ICES WGITMO REPORT 2009

ICES ADVISORY COMMITTEE

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Report of the Working Group on Introduction and Transfers of Marine Organisms (WGITMO)

11 - 13 March 2009

Washington D.C., USA

ICES
International Council for the Exploration of the Sea

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Conseil International pour l'Exploration de la Mer

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Executive Summary

In 2009 the ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) met in Washington, D.C., U.S.A with Judith Pederson, U.S.A. serving as chair and Amy Williams, Canada, serving as rapporteur. The meeting venue was the Smithsonian Museum of Natural History with Gregory Ruiz, Smithsonian Environmental Research Centre as our host. Representatives from Belgium, Canada, Estonia, Denmark, Germany, Norway, Spain, Sweden, United Kingdom, and the United States of America attended the meeting.

Synopsis of WGITMO and WGBOSV combined meeting

Because the Working Group on Introductions and Transfers of Marine Organisms (WGITMO) and the Working Group on Ballast and Other Shipping Vectors (WGBOSV) share one half day of meetings, the following minutes cover the joint meeting first and the WGITMO meeting second reflecting the order of the meetings. The main issues for the 2009 WGIMTO and WGBOSV meeting were (1) the joint effort with PICES WG 21 (the equivalent of both WGBOSV and WGIMTO), and (2) issues related to hull and other hard surface vessel fouling where WGBOSV has taken the lead in drafting a Code of Practice.

Synopsis of highlights of the National Reports

This section highlights the new marine introductions of the National Reports and other important changes in the reporting ICES countries. Table 1 lists new marine species introductions reported in this year's annual reports. Table 2 lists some species that have expanded their ranges and Table 3 list some single species identifications that were reported this year. Three countries that provided annual reports, Belgium, Germany and the U.S. did not report new species introductions. One aquaculture release was reported by the U.S. Adults of the shrimp *Penaeus monodon* were observed off the coast of North Carolina, but no reproducing population were found. This is the northern-most sighting for this species which is from Guayana. *Crassostrea gigas* is also an aquaculture escape and is reported as range expansion in Irelans. More information is provided in the National Reports, Annex 3, including references to species not seen in various countries and general information on range expansions.

Table 1. List of marine species identified as new reports in the ICES National Reports

Genus	Species	Common name	Country	Location notes
Carcinus	*maenas*	European green crab	Canada	West Coast of Newfoundland
Mertensia	*ovum*	Arctic comb jelly	Finland	Gulf of Finland, Aland Sea and Bothnian Sea, Baltic Sea
Evadne	*anonyx*	cladoceran	Finland	Gulf of Finland, Bothnian Sea, Northern Baltic Sea
Neogobius	*melanostomus*	round goby	Sweden	Karlskrona, Southern Sweden
Homarus	*americanus*	American lobster	Sweden	North of Skagen at 80-100 fathoms) and North of Smögen
Evadne	*anonyx*	cladoceran crustacean	Sweden	Gulf of Finland and Northern Baltic Sea
Necora	*puber*	European velvet fiddler crab	Sweden	Swedish West Coast at Maseskar, Ramsö and West of Hallö
Telmatogon	*japonicus*	marine chironomid	Sweden	Utgrunden and Yttre Stengrund
Chaetoceros	*concavicornus*	diatom	Sweden	Eastern Kattegat and Skagerrak
Paramysis	*intermedia*	mysid shrimp	Estonia	Eastern Gulf of Finland and Central Gulf of Riga, Baltic Sea
Evadne	*anonyx*	cladoceran	Estonia	Northeast Baltic Sea
Didemnum	*vexillum*	sea squirt	United Kingdom	Harbors of Plymouth, Devon and Holyhead, Anglesey
Watersipora	*subtorquata*	bryozoan	United Kingdom	Plymouth and Poole Quay, Dorset
Dinophysis	*sacculus*		Denmark	Limfjord and Isefjord
Peridinium	*quinquecorne*		Denmark	Kattegat
Mnemiopsis	*leidyi*	comb jelly	Denmark	
Neogobius	*melanostomus*	round goby	Denmark	Near Bornholm in the Baltic Sea
Bugula	*neritina*	marine bryozoan	Ireland	Details next year
Tricellaria	*inopinata*	marine bryozoan	Ireland	Details next year
Dikerogammarus	*villosus*	invertebrate	Poland	Vistula River near Wyszogrod
Proterorhinus	*marmoratus*	tubenose goby	Poland	Vistula River near bridge at Plock at down-stream of Wloclawski Reservoir
Paratenuisentis	*ambiguous*	parasite	Poland	Lake Lebsko (found in eels)
Pleistophora	*muelleri*	microparasite	Poland	Piasnica River (in *G. pulex*)
Nosema	*pontogammari*	microparasite	Poland	Vistula deltaic system
Cladocora	*debilis*	scleractinian species	Croatia	Croatian part of Adriatic Sea
Cladopsammia	*rolandi*	Mediterranean endemic scleractinian coral	Croatia	South of Lastovo Island and southwest of Mljet Island (Southern Adriatic)
Pinctada	*radiata*	Lessepsian bivalve	Croatia	Northern Adriatic Sea
Thysanoteuthis	*rhombus*	squid	Croatia	Eastern Northern Adriatic Sea

Ostreopsis	*ovata*	dinoflagellate	Croatia	Northern Adriatic Sea
Osmundea	*oederi*	red alga	Italy	Mar Piccolo of Taranto
Paraleucilla	*magna*	calcareous sponge	Italy	Taranto, Porto Cesareo, Brindisi and Naples
Haminoea	*cyanomarginata*	cephalaspidean mollusc	Italy	Saline Joniche
Bonamia	*exitiosa*	protozoa	Spain	Cambados, Galicia, Atlantic Coast
Dictyota	*ciliolata*	brown alga	Spain	Palamos, Catalonia, Mediterranean Coast
Plocamium	*secundatum*	red alga	Spain	Mediterranean Coast
Ulva	*pertusa*	green alga	Spain	A Coruna Bay, Galicia, Atlantic Coast
Branchiomma	*luctuosum*	annelid	Spain	Valencia, Mediterranean Coast
Rapana	*venosa*	mollusk	Spain	Cambados, Galicia, Atlantic Coast
Xenostrobus	*secures*	mollusk	Spain	Arcade, Vigo Ria, Galicia and Atlantic Coast

Table 2. Range expansions reported from 2008 National Reports.

Genus	Species	Common name	Country	Location notes
Eriocheir	*sinensis*	Chinese mitten crab	United Kingdom	Various areas in Southern England
Bonamia	*ostreae*	pathogen	United Kingdom	North Kent Coast and Strangford Lough, Northern Ireland
Caulerpa	*racemosa*	green algal	Croatia	
Pterois	*miles/volitans* complex	lion fish	United States	Florida to North Carolina, throughout the Caribbean Island area
Dreissena	*polymorpha*	zebra mussel	United States	Northern Chesapeake Bay; with quagga mussel western U.S.
Necora	*puber*	crab	Sweden	
Crassostrea	*gigas*	Japanese oyster	Ireland	Recruited to several locations
Mnemiopsis	*leidyi*	comb jelly	Germany	Continues to spread

Table 3. Single species or dead animal sightings from the 2008 National Reports.

Genus	Species	Common name	Country	Location notes
Fistularia	*commersonii*	bluespotted cornetfish (dead)	Croatia	Montenegro, Southern Adriatic
Eriocheir	*sinensis*	Chinese mitten crab	United States	New York
Zebrasoma	*scopas*	brushtail tang	United States	Florida
Mytella	*charsuana*	So. American mussel	United States	South Carolina

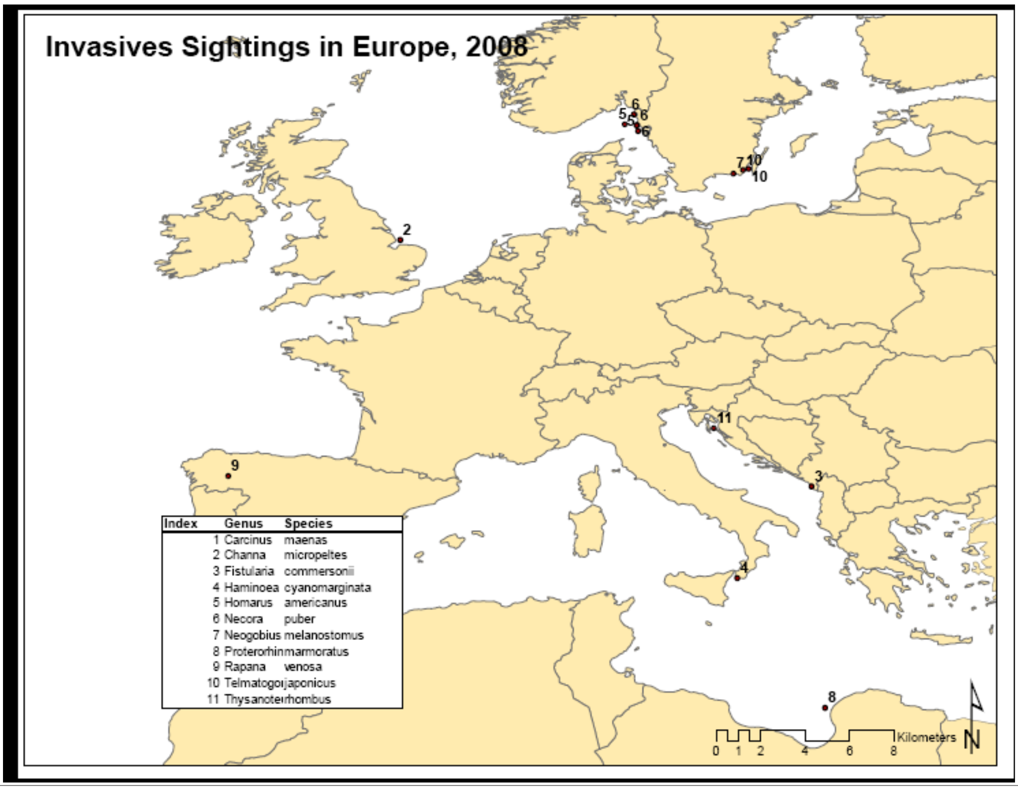

Figure 1. Map of new sightings submitted by ICES Member countries.

1 Summary of WGITMO 2009 Meeting

1.1 Terms of Reference

1.2 Meeting Attendance

Participants:

Judith Pederson, Chair (USA); Gregory Ruiz Local Host (USA); Jim Bean (USA); Paul Fofonoff (USA); Whitman Miller (USA); Francis Kerckhof (Belgium); Nathalie Simard (Canada); Amy Williams (Canada); Kathe R. Jensen (Denmark); Henn Ojaveer (Estonia); Stefan Gollasch (Germany); Anders Jelmert (Norway); Gemma Quilez-Badia (Spain); Inger Wallentinus (Sweden); Ian Laing (UK); Tracy McCollin (UK); and Diane Lindeman (ICES Secretariat)

Progress with Terms of Reference

This section addresses the terms of reference discussed at the meeting and gives a brief overview of the highlights. Each Term of Reference (ToR) is discussed below in more detail and appears in the order as discussed based on the Agenda (joint meeting and WGITMO meeting).

