage. Ships that transport stone from central Dalmatia to Italian ports of the western Adriatic pose a particular problem, making it easier to spread non-native species already present in the Italian (western) part of Adriatic Sea to the Croatian (eastern) part.

In summer 2005, several *Lappanella fasciata* (Labridae) were observed at the southeastern part of the island of Sušac (Cape Triščavac) at depths ranging from 65 to 77 m, the first confirmed records of *L. fasciata* for the entire Adriatic.

An oceanic puffer, *Lagocephalus lagocephalus lagocephalus*, was caught at night by commercial trawl 7 nautical miles from the coast (off Molunat Bay, southern Adriatic, Croatian coast, 42°26'N 18°26'E) approximately 70 m deep in September 2004. The fish was measured and stored in the ichthyological collection of the Institute of Oceanography and Fisheries in Split.

5.3.4 Pacific coast/Pacific Ocean (Australia, New Zealand)

Australia (2003, 2004, 2007)

In all, 15 species of marine (or salt-tolerant) fish are currently recognized as introduced (14) or cryptogenic (one) in Australian waters, but none are currently considered to be pests of national concern (i.e. causing significant social, economic, or environmental degradation). No new marine fish introductions to Australia were recorded in either 2003 or 2004.

Imports and exports

All live imports into Australia are regulated by the Australian Quarantine and Inspection Service. Requests to import live biological material into Australia are subject to an import risk assessment conducted by Biosecurity Australia. To date, all requests to import live marine organisms have been denied, however, usually because the potential disease risks are considered to be too high. Imports of dead frozen salmon fillets (Canada) and prawns (Thailand) are permitted under strict quarantine conditions.

During the period 2006–2007, no marine species that could have been released into the wild were imported live into Australia for the purposes of release into open water or were imported directly for human consumption.

New Zealand (2003–2004)

Historically, quinnat salmon *Oncorhynchus tshawytscha* became established after being introduced deliberately to New Zealand (Cranfield *et al*., 1998). Information on recent deliberate introductions is not available.

Four new species of goby have been discovered in New Zealand. Bridled goby *Arenigobius bifrenatus* was first reported in 1996. This introduced species is native to Australia. The cryptogenic goby *Favonigobius exquisites* was first discovered in 2001. Another new goby species from northern New Zealand was identified in 2002. This species was identified by molecular markers as *Acentrogobius* (cf) *pflaumi*, a native to Japan and Korea, with small populations (possibly introduced) in New South Wales, Australia. A dart goby *Parioglossus marginalis* was reported from Great Barrier Island in northern New Zealand. The introduction status of this last species is unknown.

A new species of blenny was discovered in New Zealand in 2004. *Omobranchus anolius*, native to Australia, is restricted to the eastern shores around Auckland. The species is cryptic in habitat, found under rocks along the high shore.

Table 5.2. New, accidentally introduced fish species reported, 2003–2007.

Area	Species	Year	Country	Comment
Eastern Atlantic				
	Megalops atlanticus	2003	Spain	
	Neogobius melanostomus	2005	The Netherlands	

Area	Species	Year	Country	Comment
	Fistularia commersonii	2007	Spain	
Baltic coast				
	Hypophthalmichthys molitrix	2002	Estonia	
	Neogobius melanostomus	2002	Estonia	
	Neogobius melanostomus	2005	Finland	
	Carassius gibelio	2005	Finland	Probably present since 2001
Northwest Atlantic and Pacific coast of Canada and USA				
	Platax orbicularis	2004	USA	Florida
	Cephalopholis argus	2004	USA	Florida
Great Lakes				
	Ctenopharyngodon idella	2003	Canada	Great Lakes, one fish
	Ameiurus nebulosus (= *Ictalurus nebulosus*)	2006	Canada	Atlantic region, one fish
Mediterranean Sea				
	Siganus luridus	2000	Italy	
	Fistularia commersonii	2002	Italy	
	Seriola rivoliana	2003	Italy	
	Etrumeus teres	2005	Italy	
	Elates ransonnettii	2005	Italy	
	Lagocephalus lagocephalus lagocephalus	2004	Croatia	
	Lappanella fasciata	2005	Croatia	
Pacific Ocean				
	Arenigobius bifrenatus	1996	New Zealand	Reported in 2003
	Favonigobius exquisitus	2001	New Zealand	Reported in 2003
	Acentrogobius (cf) *pflaumii*	2002	New Zealand	
	Omobranchus anolius	2004	New Zealand	