WGITMO Terms of Reference for 2008

2008/2/ACOM25 The **ICES Working Group on Introduction and Transfers of Marine Organisms** (WGITMO) (Chair: Judith Pederson, USA) will meet in Washington, DC, USA, 11–13 March 2009 to:

a) Prepare an overview assessment of non-indigenous species in the OSPAR maritime area

b) To prepare an overview assessment as a contribution to the OSPAR QSR 2010 of information that is available within the ICES framework on:

    i) the distribution, abundance of non-indigenous species introduced into the OSPAR maritime area as a result of human activities, and;

    ii) whether the presence of these species has an adverse impacts on marine ecosystems.

c) Where possible, graphic material should be included e.g. illustration of trends in the number of detections of new indigenous species or the number of observed established non-indigenous species or equivalent material, would be welcomed. (Points a-c) relate to OSPAR request no. 3, 2009).

d) Synthesize and evaluate national reports using the new format for reporting and contributions to the database that includes species, locations (latitude and longitude), status of invasion and other relevant information (also including information of relevant species from other ICES member countries as appropriate), and develop an annual summary table of new occurrences/introductions of aquatic invasive species in Member Countries. And also to prepare an information bulletin of highlights for the ICES Internet site;

e) Finalize the five year summary of national reports (2003–2007) and begin to prepare for a draft 25-year summary based on earlier reports (this requires intercessional editing of draft reports prior the meeting);

f) Finalize the draft Alien Species Alert report on *Crassostrea gigas* and initiate development of a report on the blue crab *Callinectes sapidus* as the next Alien Species report;

g) Continue to develop joint projects (e.g. management of database and taxonomic expertise) with PICES WG21 during intersession that furthers cooperation and communication for resource sharing and information on introduced species.

h) Finalize the preparation of a draft report on the impact of targeted fisheries on non-indigenous species with an emphasis on ICES Member Countries; this will require intersession discussion to select species that were considered with the Code of Practice;

i) Review the Internet-based Appendices of the ICES Code of Practice on the Introduction and Transfer of Marine Organisms. These Appendices were prepared in 2002 and may need some editing to ensure up-to-date requirements;

j) Discuss the need of harmonizing selection criteria to develop lists of high risk, moderate risk and low risk lists for intentional introductions and for mitigating new unintentional introductions (see e.g. the Norwegian 2008 National Report);

k) Continue to encourage all ICES Member Countries to submit WGITMO National Reports.

WGITMO will continue to meet with WGBOSV on areas of interest to both of Expert Groups. These will include hull fouling, monitoring (e.g. Port Sampling Protocol (a TOR of WGBOSV of interest to WGITMO as some aquaculture facilities are in close proximity to ports, e.g ballast water discharge zones).

WGITMO will meet at the same time with WGBOSV with a common meeting on 11 March 2009.

WGITMO will report by 21 April 2009 to the attention of the ACOM. **A draft text on TOR a) must be provided to ICES by 1st April 2009.**

2 WGITMO and WGBOSV combined Meeting Summary

An overview of PICES WG 21 and the meeting that was held in Dalian, China in 2008 were given. Currently PICES is focused on two main issues: developing a database and a rapid assessment program (pilot project in China).

The PICES 2009 TORs were also reviewed in context of how they fit into the work of WGITMO and WGBOSV. Areas of possible interaction are: the ICES Code of Practice which PICES is also working on with respect to prevention and mitigation; development of a taxonomic expert database; and possible joint meetings between ICES and PICES.

Judith Pederson reviewed the U.S. experience with rapid assessment surveys and her experience with the PICES rapid assessment pilot project in China. She noted that China had very limited identification manuals and this may have impacted the results of the rapid assessment survey. Approximately 120 species were identified, but the number of non-native species was not identified.

An overview of the PICES database was presented and a discussion was initiated on the utility of a similar database for ICES. The PICES database is very detailed and in its current form is not easy to share with other users, although WGITMO has not committed to developing this type of database, the excel-based one that we have started is similar. It was suggested that ICES review the requirements of the PICES database and compare those to their own needs. It was generally agreed that the PICES approach is good, with an adequate level of thought put into its development and structure, and although there is lots of information to be gained from it, the amount of work required to accomplish this for each species is enormous. Judith Pederson noted that the database does not integrate information from country to country. It may be advisable to begin with a less ambitious approach with much less detail that can be built upon is deemed necessary. One option is to begin with a wide range of organisms but a small amount of detail on each one. Also, it would be advisable to begin with invasive species, followed by other aliens. If time permits, it may be advisable to add native species and/or link to an existing native species database. It was also suggested that a link to one or more potential vectors should be added.

The inclusion of references is necessary, although some references are in obscure journals and publications that may be difficult to access. However, it provides a context for the identification and will facilitate researchers to verify the sources. References may also reduce the necessity of including a lot of species information. However, as it is possible to add more than one reference it is difficult to identify which reference is for which piece of data.

Even though, other databases (such as DAISIE) do not require references and allow for best guesses, the ICES database should have referenced publications. If some information with respect to invasive species is not published, special notations should be included

The PICES database, currently being developed requires a reference, although pers. comm. may be accepted. It was suggested that our database include confidence levels or levels of certainty for each piece of data.

The WGITMO generally agreed that this would be a better approach than the current national approaches as it would allow for a more efficient aggregation of data. However, as there are so many different databases out there with similar information it is important for all these to be compatible. Funding implications must also be considered as it is expensive to maintain a database over long periods of time. If databases are not updated regularly, they may soon be of little value.

Several countries identified databases currently in existence, participants all knew bits and pieces about the various databases but it was unknown if anyone has ever tried to align them. It was recommended that we review the structure of the existing databases to determine if alignment is a possibility. It is assumed that the alignment of these databases would likely only require small, mechanical changes. It was recommended for each country to review the structure of their database,identify the purpose of the database, the key fields, and the programming language in order to continue this discussion during the 2009 WGITMO meeting. Some databases exist in native languages limiting their universal use.

The need for a database was also discussed in detail during the WGBOSV meeting and it was agreed to have follow-up discussion intersessionally.

3 WGITMO Meeting Summary

3.1 Highlights of National Reports

ToR d *to synthesize and evaluate national reports using the new format for reporting and contributions to the database that includes species, locations (latitude and longitude), status of invasion and other relevant information, and develop an annual summary table of new occurrences/introductions of aquatic invasive species in Member Countries. And also to prepare an information bulletin of highlights for the ICES Internet site.*

The following discussion highlights the new introductions and other important actions by ICES countries. The WGITMO continues to strive to improve the national reports to make them relevant. We have added a new section called, Species Not Yet Reported or Observed to better document dispersal. A few members have included this information in the 2008 reports. We did not prepare an information bulletin, as it was not recommended by ICES.

Belgium

During 2008, no new invasive species were recorded. All introduced species that were reported during previous years are still present and seem to be well-established and thriving.

Canada

While a number of activities and introductions are described in this report, these are primarily updates on issues reported in past years. Canada continues to import a range of organisms for aquaculture as described in the National Report. The pattern of these imports is much the same as in past years and no new activities were reported in 2008 that would raise particular concerns with respect to risks to aquatic resources.

From an Aquatic Invasive Species (AIS) perspective, there were several new sightings and range extensions in 2008 including significant new occurrences of green crab (*Carcinus maenus)* on the southwest coast of Newfoundland; and a new record of New Zealand mudsnail (*Potamopyrgus antipodarum*) in British Columbia. This is the first Canadian record outside of the Great Lakes. On Prince Edward Island, no new species of tunicate have been found, however the existing species have expanded to Souris Harbour (*Ciona intestinalis*, *Styela clava*, *Botrylloides violaceus* and *Botryllus schlosseri*) and Dock River, Alberton (*B.schlosseri*). In 2008, Malpeque disease was detected in the Eskasoni area of the Bras d'Or Lakes in Nova Scotia. Malpeque disease was not detected in this location in the past. Additionally, MSX, which is typically found in the Bras d'Or Lakes was detected in MacDonalds Pond in the Mira Bay. This new location is located outside the Bras d'Or Lakes.

Croatia

In 2007, a specimen of the bluespotted cornetfish, *Fistularia commersonii* was found washed up on the shore of Bar (Montenegro, Southern Adriatic). This record represents the third record of *F. commersonii* in the Adriatic Sea. In 2006, two specimens of *F. commersonii* were recorded in the waters off Tricase Porto (South-Western Adriatic, Italy) and off Sveti Andrija Island (South-Eastern Adriatic, Croatia), respectively.

New species of gelatinous zooplanktonic organisms (Chaetognatha, Sagittoidea and Tunicata, Appendicularia) were reported in the Southern Adriatic Sea during 2007 and 2008.

Investigations of the benthos in the Croatian portion of the Adriatic Sea in last few years have resulted in the discovery of scleractinian species that proved to be new to the area, e. g. *Cladocora debilis* Milne Edwards & Haime, 1849, and the colonial Mediterranean endemic scleractinian coral *Cladopsammia rolandi* Lacaze-Duthiers, 1897, was found in spring 2002 on the cliff at the south of Lastovo Island and in the summer 2005 on the two locations at the southwest of Mljet Island (South Adriatic). These new records are the first confirmations of *C. rolandi* in the Adriatic Sea.

Two specimens of Lessepsian bivalve *Pinctada radiata* Leach, 1814 were found in a benthic study in the Northern Adriatic Sea in April 2006, a first record of the species in the Croatian portion of Adriatic Sea.

A single male specimen of *Thysanoteuthis rhombus* Troschel, 1857 was caught in December 2006 in the eastern part of the Northern Adriatic Sea and is the first record of this species in the Adriatic Sea and the northernmost capture in the Mediterranean Sea.

The first record of the epiphytic and potentially toxic dinoflagellate *Ostreopsis ovata* Fukuyo, 1981 was reported for Northern Adriatic Sea.

New data on the expansion of the invasive alga *Caulerpa racemosa* (Forssk.) J.Agardh, 1873 were published.

Denmark

The National Action Plan on Invasive Species has been drafted and sent out for public hearing. It was published in February 2009.

The invasive ctenophore *Mnemiopsis leidyi* had mass occurrences in Danish waters in 2007. It was also widespread, though not as abundant in 2008. The red seaweed *Gracillaria vermiculophylla* first appeared in Danish waters in 2003. It is now spreading and forming mass occurrences in several localities. *Marenzelleria viridis* and *Crassostrea gigas* continue to spread in Danish waters. *Crepidula fornicata* seems to increase in abundance in several places. Offshore windmill farms appear to act as stepping stones for introduced species, e.g., the chironomid *Thelmatogeton japonicus* and *Caprella mutica*. The first live specimen of *Neogobius melanostomus* was found near Bornholm in September 2008.

Estonia

The current report describes recent findings of two new alien species in Estonian marine waters: the mysid shrimp *Paramysis intermedia* (Czerniavsky) in 2008 and the cladoceran *Evadne anonyx* G. O. Sars in 1999. Both species have formed permanent populations. Estonia continues live fish imports from various countries. The statistical nomenclature categories does not allow the identification of the species, rather it lists fish by origin or taxonomic groups. During the past two years, only salmonids (salmon and sea trout) were released to the natural water bodies in order to enhance fishery resources.

Finland

The Gibel carp, *Carassius auratus* m. *gibelio* was caught in several places along the south coast of Finland; however the northernmost observation is still the Archipelago Sea. In 2008, several dozen Russian sturgeons, *Acipenser gueldenstaedtii*, were caught along the coast of Finland. Some information on escapes from an Estonian fish farm was received. The arctic comb jelly *Mertensia ovum* was recorded for the first time from the Baltic Sea in September 2008. The species was found in open sea stations in the Gulf of Finland, the Åland Sea and the Bothnian Sea. It is not known whether the species is an invasive alien species or a relict species that has not been identified from the Baltic Sea before. Research to study whether the invasive American comb jelly (*Mnemiopsis leidyi)* occurred earlier in the northern Baltic Sea is underway, although the comb jelly community was formed of only *Mertensia* individuals in September 2009. A question of whether *M. leidyi* was present in earlier studies is unknown. The invasive predatory cladoceran *Evadne anonyx* was recognized for the first time in Finnish waters (Helsinki sea area) in July 2008. However, when looking back at preserved samples, the species was found for the first time in the samples from September 2000. The species was also observed in August 2008 in coastal areas of the Gulf of Finland as well as at open sea stations of the Gulf of Finland, the northern Baltic Proper and the Bothnian Sea.

Germany

No new sightings were reported in 2008.

The invasive ctenophore *Mnemiopsis leidyi* was first recorded in the Kiel Bight (western Baltic Sea) in October 2006. Investigations on its presence, distribution and spread are ongoing in Germany with an emphasis on its potential impact.

The EU-funded project "Environmental impacts of alien species in aquaculture" (IMPASSE) was completed with several reports. The key objectives include to review and assess the impact of alien species in aquaculture and also to provide recommendations on containment facilities for alien species in aquaculture use, among other considerations of impacts on aquaculture.

The Institute for European Environmental Policy (IEEP) is currently undertaking a comprehensive initiative regarding alien species in Europe. One task is to assess the financial impact of alien species including terrestrial species. A rough estimation suggests an economic impact of at least EUR 12 billion Euro annually.

A recently published summary of all alien aquatic species in the North Sea documents in total 166 species.

Ireland

The marine bryozoa *Bugula neritina* and *Tricellaria inopinata*, have been found for the first time in Ireland. Further details will be available for next years report. Recruitment of the Pacific oyster, *Crassostrea gigas*, has been confirmed in a number of sites in Ireland. A series of studies are currently being conducted by the Marine Institute, Galway, University College, Dublin and Queens University, Belfast to investigate the dynamics of *C. gigas* recruitment reproduction and ecological interactions. The presence of tunicate *Didemnum vexillum*, has been confirmed at a wide range of sites (predominantly marina sites) on both the east and west coasts of Ireland. Additional sightings of *Styela clava* have also been confirmed at a number of locations in Ireland throughout 2008. The presence of *S. clava*, appears to coincide with shellfish culture operations or significant boat movements.

Italy

Three new alien species have been recorded in the Italian waters: the red alga *Osmundea oederi*, the calcareous sponge *Paraleucilla magna* (which represents the first alien sponge recorded in the Mediterranean), the cephalaspidean mollusc *Haminoea cyanomarginata.* Studies on the biology and ecology of species that had been introduced previously have continued, with special emphasis on the invading algae (*Caulerpa racemosa* var. *cylindracea*) and the toxic microalgae (*Alexandrium* spp., *Coolia* sp. and *Ostreopsis* spp.).

Range expansion of some thermophilic species is reported together with new records in neighboring countries, among which the presence of *Styela clava* in the Lagoon of Thau is of special concern.

Poland

Dikerogammarus villosus (Sowinsky, 1894) was recorded for the first time in the Vistula River near Wyszogród – in the autumn of 2007 (Bącela at el. 2008).

In April 2008, *Proterorhinus marmoratus* (Pallas, 1814) was recorded for the first time in Poland. It was reported in August 2007 for the first time in the upper and middle parts of the Pripyat River, Belarus, which suggests that the species reached Poland and the Vistula basin via the Pripyat-Bug canal. The first record of *Paratenuisentis ambigous* Van Cleave, 1921 from Lake Łebsko (central Polish coast) (Morozińska-Gogol J., 2008) was recorded in eels, since 2002. Because of the spread of the intermediate host and the appearance of new adults in eels along the southern Baltic Coast, it is clear that *P. ambiguus* can complete its life cycle in Baltic coastal waters.

Gregarines (Apicomplexa, Gregarinidae) were recorded in digestive tracks of invasive *Pontogammarus robustoides* (*Uradiophora ramose* and *Cephaloidophora mucronata* from the Vistula deltaic system and in digestive system of native *Gammarus pulex* from Stradanka River, an affluent of the Vistula Lagoon. Microsporidia were found also only in two above gammarid species: *Pleistophora muelleri* in *G. pulex* from Piaśnica river, and *Nosema pontogammari* from the Vistula deltaic system.

Spain

There is a growing interest on the subject of Alien Introduced Species (AIS). Most of the studies, however, focus on terrestrial or freshwater introduced species and usually in catalogued protected areas.

Recently, law 42/2007 concerning the Spanish Natural Heritage and Biodiversity was published. Particularly, Chapter III Prevention and Control of Alien Invasive Species. Art. 61, deals with the AIS Spanish Inventory.

Worth noting is the initiative Aquatic Invasive Species (AIS) program, InvasIBER (http://hidra.udg.es/invasiber/presentacion.php). Its objective is to establish a data base of the main invasive species in the Iberian Peninsula. Up until now, it is composed of 36 animal and plant species, from these, only 4 are marine.

With regard to AIS in marine and estuarine environments, the number of studies conducted is very scarce. Of particular interest and solely marine, are two studies carried out in the Basque Country (North of Spain) (Martinez and Adarraga, 2005 and 2006).

The present study shows the first records of nonnative marine and brackish species in Spain (excluding Canary Islands) (Table I). To date 132 marine and brackish species have been identified as nonnative. From these, 45 are seaweeds, 29 crustaceans and 16 mollusks. In 2007-2008 7 new records (or newly cited, although previously recorded) (* from Table I).

Sweden

The following introduced species were reported as new sightings:

– Round goby *Neogobius melanostomus* (a few caught in Karlskrona, S Baltic Sea)

– American lobster *Homarus americanus* (Swedish west coast, some with rubber bands on claws)

– The cladoceran *Evadne anonyx* (in small numbers in the Baltic Sea)

– The crab *Necora puber* (Swedish west coast, probably a range extension)

– The chironomid *Telmatogon japonicus* (on two offshore windmills in the S Baltic Sea)

– The diatom *Chaetoceros concavicornus* (Swedish west coast)

Changes for previously recorded organisms:

The occurrences of the American comb jelly *Mnemiopsis leidyi* in the N Baltic proper and the Bothnian Sea have been questioned after genetic analyses in 2008-09, since the samples analyzed belonged to an Arctic comb jelly, *Mertensia* sp.

The polychaete genus *Marenzelleria* is represented along the Swedish coasts of the Baltic Sea and Bothnian Sea by three species; *M. neglecta, M. arctica* and *M. viridis.*

A Swedish national strategy and action plan for alien species has been developed, but is not yet adopted.

United Kingdom (UK)

Two marine invertebrate species were recorded for the first time in the UK in 2008. The invasive ascidian *Didemnum vexillum* was found in harbours at Plymouth, Devon and Holyhead, Anglesey. The bryozoan *Watersipora subtorquata* was also found at Plymouth and at Poole Quay, Dorset.

There have been records of new locations for freshwater fish species either not previously reported in the wild or in areas outside the species' previous distribution. For example, fathead minnow *Pimephales promelas* has been reported for the first time in waters other than private garden ponds. And the distribution of sunbleak, *Leucaspius delineatus*, previously believe to be limited to southwest England (i.e. not further East than the county of Hampshire), has been confirmed for sites in the counties of East Sussex and Kent.

There is increasing concern from statutory nature conservation bodies on the continuing natural recruitment of Pacific oysters in the wild.

Outbreaks of *Bonamia* have occurred in two new areas.

United States (U.S)

Lionfish of the *Pterois miles/volitans* complex, continue to be reported through the Caribbean basin and on the southern Atlantic coast of the US. In 2008, no major range extensions were reported in mainland US waters, but first sightings were reported in Puerto Rico, the US Virgin Islands, the Dominican Republic, Haiti, Jamaica, Belize, the Turks and Caicos Islands, the Cayman Islands, and Colombia. This species is becoming an important resident of tropical Atlantic waters.

A single specimen of another marine aquarium fish, Brushtail Tang, *Zebrasoma scopas*, was seen by a trained observer off Fort Lauderdale, Florida. Most of these records are single specimens. So far, only the lionfish is known to have established populations in US Atlantic/Gulf of Mexico/Caribbean waters.

In November 2008, a single zebra mussel, *Dreissenia polymorpha* was found alive, inside an intake at the Conowingo Dam, just above the head of tide of Chesapeake Bay and also found further upstream in Pennsylvania, in Muddy Run, a tributary near the Maryland border. The limited salinity tolerance of the zebra mussel is likely to limit its distribution, but the potential invaded areas are ecologic ecologically important to a variety of fishes, blue crabs (*Callinectes sapidus*), and waterfowl.

A single specimen of the South American, mussel *Mytella charruana* was found in the Ashepoo River, Colleton County, South Carolina, on an abandoned crab pot float line**.** This is the northernmost record for this mussel**.**

In 2008, 22 specimens of the Chinese mitten crab, *Eriocheir sinensis* were caught in US Atlantic Coast tributaries. Surprisingly, no Mitten Crabs were reported from Chesapeake or Delaware Bays in 2008, despite occurrences in previous years.

In 2008, at least 15 Asian tiger shrimp, *Penaeus monodon* were reported, from Mobile Bay, Alabama, to Pamlico Sound. So far, there is no evidence for reproduction in US waters.

Two colonies of smooth cordgrass (*Spartina alterniflora*), native to the Atlantic coasts of North and South America, were discovered, and eradication programs begun, near Warrenton, Oregon, on the Columbia River estuary in September 2008, and in Mukkaw Bay, on the Olympic Peninsula, Washington, in October 2007.

3.2 Status of OSPAR Report

ToR a *to prepare an overview assessment of non-indigenous species in the OSPAR maritime area.*

ToR b to prepare an overview assessment as a contribution to the OSPAR QSR 2010 of information that is available within the ICES framework on: i) the distribution, abundance of non-indigenous species introduced into the OSPAR maritime area as a result of human activities, and; ii) whether the presence of these species has an adverse impacts on marine ecosystems.