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Annex 1: Sequence of WGITMO meetings and national reports received

Table A1. Sequence of WGITMO meetings with meeting dates, venues, and Chairs.

Year	Date	Location	Chair	Meeting number
2003	26–28 March	Vancouver, Canada	S. Gollasch	25
2004	25–26 March	Cesenatico, Italy	S. Gollasch	26
2004/2005	4 October–5 April	By correspondence	S. Gollasch	27
2006	16–17 March	Oostende, Belgium	S. Gollasch	28
2007	21–23 March	Dubrovnik, Croatia	J. A. Pederson	29

Table A2. National reports received at WGITMO meetings 2003–2007.

National report	2003	2004	2005	2006	2007
Australia	X			X	X
Belgium	X	X	X	X	X
Canada	X	X	X	X	X
Croatia					X
Estonia	X	X	X	X	
Finland	X	X	X	X	X
France	X	X	X	X	X
Germany	X	X	X	X	X
Ireland	X		X	X	X
Italy	X	X	X	X	X
The Netherlands			X		
New Zealand	X				
Norway	X		X	X	X
Poland	X			X	X
Russian Federation	X				
Spain			X	X	X
Sweden	X	X	X	X	X
United Kingdom	X	X	X	X	X
United States	X	X	X	X	X
Total	16	10	14	15	15

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8 Abbreviations and acronyms

aff.	Species is unknown but similar to known specimen (*affinis*)
AREVAL	Association pour la Récolte et la Valorisation de la Crépidule
Cefas	Centre for Environment, Fisheries and Aquaculture Science, UK
CI	Conservation index
CLO–SFD	Centrum Landbouwkundig Onderzoek (Agricultural Research Centre, Belgium)
DFO	Department of Fisheries and Oceans Canada
DIPNET	Disease Interactions and Pathogen Network
DNA	Deoxyribonucleic acid
DYNECO	DYNamiques de l'Environnement CÔtier
EHN	Epizootic haematopoietic necrosis
EIA	Environmental impact assessment
ESV	European sheatfish virus
EVEX	Eel Virus Europe X
EZ	Economic Zone
FFV	Foreign fishing vessel
FIFS	A compendium of regulations issued by the Swedish National Board of Fisheries
ILFA	Import of Live Fish Act 1980
IMO	International Maritime Organization
IMR	Institute of Marine Research, Norway
IPN-V	Infectious pancreatic necrosis virus
MSX	*Haplosporidium nelsoni*
NOV	Notice of variation
OIE	World Organisation for Animal Health (formerly Office International des Epizooties)
PEI	Prince Edward Island
PSI	Phase-shift index
PST	Paralytic shellfish toxin
QPX	Quahog Parasite X
rDNA ITS	Ribosomal DNA internal transcribed spacer
REPAMO	Réseau de Pathologie des Mollusques
SAC	Special area of concern
SAMS	Scottish Association for Marine Science
SFS	Swedish Code of Statutes (*Svensk författningssamling)*
SGBOSV	Study Group on Ballast and Other Shipping Vectors
SI	Substitution index
SNH	Scottish Natural Heritage

SSO	*Haplosporidium costale*
SVC	Spring viraemia of carp
USGS	United States Geological Survey
VHS	Viral haemorrhagic septicaemia
WGITMO	Working Group on Introductions and Transfers of Marine Organisms
WGPDMO	Working Group on Pathology and Diseases of Marine Organisms
WoRMS	World Register of Marine Species

9 Websites

www.cbs.nl

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