ToR c where possible, graphic material should be included e.g. illustration of trends in the number of detections of new indigenous species or the number of observed established non-indigenous species or equivalent material, would be welcomed. (Points a-c) relate to OSPAR request no. 3, 2009).

In preparing the OSPAR report, the Working Group raised the issue of identifying information sources for the OSPAR report that complements the annual National Reports, and identifies nonindigenous species in countries that have not submitted reports. It was suggested that a fellowship could be provided for students from a variety of countries to carry out research in the Atlantic and the South Pacific. Another source of information could be the DAISIE satabase, which contains a list of species from Portugal to Norway, but no data for region III. It was agreed that this information should be added. Information could also be gained from published articles by highlighting main species. A paragraph that summarized where data could be found and the need for expert opinions will be compiled, but has been superceded by later the consensus was to highlight the main nonindigenous species, but do not ignore the rest. This was adopted as the taxonomic table in the report. Included in the table was a column about why countries should care and give an example that highlights the main issues.

Although WGITMO has not focused on plankton in the national reports, these were discussed. A short summary of phytoplankton introductions was prepared by Tracy McCollin, Gemma Quilez-Badia, and Nathalie Simard.

Phytoplankton

Phytoplankton can be introduced into new areas in a variety of ways e.g. ballast water and sediments and the ability of some species to form protective cysts means that they are able to survive for long periods of time and can thus be transported considerable distances. Once there are suitable conditions the cysts may hatch and the motile cells become part of the phytoplankton community in a new area. However, phytoplankton species can be difficult to differentiate, often relying on specialized microscopy techniques to identify the cell features that are unique to a particular species. This means that in many cases it is difficult to know whether a "new" species has been introduced or has simply not been indentified accurately in previous work.

Large cells such as the diatoms *Coscinodiscus wailesii* and *Odontella sinensis* that are found in European waters are easier to identify because of their size and/or their distinct morphology and there is more confidence that the first records of the occurrence of these species in 1977 and 1889 respectively are correct.

Phytoplankton occur in large abundances in spring as daylight and temperature increases and these blooms can sometimes have adverse effects as they can lead to anoxic conditions, smothering of benthic organisms or can cause irritation of fish gills. Some species can also produce toxins, which can accumulate in shellfish and can therefore have adverse effects on the shellfish industry, which will be restricted from selling the shellfish when there are toxins present in the flesh.

Of the two diatoms mentioned above *C. wailesii* has caused some problems by producing a mucilage during the bloom die off that has clogged fishing nets. However, as with all phytoplankton, the abundance of this species fluctuates depending on environmental conditions and the nuisance features of this diatom do not always occur.

The OSPAR report is provided for 2009 as Annex 4.

Abstract

Over 160 established marine introduced species have been identified in the OSPAR region based on an analysis of data entered in the DAISIE databank, a database managed and compiled by European scientist, but this number under represents the total number of species. A list of references provides data on invasions collected over the past decade or more. We have selected four algal species, one higher plant, and 18 invertebrate species as problematic invaders that have human health, economic and ecological impacts of concern.

3.3 Status of 5 and 25 year reports (ToR e)

ToR e *to finalize the five year summary of national reports (2003–2007) and begin to prepare for a draft 25-year summary based on earlier reports (this requires intercessional editing of draft reports prior the meeting).*

The group discussed the purpose and the utility of the summary reports in their current format. A major issue is that as the information in the summary reports comes from the national reports, which are incomplete and inconsistent in coverage. For example, many current national reports include little to no information on seaweeds or plankton species. It was recognized that the compilation of these reports requires a significant amount of work but the reports are rarely if ever used. Previous ICES feedback states that the goal of these summary reports is to identify trends of AIS spread in and between countries.

WGITMO agreed that the current approach is not effective; there were three main suggestions as to the best way to approach this in the future. The first recommendation was that the group should focus on creating a set of data using sources other than the national reports that can then be compiled into a report looking at invasion status and trends, as was done for the earlier algae and higher plant sections. This type of report could also be used to start looking at effects that are expected as a result of climate change and to compile all the information the group has on vectors. Another suggestion was to build on the current excel spreadsheets that are submitted with the national reports to build a solid AIS dataset within the ICES statistical database. It was not clear if this option was technically feasible, nor was it clear how to include information from countries that are not reporting annually. Judith Pederson will explore with ICES.

This idea was generally accepted; however it was felt that the current summary reports should be cleaned up regardless as it could still be used as a source of data, albeit limited in scope.

Many introductions of fish species are into freshwater environments, and there is debate over whether or not these species should be included in ICES reports. It was decided that only species which have at least part of their lifecycle in the marine or brackish environments should be included in reports. Other fresh water species will not be included (i.e. those that spend their life in fresh water).

3.4 Status of *Crassostrea gigas* report (ToR f)

It was noted that this report needed to be finalized. Any final comments should be sent to Laurence Miossec as soon as possible. Judy Pederson will request a publication for the Species Alert Report for *Crassostrea gigas*.

3.5 Development of joint projects with PICES WG 21 (ToR g)

ToR g *continue to develop joint projects (e.g. management of database and taxonomic expertise) with PICES WG21 during intersession that furthers cooperation and communication for resource sharing and information on introduced species.*

There were three main areas proposed as possible areas of cooperation with PICES:

1) Joint research projects: It was recognized that while this is a good idea, it is probably not feasible right now, primarily as there is no funding.
2) Provision of a list of country experts: this could be linked to DAISIE by taxonomic expertise. It was recommended that PICES be asked what type

of taxonomic expertise is required so that our advice could be better targeted.

3) Support of the PICES database with information on native species: this was recognized as a large task, recommended that we focus on one group of species. It was recognized that PICES likely already had specific species in mind that they would like information on – it would be best to start with these as trials.

It was recommended that a joint ICES-PICES meeting be held next year at the Sixth International Conference on Marine Bioinvasions being held in Portland, Oregon to further discuss potential areas of collaboration (see http://www.ices.dk/indexfla.asp and http://www.clr.pdx.edu/mbic/index.html).

WGITMO also followed up on the database discussion from the joint WGITMO – WGBOSV meeting by conducting a roundtable with each country identifying which elements its database had. The results were put into an excel spreadsheet and further prioritized. Discussion was held over which taxonomic source countries used and specifically mentioned were ITIS, WoRMS, algaebase, and/or others. The major concern is the accuracy of the taxonomic name and the ability of the source to keep the list current.

It was suggested that it could be possible to insert information from neighboring countries who do not submit ICES National Reports as information would be contained in the existing databases.

It was recommended to have a special session at next year's meeting on databases with invited experts including a PICES representative to review the PICES database and determine the potential overlap with the ICES data.

3.6 Status of the impact of targeted fisheries on non-indigineous species (ToR h)

ToR h *finalize the preparation of a draft report on the impact of targeted fisheries on non-indigenous species with an emphasis on ICES Member Countries; this will require intersession discussion to select species that were considered with the Code of Practice.*

As mentioned in the ICES WGITMO 2008 report, there was confusion over the meaning and intention of this ToR. None of the species that have been introduced using the Code of Practice currently have targeted fisheries, thus there are no examples to be discussed based on the way the ToR is currently written. It was suggested that this ToR be broadened to look at examples of targeted fisheries of nonindigenous species and evaluate if the fishery was effective in delaying the growth of the population. It was recommended that WGITMO work intersessionally to prepare a draft report summarizing how each country approaches the issue of targeted fisheries on nonindigenous species in the Atlantic Ocean. Canada and Denmark were requested to lead the compilation of this report.

The second part of this ToR looks at what species have been assessed using the Code of Practice or equivalent (The National Code on Introductions and Transfers in Canada, for example). Although in many countries, many species have been grandfathered in because of their historical significance in commerce and thus did not apply the Code, it was decided not to include these species in the list for simplification. This list will be compiled and during intersession and included in next year's report.

3.7 Review of the appendices of the ICES Code of Practice (ToR i)

ToR i *review the Internet-based Appendices of the ICES Code of Practice on the Introduction and Transfer of Marine Organisms. These Appendices were prepared in 2002 and may need some editing to ensure up-to-date requirements.*

WGITMO was tasked with reviewing the appendices of the ICES Code of Practice (CoP) with a view to finalizing them for publication.

The discussion centered on the correct level of detail to be included in the risk assessment portion of the appendices. Concern was raised that the current assessment procedure in the CoP was so detailed that it may act as a deterrent to people from using it and this could explain why ICES has received so few requests. Although this point was generally accepted, the counter argument was also made, which is if the assessment were simplified too much then the CoP would not represent an appropriate risk assessment.

During the meeting, it was discovered that the appendices are currently online, thus there does not seem to be an immediate need to review and revise them. It was recommended that the link to the appendices should be made explicit in the CoP and identified as a companion to the CoP such that the documents should be repackaged in a more attractive way. It was also recommended that the risk assessment portion be re-reviewed once the results from IMPASSE are available, and at that point reference should be made in the document to IMPASSE.

3.8 Development of criteria for the creation of high-low risk species lists (ToR j)

ToR j *discuss the need of harmonizing selection criteria to develop lists of high risk, moderate risk and low risk lists for intentional introductions and for mitigating new unintentional introductions (see e.g. the Norwegian 2008 National Report).*

Some confusion over intended goal of ToR j was expressed by several countries, the concept made sense to people for intentional introductions but it was not clear how such lists could be used for invasive species. Although many countries are creating lists, they are often using different type of criteria. This is particularly a problem for neighboring countries.

It was noted that there was a lot of demand in Sweden for this sort of criteria, specifically for those species that are already present. It may be less important for newly introduced species, especially in relation to the new EU Marine Strategy Framework Directive, but also if possible to include it for quality assessment within the EU Water Framework Directive..

It was also noted that "black" list species are usually those which are known to have caused problems in other countries, and are fairly easy to list. However, many countries are hesitant to develop "white" lists, as it is very hard to know how a species will react in another country and it implies that we are able to predict that the species will not have any impact. This is often why we end up with very different lists around the world. Denmark advised that focus be put into developing "black" lists as these are the ones that decision-makers would be most interested in.

The UK noted that there are a series of lists under the UK water framework directive and that they are trying to harmonize these lists right now.

Norway reviewed their Norwegian alliance list, which is currently being revised. During the review they found that many species that were listed as black or grey were actually very low risk, and many of the original criteria were tweaked. They recommend using a dichotomy of high risk and unknown risk, rather than High and Low.

The issue of the impact of such lists on commerce was also discussed. It was pointed out that the aquaculture industry would probably want a white list of some sort developed; otherwise they may need to do a risk assessment for all introductions if all species were either black or grey listed. It was recommended that a similar approach be taken as in the UK, where they have included a list of new species allowed for aquaculture in their new regulations.

The point was also made that many white list species are already established or already part of commerce in a country and many people just want to be able to continue importing/moving it. The requirement under ICES is that you are not allowed to bring in new generic material of that species. The other aspect to consider is climate change, species that have been benign may express themselves differently when the climate changes. It was suggested that the creation of these lists is going around the ICES protocols.

Canada pointed out that a single list may never be agreed upon because the conditions are too different in each country, but it is possible to come up with a common list of criteria that each country could then use to develop their own list.

It was recommended that because this is a complex issue that is not going to be resolved during this session, the group should work intersessionally to describe the work that is already underway in many countries and to identify major issues of concern, such as genetics and climate change. This will be compiled into a white paper that will be sent to ICES for their review and consideration.

3.9 Review of the use of the ICES Code of Practice in U.S. case study

Roger Mann gave an overview of the process that took place in the U.S. with respect to the proposed introduction of the Suminol oyster in Chesapeake Bay to rehabilitate the Bay and revitalize the fishery. This case study provided a good example with which to discuss the application of the ICES Code of Practice, in particular with respect to the utilization of triploidy (i.e. sterilization). The recidivism rate is ~0.1%, which can result in breeding oysters if large numbers are released. Roger Mann noted additional risk assessments underscored the risk is greater than current analyses suggest. It also raised the issue of jurisdictional complications and protocol in countries such as the U.S. where the state has the authority to approve an introduction but the federal government is ultimately the signatory to ICES.

It was recommended that WGITMO should convey to US that they were supposed to contact ICES directly and make a request, not through a specific WG and find out from the State department who the responsible party is to avoid this in future. WGITMO also recommended requesting information from ICES on appropriate protocol and requesting permission to submit WGITMO comments on this specific case.

3.10 Climate Change

As part of their involvement in the Study Group on Climate Change, Judith Pederson and Anders Jelmert have been asked to write a chapter on the effects of climate change on aquatic invasive species in the North Atlantic. The book will have the following chapters: warming of the North Atlantic over past decade, hotspots, circulation (sea level rise, chemical and physical changes), acidification and biogeography, chlorophyll, trends in plankton, benthos, migration, climatic events and bioinvasions, models, and socioeconomic issues.

They both felt that WGITMO should start bringing these topics into our discussion on AIS.

It was noted that in order to discuss the topic properly we need to think of good examples of introduced species that have well documented range extensions that could be linked to climate change. The issue is often getting the necessary information. The group was asked to identify any information sources that they knew of and forwarded to Judith Pederson and Anders Jelmert.

It was noted that The Dega Marine Lab at the University of California (Cascade Sort (sp), graduate student of Susan Williams) are looking at effects of climate change on induced range extensions around the world. Currently they are looking at about 150 species that are known to be extending. This includes both native and introduced species, but excludes El Niño species, normal range extensions and vagrants. All the information is being compiled in a database, with a manuscript being released in the near future.

It was requested that any other information sources or references be sent to Judith Pederson and Anders Jelmert. The group was asked to identify any known long term collections of environmental data (salinity, sea surface temp, etc). It was noted that these types of information exist in most places for the offshore, but very few places collect it for the nearshore. However, the following examples were given:

- Denmark gets this data from old lighthouses – salinity at surface and depth, temperature, plankton samples (discarded). Currently the information is maintained in reports, not a database.
- Scotland has approximately 10 yrs of nearshore data, plus lots of offshore. Some of this may be publicly available; Tracy McCollin will check and report back.
- Norway and Sweden have both offshore and nearshore data – extensive datasets.

It was noted that what information a country has will depend on the spatial/temporal scale that we are looking at; much of this should already be present in other ICES working groups.

The question was raised as to whether the species chosen in last OSPAR report were reasonable indicators of climate change. It was indicated that the group never solved some of the expansion/range extension issues. However, as we were asked by ICES to only include species that were introduced and established, we focused this year's report on selected species.

It was noted that there is a very good German dataset that goes back about 100 years and is available online.

It was also noted that we need to state caveats to the broad statements being made because there are many differences. For example, there was a paper from last year in Ecology Letters that describes that the warming in the Northern Hemisphere is not consistent, some places are warming, some are cooling, etc.

The group was polled to see if anyone had published papers on climate changes and species and could provide advice based on those papers. Tracy McCollin, James Carlton, Greg Ruiz, and Anders Jelmert noted that they have all produced papers on this topic.

In his paper, Greg Ruiz reviewed what the human response is going be in response to things such as shift in vectors, shoreline development, and oil and gas exploration. Most work focuses on shifting range of species, rather than the human response; however new areas will open up because of the huge potential consequences of this issue.

The group was asked their opinion of what would be the greatest contributor to cause species to expand their range?

It was felt that terrestrial criteria may apply, meaning an earlier onset of spring and warmer winter temperatures. This would alter overwintering survival and reproductive success.

In Norway, the water was colder this year than normal, resulting in an earlier spring bloom.

In the UK a report was released that says that the spread of *Sargassum muticum* and Chinese mitten crab is a combination of climate change, human involvement and natural range extension. The conclusion was that climate change will result in more species spreading and becoming established, likely displacing native species. It also looked at the changes in shipping routes due to the reduction in ice as a possible new vector for non native species.

4 WGIMTO 2010 Terms of Reference

2010 Proposed Terms of Reference for WGITMO 2010

ToR a

- Synthesize and evaluate national reports using the new format for reporting and contributions to the database that includes species, locations (latitude and longitude), status of invasions and other relevant species from other ICES member countries as appropriate), and develop an annual summary table of new occurrences/introductions of aquatic invasive species in Member Countries. We will add a section to our format on eradication methods undertaken by countries that have been used and whether or not they have been successful.

ToR b

- Review options for utilizing existing databases and information resources (in ICES countries and elsewhere) to provide a more complete picture of introduced species distribution.

ToR c

- Publish the *Crassostrea gigas* report. And explore the opportunities for the development of short communications materials on species of concern to be peer reviewed and published by ICES on the web or elsewhere.

ToR d

- Continue to develop and discuss joint activities with PICES WG 21 during intersession that furthers cooperation and communication for resources sharing and information on introduced species (example: databases).

ToR e

- Identify the criteria used by ICES countries to develop lists of high, moderate and low risk for intentional introductions and for those introduced species already established.

ToR f

- Finalize the 5 year summary report (2003-2007) during intersession. Note: WGITMO has a draft five-year report, but it is missing a fisheries section including in this report.

ToR g

- Prepare a draft of the 25-year report based on earlier National reports, literature, and other ICES country information, based on new discussions about how best to present this information to be most useful to ICES member countries. We will discuss how best to accomplish this with ICES.

ToR h

- Finalize preparation of a draft report on the different approaches taken by ICES countries on targeted fisheries of nonindigenous species and the impact that these fisheries have had in reducing the spread and abundance of nonindigenous species. This will require intercessional preparation and editing of the report.

Supporting Information

PRIORITY:	The work of the Group is the basis for essential advice to prevent future unintentional movements of invasive and/or deleterious aquatic species including disease agents and parasites with the legitimate trade in species required for aquaculture, table market, ornamental trade, fishing and other purposes and to assess the potential of species moved intentionally to become a nuisance in the area of introduction. The work of this Group supports the core role of ICES in relation to planned introductions and transfers of organisms.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	a) We want to document successful eradication efforts by ICES countries and identify those that were unsuccessful and why they failed. This information should be of use to developing rapid response plans. b) We have been developing a simple excel database on new introductions or expanding introductions and will be requesting that ICES adopt the data and maintain the database for the Working Group and ICES countries to access. c) We request that the Final *Crassostrea gigas* report be published by ICES. The draft is attached, final not yet received. d) We plan joint meetings with PICES at International Conferences and the chairs of the Working Group on Introductions and Transfers has attended PICES meetings. We propose to continue to explore options for collaboration, particularly focusing on database management options for introduced species. e) One of the issues raised is the ranking of invaders as high, moderate, and low risk for intentional introductions. Each country has its own criteria, but these are often contradictory between and among the ICES countries. There is a need to identify criteria used and to develop assessments that are consistent and/or identify a process for reconciling

	differences. Intercessionally we will compile these criteria and review them.. f) We have not been able to finalize the 5-year report and would propose integrating the five year report into a more comprehensive report as discussed in ToR f. g) In reviewing the data from the first two ten year reports, we identified many gaps in the data from countries that did not report and data that was overlooked. In addition some species are identified once, but not further information on their establishment is discussed. We are proposing to request that we reorganize the report to include data from National databases, literature and the ICES Annual reports to provide a comprehensive, and list of species that reflects current nomenclature and addresses reports that remain unverified. h) Once species like the Chinese mitten crab are released and established, they may become a target for a fished species. Intercessionally, WGITMO will compile country records of nonindigenous species that have become targeted fisheries and report on the success of this effort next year.
RESOURCE REQUIREMENTS:	None required other than those provided by ICES Secretariat and national members
PARTICIPANTS:	WGITMO members and invited experts from, e.g., Australia, New Zealand, Mediterranean countries that are not members of ICES, representatives of relevant PICES WGs. WGITMO recommends inviting experts with relevant expertise to contribute to the Aliens Species Alert reports and experts from countries which have developed/are developing rapid response plans.
SECRETARIAT FACILITIES:	Meeting room providen by the host
FINANCIAL:	None required
LINKAGES TO ADVISORY COMMITTEES:	WGITMO reports to ACOM
LINKAGES TO OTHER COMMITTEES OR GROUPS:	WGHABD, WGEIM, WGBOSV, WGAGFM, WGMASC, Mariculture Committee
LINKAGES TO OTHER ORGANIZATIONS:	WGITMO urges ICES to encourage and support a continued dialogue between WGBOSV and BMB, PICES, IMO, IOC, EU, HELCOM, EIFAC, CIESM.

Annex 1 List of Participants

ICES Working Group on Introduction and Transfers of Marine Organisms

11-13 March 2009

Smithsonian Museum of Natural History

Washington DC., USA

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Annex 2: Agenda of the March 2009 WGITMO meeting

Agenda for the WGITMO Meeting

11-13 March 2009

Smithsonian National Museum of Natural History

Washing ton D.C.

As has been the tradition for the past several years the ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) will meet for half a day with the Working Group on Ballast and Other Shipping Vectors (WGBOSV). The agenda below includes the half day meeting with SGBOSV and the WGITMO 11 March 2009, 1-5 pm joint meeting with WGBOSV and the two day meeting with WGITMO and invited guests.

Agenda for the Joint meeting of SGITMO and WGBOSV

11 March 2009

1.00 pm – 5.00 pm

The items for a joint meeting are based on shared interest in our terms of reference (ToR) that are provided by the ICES Advisory Committee.

1:00 p.m. Discussion of ongoing collaborations with PICES WG 21 (ToRg)

The North Pacific Marine Science Organization (PICES) Working Group 21 (WG21) is the equivalent of both the WGBOSV and WGITMO. They have been focussed on developing a marine invasive species database for the five countries (Canada, China, Japan, Korea and the U.S.) with funding from the Japanese government. In addition to invasive species, they are interested in developing an expert database and to having information on species introduced to the Pacific that originate in the Atlantic (i.e., they would like life history, invasiveness, etc. information for the database). We will review the database structure and status and discuss how to address the issues of an expert database and support of species life history information.

2:00 p.m. Discussion on hull fouling (commercial and recreational b oats) and sea chests etc. (ToRb)

The WGBOSV has a draft guideline on hull fouling for commercial vessels. However, hull and other hard surface fouling of vessels (sea chests, bilge pumps, anchors, etc.) are an important topic for the WGITMO. This discussion will review the WGBOSV guidelines and discuss applicability to the WGITMO effort to prevent and reduce new introductions. This is relevant to our interest in vectors in general and hull fouling in particular.

3:00 p.m. Break

3:30 p.m. Climate change impacts on communities (ToRj)

Climate change is a concern for all the ICES countries. The WGITMO will be preparing a report for OSPAR Commission which is comprised of 15 European countries in the Northeast Atlantic. In addition, climate change has implications for all countries as both non-native and native species expand their ranges, currents, temperature, and sea-level changes impact the marine ecosystems. This discussion will focus on issues of joint interest to WGBOSV and WGITMO as we prepare for completing the OSPAR Report.

Agenda

WGITMO Meeting

12-13 March 2009

Thursday 12 March 2009

8:30 am

Welcome and Introductions

Review of Terms of Reference and Agenda

Designation of Rapporteur

9:00 – 11:00 am

Prepare an overview assessment of nonindigenous species in OSPAR region on distribution and abundance of invasive species related to human activities and impacts to marine systems. This directly related to three terms of reference, ToRs a-c. We need to indicate trends which should emerge from our 5-years documents. A draft document will be prepared, with time spent by the committee preparing a final draft for the OSPAR committee.

11:00 am – 12:30 pm

Highlights of National Reports (I have inserted a copy of the 2007 excel sheet for species listings and a copy of the template for the National Report format (ToRd).

12:30 – 1:30 pm Lunch

1:30 – 3:00 pm

Discussion with invited guests on the U.S. approach to invasive species, application of the Code of Practice on Introductions and Transfers of Marine Species, research efforts, risk assessment, and addressing climate change and introduced species. TBD.

3:00 – 3:30 p.m. Break

3:30 – 5:00 pm

Review Appendices for Code of Practice for FINAL edits. The appendices are an integral part of the Code of Practice, but ICES has been reluctant to publish them, as I understand it, because they are too detailed. We will break into groups and finalize drafts for ICES approval. (ToRi).

Friday 13 March 2009

8:30 – 10:30 a.m.

Finalize comments on *C. gigas* Species Alert

Discuss how to proceed with the next Species Alert report. My suggestion is to consider using the impact of nonindigenous species on targeted fisheries as the focus rather than focus on a specific species. My rationale is that this is a large task but if done carefully is of great value to ICES. Therefore, I would recommend postponing developing a *Callinectes sapidus* Species Alert Report for a year or two. Specifically, I think it would be most useful to review introductions that were done under the aegis of the Code and evaluate the outcome. Did the introduction behave as expected and predicted? Why or why not? It will also be interesting to see how many introduction have used the ICES Code or a similar country Code of Practice for introductions. (ToRf).

10:30 – 11:00 Break

11:00 am – 12:30 pm

Review 5 year report, finalize edits and discuss development of 25 year report. I expect that we will have prepared some of this for the OSPAR report. I am working on preparing an excel sheet with all the data from the 15 years. As noted in earlier correspondence, we need to decide about the validity of one observation, one species, and potential misidentifications in preparing the longer term report (ToRe).

12:30 – 1:30 pm Lunch (possibly a working lunch which would allow us to adjourn earlier

1:30 – 3:00

The Rapid Response document is unfinished and I am inclined to postpone for yet another year. I think the greatest value we can contribute is to the Appendices, which strengthens the Code of Practice. The Rapid Response can evolve from the development of risk assessments based on your comments and from the further development practiced by Canada, UK (and proposed adoption by other countries) and the U.S. There were many valid comments from last year on the Rapid Response report of two years ago, but I have not had time to integrate them and revise the document to address the issues. If someone wants to volunteer to take this on I can send the comments that I received. I will send a draft of the current Rapid Response document (ToRj).

3:00 – 4:00 p.m.

Review status of ToRs

Prepare recommendations for 2009.

We will plan to adjourn by 4 p.m.

Annex 3 National Reports

Belgium, 2008

Prepared by: F. Kerckhof MUMM/BMM

Highlights

During 2008, no new invasive species were recorded.

All introduced species that were reported during previous years are still present and seem to be well-established and thriving.

Laws and regulations

There is no new legislation to report.

Intentional introductions

There is no information available on intentional introductions, if any.

Unintentional introductions:

Rangia cuneata: A vast population of this estuarine bivalve is present in the port of Antwerpen. This species was first reported in August 2005, in the pipes of the cooling water system of an industrial plant. Since its discovery, the species has and Noordzeekanaal and in the IJ in the vicinity of Amsterdam.

Megabalanus coccopoma (Darwin, 1854): This alien barnacle which was already present in Belgian waters on artificial hard substrates off shore, such as buoys; was found in 2008 on the foundations of the newly established first windmill park off the Belgian coast.

All introduced species that were reported during previous years are still present and seem to be well-established and thriving. An overview of the current status of alien species in Belgian marine waters can be found in Kerckhof *et al*. 2007.

Species not yet seen

Fenestrulina delicia: This alien bryozoan was reported for the first time in Europe in 2008 (De Blauwe, 2008). The first record may have been in 2002 from Wemeldinge in the Eastern Scheldt (The Netherlands), then indentified as the European autochthonous species *F. malusii*. Unfortunately this material could not be traced. In 2005 and 2006 few colonies were collected on mussel shells at Goesse Sas in the Eastern Scheldt while scuba diving. In 2007 a colony was collected at Granville (Normandy, France) on an oyster shell and in May 2008 several colonies were collected at Le-Val-André (Brittany, France) on the inner side of several bivalves. As all European places are known for their aquaculture, import of shellfish is the most likely vector of introduction.

Ruditapes philippinarum: In 2007 fresh specimens of this bivalve were found in the wild in several locations in de Eastern Scheldt (The Netherlands) and during 2008 live specimens were recorded. It appears that this species is now established the Eastern Scheldt.

Both species cited above can be expected to turn up in the Spuikom in Oostende. The Spuikom is a saline pond in connection with the harbour were some aquaculture (including relaying of oysters) takes place, and R. philippinarum has already been relayed in that pond in the past.

Pathogens

No information

Meetings

The second Belgian Conference on Biological Invasions entitled "Science facing Aliens" an initiative of the Belgian Forum on Invasive Species, will take place on May 11th 2009 in Brussels.

http://ias.biodiversity.be/conference_2009

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Faasse, M.; Ligthart, M. 2008. De exotische tapijtschelp *Ruditapes philippinarum* (Adams & Reeve, 1850) vestigt zich in Nederland. Het Zeepaard 68(6): 175-179

Kerckhof, F.; Haelters, J.; Gollasch, S. 2007. Alien species in the marine and brackish ecosystem: the situation in Belgian waters. *Aquatic Invasions 2(3)*: 243-257.

Lente, I. van & R.H. de Bruyne 2008. Brakwater-strandschelp *Rangia cuneata*: nieuw voor Nederland; gevonden in het IJ bij Amsterdam! - Voelspriet 7(1): 1 (with photo)

Verween, A. 2008. Optimale biofoulingcontrole van *Mytilopsis leucophaeata* door chlorering op BASF Antwerpen NV. Sectie Mariene Biologie, Universiteit Gent: Gent, Belgium. 62 pp

Canada, 2008

Prepared by: Amy Williams, DFO

Highlights

While a number of activities and introductions are described in this report, these are primarily updates on issues reported in past years. Canada continues to import a range of organisms for aquaculture as described in this report. The pattern of these imports is much the same as in past years and no new activities were reported in 2008 that would raise particular concerns with respect to risks to aquatic resources.

From an Aquatic Invasive Species (AIS) perspective, there were several new sightings and range extensions in 2008 including significant new occurrences of green crab (*Carcinus maenus)* on the southwest coast of Newfoundland; and a new record of New Zealand mudsnail (*Potampyrgus antipodarum*) in British Columbia - this is the first Canadian record outside of the Great Lakes. On Prince Edward Island, no new species of tunicate have been found, however the existing species have expanded to Souris Harbour (vase, clubbed, violet and golden star) and Dock River, Alberton (golden star).

Several provinces have established AIS control programs and policies:

- Newfoundland began experimental control projects for violet tunicate (Botylloides violaceus) in Belloeoram, Fortune Bay, NL and green crab in Placentia Bay, NL.
- Newfoundland has also developed a management framework/tool to guide the transfers of molluscan bivalves where risks of movement of aquatic invasive species were identified.
- New Brunswick has established a provincial policy prohibiting the transfer of mussels from the Bay of Fundy to Northeast NB and PEI, due to prevalence of tunicates.

Laws and regulations

In 2004, the Canadian Council of Fisheries and Aquaculture Ministers formed an AIS task group which developed an Action Plan to address the threat of AIS in Canadian waters. This Action Plan called for the development of AIS regulatory framework to respond to the lack of legislative or regulatory authorities that directly target AIS. A draft framework was developed in 2008, and initial consultations have begun. These consultations are expected to continue into 2009, after which point it is anticipated that a finalized framework would be presented to the DFO management committee for departmental approval.

Deliberate releases and planned introductions

Table 1: Domestic Introductions and Transfers

Province	Species	Number	Reason
Quebec	Cod (*Gadus Morhua)*	3,000	Training and research
	Giant scallop (*Placopecten magellanicus*)	2,000	Production
	Atlantic oyster *(Crassostrea virginica)*	90,000	Production and development
	Snow crab *(Chionoecetes opilio)*	500	Research
	Iceland scallop *(Chlamys islandica)*	200	Research
	Skeleton Shrimp *(Caprella mutica)*	Several hundred thousand	Research
New Brunswick	Atlantic Salmon (*S. Salar*)	9.158 M	Aquaculture (all life stages)
	Atlantic Salmon (*S. Salar*)	1.168 M	Enhancement
	Atlantic Salmon (*S. Salar*)	1.4 M	Research
	Brook Trout *(Salvelinus fontinalis)*	816 K	Enhancement
	Artic Char *(Salvelinus alpinus alpinus)*	95.5 K	Aquaculture / Research
	Halibut *(Hippoglossus hippoglossus)*	60 K	Aquaculture
	Rainbow Trout (*Oncorhynchus mykiss)*	24 K	Aquaculture
	Shortnose Sturgeon (*Acipenser brevirostrum)*	60 K	Aquaculture
	American Oysters *(C. virginica)*	8 M	Aquaculture
	Mussels (*Mytilus edulis)*	<> 500 kg	Aquaculture
Newfoundland	Brook trout *(S. fontinalis)*	10,000	Component of formal fish habitat compensation agreement for a hydroelectricity project
	American lobster (*Homarus americanus)*	5,000	Experimental enhancement project, Placentia Bay
Prince Edward Island	Atlantic Salmon (*S. salar)*	1,000,000	Aquaculture (smolt production)
	Rainbow Trout (*O. mykiss)*	200	Aquaculture
	Brook Trout *(S.fontinalis)*	4,000	Population Enhancement
	Blue Mussel [1] (*M. edulis)*		Aquaculture
	Oysters[2] *(C. virginica)*		Enhancement Aquaculture
	Giant Scallop (*P. magellanicus*)	20,000	Not available

	Bay Scallops *(Argopecten irradians)*	50,000	Aquaculture
Nova Scotia	Rainbow Trout *(O. mykiss)*	Unknown	Provincial Stocking Program
	Brook Trout *(S. fontinalis)*	Unknown	Provincial Stocking Program
	Land Locked Salmon (*S. salar)*	unknown	Provincial Stocking Program
	Atlantic salmon (*S. salar)*	40000	Provincial Stocking Program
	Atlantic whitefish *(Coregonus huntsmani)*	5000	DFO stocking program
British Columbia	*Chinook (O. tshawytscha)*	457,700	Enhancement[3]
	Chum *(O. keta)*	1,008,000	enhancement
	Coho *(O. kisutch)*	421,000	enhancement
	Sockeye/kokanee *(O. nerka)*	1,040,500	enhancement
	Steelhead *(O. mykiss)*	20,080	enhancement
	Sablefish *(Anoplopoma fimbria)*	62,300	aquaculture
	Atlantic salmon *(S. salar)*	9,118,000	aquaculture
	Chinook *(O. tshawytscha)*	520,000	aquaculture
	Geoduck (*Panope abrupta)*	2,000,000	Aquaculture (Beach or sub-tidal seeding)
	Cockles (*Clinocardium nuttali)*	1,600,000	Aquaculture (Beach or sub-tidal seeding)
	Scallops (Mizohupecten yessoensis)	1,670,000	Aquaculture (Culture in lantern nets or by ear-hanging)

1) Mussel seed is used to restock mussel grow-out leases. Transfer of seed between estuaries does occur, but growers attempt to meet their needs from within the same body of water where grow-out occurs.

2) Oyster spat is transferred from Ellerslie Reserve to a number of estuaries within the province for purpose of enhancing public beds. In addition, lease holders transfer spat between estuaries. Where transfers involve movement between estuaries, I&T licence requirement applies.

3) All enhancement activities listed here are transfers between water bodies. In addition to these transfers, there are large number of juvenile salmonids released from hatcheries to the streams of origin

Table 2: Imports into Canada

Province	Species	Country of Origin	End Use
New Brunswick	Atlantic Salmon (*Salmo salar*) (9.5 million)	USA	Aquaculture (Fry/eggs)
New Brunswick	Cod (*Gadus Morhua*) (55 000)	USA	Aquaculture / Research
New Brunswick	American Oysters (*Crassostrea virginica*) (1800)	USA	Research
New Brunswick	Soft Shell Clams (*Mya arenaria*) (4000)	USA	Enhancement
Newfoundland	Tautog (*Tautoga onitis*)	USA	Research (lab based)
Newfoundland	Cunner, (*Tautogolabrus adspersus*)	USA	Research (lab based)
Newfoundland	Ghost shrimp (*Callianassa californiensis*)	USA	Research (lab based)
Prince Edward Island	Atlantic Salmon/Gaspe (*S. salar*) (30 000)	USA	Research – vaccine trials
Prince Edward Island	Koi (10,500)	USA	Research – vaccine trials
Prince Edward Island	Rainbow Trout (*Oncorhynchus mykiss*) (423,000)	USA	Population Enhancement, Research, & Broodstock, Aquaculture
Nova Scotia	Zebrafish (*Percina caprodes*) [Adults (324) and Embryos (260)]	USA	Research
Nova Scotia	Rainbow Trout (*O. mykiss*) [Eggs (2,999,000)]	USA	Aquaculture
Nova Scotia	Atlantic Salmon (*S. salar*) [Smolts (2,000,000)]	USA	Aquaculture
British Columbia	Atlantic salmon (Salmo salar)	Iceland	Aquaculture
British Columbia	Manila clams (*Venerupis philippinarum*)	Western USA incl. Hawaii	Aquaculture
British Columbia	Pacific oyster (*Crassostrea gigas*)	Western USA incl. Hawaii	Aquaculture

Unintentional Releases

An excel spreadsheet with detailed information is attached, however below are some important highlights.

In Newfoundland, no new invasive species were reported in 2008, however significant new occurrences of green crab, *Carcinus maenus* were reported for the southwest coast of Newfoundland. Over 20 days from July-Sept 2008, there were 25,463 pounds or an estimated 334,555 individual green crabs collected. As well, experimental control projects were initiated for violet tunicate (*Botylloides violaceus*) in Belloeoram, Fortune Bay, NL and green crab in Placentia Bay, NL.

On Prince Edward Island, tunicate species have expanded to Souris Harbour (*Ciona intestinalis*, *Styela clava*, *B. violaceous*, and *Botryllus schlosseri*) and Dock River, Alberton (*Botryllus schlosseri*).

In Nova Scotia, a monitoring/surveillance program has been put in place for aquatic invasive species. This program is being lead by DFO-Science with assistance from the Nova Scotia Department of Fisheries and Aquaculture and various community groups. To date the species of tunicates found in coastal waters of NS include: Golden Star (*Botryllus schlosseri*), Vase (*Ciona intestinalis*) and Violet (*Botrylloides violaceus*).

In British Columbia, a new record of New Zealand mudsnail (*Potampyrgus antipodarum*) was made in 2008, this is the first Canadian record outside of the Great Lakes.

Spatial distribution and densities of *Codium* have been importantly increased in the Magdelen Islands in the 2-3 last years.

Preliminary results on the impacts of this species on associate epibenthic communities showed that the communities' associates to *Codium* and *Zostera* are different. Results showed that a higher abundance and species richness were associated to *Codium* canopy. All the identified taxa were present on both native and introduced canopies, but some species were significantly more abundant when associated to *Codium*.

Pathogens

In 2008, Malpeque disease was detected in the Eskasoni area of the Bras d'Or Lakes in Nova Scotia. Malpeque was not detected in this location in the past. Additionally, MSX, which is typically found in the Bras d'Or Lakes was detected in MacDonalds Pond in the Mira Bay. This new location is located outside the Bras d'Or Lakes.

Meetings, conferences, symposia or workshop on Introductions and Transfers

Past Meetings (2008)

National I&T meeting in Ottawa, February 28/29, 2008

CEARA Risk Assessment Review for European Green Crab and Chinese Mitten Crab – Montreal, Canada, February 13-15 2008.

PCMFC West Coast Green Crab Meeting – Vancouver and Ucluelet, Canada, March 11-13 2008.

ASLO Summer Meeting, St. John's, NL.

Exotic and Invasive Alien Species Workshop, January 22-23, 2008, Corner Brook, NL

Finfish Aquaculture Biosecurity Workshop, September 17, 2008, Harbour Breton, NL

Aquatic Invasive Species Workshop, December St. John's, NL

CEARA risk assessment guidelines workshop, June 2008, Parkville, BC

CEARA risk assessment review for six invasive freshwater fishes in BC (yellow perch, smallmouth bass, largemouth bass, pumpkinseed, walleye and northern pike), March 2008, Vancouver, BC

CEARA risk assessment review for bloody red shrimp (Hemimysis anomaia), January 2008, Burlington, Ontario.

Upcoming Meetings (2009)

Aquatic Invasive Species Workshops in Vancouver, Halifax and Ottawa I&T National Meeting, Date TBD, Halifax, NS

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Croatia, 2008

Prepared by: Marijana Pećarević and Josip Mikuš; University of Dubrovnik, Dubrovnik, Croatia

Laws and Regulations

The Croatian Law System (Marine Fisheries Act from 1997, updated in 2005), prohibits the introduction of non-indigenous marine species into the Adriatic Sea. Farming of non-indigenous marine species is allowed by special permission from the Ministry of Environmental Protection, Physical Planning and Construction and Ministry of the Sea, Tourism, Transport and Development, but such cases have not yet been recorded.

Deliberate Introductions and Transfers

Due to restrictive Croatian legislation deliberate introductions are not recorded.

Accidental Introductions and Transfers

Two major vectors of introduction of non-indigenous species into the Adriatic Sea are: 1. main entering current from Eastern Mediterranean through Otranto Strait along Eastern Adriatic Coast, and 2. ships (both ballast water and biofouling). Mariculture production still does not play an important role in non-indigenous species introduction but planned aquaculture development along some parts of Croatian coast of Adriatic Sea may have a considerable impact on appearance of non-native species in future.

Croatian ports are used mostly for import, so ships entering Adriatic Sea carry cargo and not ballast water, the majority of non-indigenous species found along the Eastern Adriatic Coast could be of hull fouling provenience.

1. Fish

On 19th of December 2007, a 715 mm long specimen of the bluespotted cornetfish, *Fistularia commersonii* (Rüppel, 1835), was found washed up on the shore of Bar (Montenegro, Southern Adriatic 42°04'N 19°05'E), probably as a consequence of an evident injury (Joksimović *et al*., 2008). This record represents the third record of *F. commersonii* in the Adriatic Sea. In the summer of 2006, two specimens of *F. commersonii* were recorded in the waters off Tricase Porto (South-Western Adriatic, Italy) and off Sveti Andrija Island (South-Eastern Adriatic, Croatia), respectively (Dulčić *et al*., 2008). This is the only Lessepsian migrant with multiple confirmed records, separated in time and space, for the Adriatic.

2. Invertebrates

According to Batistić (unpublished data) some new species of gelatinous zooplanktonic organisms (Chaetognatha, Sagittoidea and Tunicata, Appendicularia) occurred in the Southern Adriatic Sea during 2007 and 2008.

Investigations of the benthos in the Croatian portion of the Adriatic Sea in last few years have resulted in the discovery of scleractinian species that proved to be new to the area, e. g. *Cladocora debilis* Milne Edwards & Haime, 1849 (Kružić *et al*, 2005). Also, colonial Mediterranean endemic scleractinian coral *Cladopsammia rolandi* Lacaze-Duthiers, 1897 (Cnidaria: Anthozoa) was found in spring 2002 on the cliff at the south of Lastovo Island and in summer 2005 on the two locations at the south-west of Mljet Island (South Adriatic) (Kružić, 2008). These new records are the first confirmations of *C. rolandi* in the Adriatic Sea.

Two specimens of Lessepsian bivalve *Pinctada radiata* Leach, 1814 were found in a benthic study conducted at a depth of 59 m on a silty-sand bottom in the Northern Adriatic Sea in April 2006 (Doğan and Nerlović, 2008). This is the first record of the species in the Croatian portion of Adriatic Sea.

A single male specimen of *Thysanoteuthis rhombus* Troschel, 1857 (Cephalopoda: Thysanoteuthidae) was caught using a hand squid jig after dusk on the 26th of December 2006, 1 meter offshore of Dolfin Islet (44°41'N 14°41'E) at a depth of 10m in the eastern part of the Northern Adriatic Sea (Marčić *et al.*, 2008). This is the first record of this species in the Adriatic Sea and the northernmost capture in the Mediterranean Sea.

3. Algae and Higher Plants

The first record of the epiphytic and potentially toxic dinoflagellate *Ostreopsis ovata* Fukuyo, 1981 was reported for Northern Adriatic Sea (Monti *et al.*, 2007). This species, already known from Southern Adriatic Sea, was isolated from macroalgae in two areas, the Gulf of Trieste (Italy) and close to Rovinj (Croatia).

New data on the expansion of the invasive alga *Caulerpa racemosa* (Forssk.) J.Agardh, 1873 were published (Kružić *et al.*, 2008).

Live Imports and Transfers

No information.

Live Exports to ICES Member Countries

No information.

Meetings, Conferences, Symposia, Workshops, Research Programs etc.

The First National Task Force Meeting was held in Zagreb, capital of the Republic of Croatia, from the 29th to the 30th of May 2008. The Meeting was an important milestone for the GloBallast Partnerships Project in Croatia. The Republic of Croatia is a part of the GloBallast Partnerships Project as a Lead Partnering Country (LPC) in the Mediterranean region. The Meeting covered various aspects of the issue, such as invasive species issue in the Adriatic Sea, overview of the IMO Ballast Water Management Convention, ballast water treatment technologies, inspection procedures and issuance of certificates, ship documents and reporting aspects, sampling and analyzing and baseline studies and monitoring of harbour areas. A major outcome of the meeting was the formalization of various working groups within the national Task Force and identification/nomination of chairs of various working groups.

As a part of scientific programs supported by Croatian Government (Ministry of Science) few projects regarding biological invasions have been carried out.

Ministry of Culture is responsible for the problems caused by invasive species in Croatia which is regulated by the Law on Nature Protection. One of the major projects supported by Ministry of Culture is monitoring and eliminating of algae *Caulerpa taxifolia* and *Caulerpa racemosa*.

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Denmark, 2008

Prepared by: Kathe R. Jensen, Zoological Museum, Copenhagen, Denmark

Highlights:

The National Action Plan on Invasive Species has been drafted and sent out for public hearing. It was published in February 2009.

The invasive ctenophore *Mnemiopsis leidyi* had mass occurrences in Danish waters in 2007. It was also widespread, though not as abundant in 2008.

The red seaweed *Gracillaria vermiculophylla* first appeared in Danish waters in 2003. It is now spreading and forming mass occurrences in several localities.

Marenzelleria viridis and *Crassostrea gigas* continue to spread in Danish waters.

Crepidula fornicata seems to increase in abundance in several places.

Offshore windmill farms appear to act as stepping stones for introduced species, e.g., the chironomid *Thelmatogeton japonicus* and *Caprella mutica*.

The first live specimen of *Neogobius melanostomus* was found near Bornholm in September 2008.

Regulations:

The full text of Danish Acts, Orders and Circulars are available at http://www.retsinformation.dk/. It is usually more convenient to access the correct text through the relevant sector ministries or agencies.

Legislation concerning fishery, aquaculture, transport, export and import of live marine organisms comes from several sector ministries and departments. These include the Ministry of Food, Agriculture and Fisheries (http://www.fvm.dk/) and the directorates under this ministry. The Danish Directorate of Fisheries (http://fd.fvm.dk/English.aspx?ID=16472) compiles information about commercial fisheries, fish and fisheries products, and also publishes fisheries statistics. The Danish Veterinary and Food Administration is responsible for food hygiene and monitoring of algal toxins and microbiological contamination of fisheries products (the English web-site does not contain information about fish and shellfish; information in Danish is available at http://www.foedevarestyrelsen.dk/). The Ministry of the Environment (http://www.mim.dk/) and the agencies under this are responsible for all non-commercial species and nature protection. The Agency for Spatial and Environmental Planning (http://www.blst.dk/English/) is responsible for monitoring effects of activities, including fishery and aquaculture that may harm the environment, especially inside protected areas, e.g. Natura 2000 areas. The Danish Forest and Nature Agency is responsible for management of invasive species (the English web-site does not have information on invasive species; information in Danish is available at http://www.skovognatur.dk/Natur/invasivearter/).

The National Strategy and Action Plan on Invasive Alien Species was sent out for public hearing during June-August 2008, and the responses have been incorporated. It was published in February 2009. Unfortunately the text is only available in Danish (see http://www.skovognatur.dk/NR/rdonlyres/D7DDAE26-520B-4652-A3B3-887CB7694CCC/0/Handlingsplanforinvasivearter.pdf). The plan comprises a "Black-list" of the invasive species known to have negative ecological and/or economical impacts, and a "Grey-list", or observation list, for species that should be monitored for presence, dispersal and impacts. Marine species on the black-list are *Spartina anglica, Sargassum muticum, Gracilaria vermiculophylla, Eriocheir sinensis, Crassostrea gigas, Ensis americanus, Teredo navalis, (Dreissena polymorpha* [only in freshwater in Denmark]), *Mnemiopsis leidyi, Pseudodactylogyrus anguillae* and *Anguillicola crassa*).

Denmark still has not signed the Ballast Water Convention. Denmark collaborates with HELCOM and OSPAR to prepare for the implementation of the convention.

Control of capture sites, wild caught and cultured bivalves for algal toxins and microbiological contamination (salmonella and faecal coliforms) follows EU regulations as set out in ministerial order no. 840 of 20 July 2006 as amended in order no. 885 of 11 July 2007. For transmittable diseases in bivalves (mostly oysters), whether wild caught or cultured, order no. 780 of 15 October 1997 applies.

For intentional release of animals, whether terrestrial or aquatic, the Nature Protection Act section 31, subsections 1-3 apply (consolidation act no. 1042 of 20 October 2008), basically stating that release in the wild of animals not native to the country is prohibited without a special permit from the Ministry of Environment. Release of fish for stock enhancement is regulated in accordance with the Fisheries Act sections 63-65 (consolidation act no. 978 of 26 September 2008). Mariculture requires a permit in accordance with the same act sections 66-70. For plants the Nature Protection Act section 31, subsection 4 applies, covering only "certain species of plants" that need a permit for planting in the wild.

Monitoring and treatment of certain infectious diseases in aquatic organisms are covered by order no. 1218 of 12 December 2008 in accordance with EU Directive 2006/88/EF of 24 October 2006.

Dansk Skaldyrcenter (Danish Shellfish Centre) (http://www.skaldyrcenter.dk/) is an institution for research and development in shellfish aquaculture, fishery and industry. The centre provides advice and carries out research projects in these fields and also produce popular brochures on various aspects of shellfish exploitation and its effects on the environment, e.g. on toxic algae, food safety, transport of live shellfish, etc. Unfortunately all information is available only in Danish. They have carried out a pilot-project for culture of American razor clams, but although they concluded that there was a great potential, no commercial production has been initiated.

Mussel production

In 2006 an action plan for mussel production in the Limfjord was adopted. There are 51 licenses for commercial dredging of mussels in the Limfjord, 6 for coastal areas along eastern Jutland, 4 for the Danish Wadden Sea, and two for the Isefjord and Roskilde Fjord. There are strict regulations about boats and gears as well as daily and weekly quotas. Screening of quality and safety is the responsibility of the fishers and has to be carried out at the Regional Veterinary and Food Control Authority in Viborg (Fødevareregion Nord, Viborg) (circular no. 9785 of 19 December 2005). The program includes testing for algal toxins, microbiological aspects and chemical pollution (Bråten & Platz, 2006). The Regional Veterinary and Food Control Authority in Viborg should produce annual reports on their results. The most recent report was published in 2006 and covers results from 2003 (Fødevarestyrelsen, 2006).

Mussel culture

Permits for establishing culture facilities are administered by the Fisheries Directorate in accordance with the Fisheries Act (Consolidation act no. 978 of 26 September 2008, section 67). Regulations are given in order no. 267 of 29 March 2006. The number of permits in the Limfjord increased from 25 in 2004 to 45 in 2007 (DTU Aqua, 2008). In addition to line culture artificial bottom culture-banks are used. Under-sized mussels caught in dredges are relaid in predetermined, approved areas. The same regulations for quality and food safety apply as for capture fishery.

Oyster fishery has increased from about 10 tons in the 1990ies to more than 500 tons in 2002 and later. This is probably due to increased temperatures. Recent stock assessments have indicated that fishery cannot be increased, and an amended order no. 24 of 23 January 2008 has been issued.

Intentional (imports of fish and shellfish):

The official fisheries statistics are available at http://fd.fvm.dk/Fiskeristatistik.aspx?ID=24356. Unfortunately the statistical tables do not distinguish between live and "whole fresh" (and possibly gutted) fish. Nor is a distinction made between fish for consumption and fish that might end up in the wild. For imports and exports species are grouped into categories. For example molluscs are divided into “bivalves” and “other molluscs”. However, legislation prohibits the release of non-native organisms in Danish marine and coastal waters. At the present time only spat and larvae from hatchery-produced fish and shell-fish obtain permission for release.

Hatchery-produced larvae and juvenile fish that are released in Danish coastal waters are locally produced, i.e. within Denmark, though mother-fish do not always come from the fjord or coastal area where fry is released. So far mostly flounder (*Platichthys flesus*) (since 1993) and turbot (*Psetta maximus*) (since 1991) have been used for release projects (http://www.fiskepleje.dk). A high proportion of juvenile turbot are exported to southern Europe (Steenfeldt, 2008). Also a project on restocking of Baltic cod (*Gadus morhua*) has been operating since 2005 (see http://www.aqua.dtu.dk/Erhvervsfiskeri/Fiskebestande/Restock.aspx). In addition stock enhancement projects have been carried out for eels (*Anguilla anguilla*) (since 1987), common whitefish (*Coregonus lavaretus*), salmon (*Salmo salar*) (http://www.fiskepleje.dk) and pike (*Esox lucius*) (Jacobsen *et al*. 2008). Juvenile eels ("glass eels") are wild-caught in southern Europe and kept in indoor culture facilities for several months for disease and parasite screening before they are released in coastal waters (http://www.fiskepleje.dk). The international trade with juvenile eels will be regulated by CITES in the future. Culture facilities are monitored for swimbladder worms and IPN (infectious pancreatic necrosis) virus by veterinary authorities, and eels from facilities where these have been detected cannot be released. Experimental production of juvenile sea bass (*Dicentratus labrax*) and gilthead seabream (*Sparus aurata*) have been carried out in Denmark, but commercial production was abandoned (Steenfeldt, 2008). The funding for fry production, release and research in relation to the stock protection project is made available from license fees from sport and recreational fishers (http://www.fiskepleje.dk).

Fish and other marine organisms intended for aquariums are no doubt imported, but there is no statistics covering this. Legislation is only concerned with endangered species (CITES) and with animal health and welfare during transport and in shops.

Denmark exports large quantities of live blue mussel (Christensen *et al*., 2008). At the present time these are all intended for human consumption. However, risk assessment has been performed in preparation for export of seed mussels to the Netherlands (Wijsman & De Mesel, 2008).

Unintentional introductions:

Introduced macroalgae have been reviewed by Thomsen *et al*. (2007a). Benthic invertebrates were reviewed by Knudsen (2001) and by Jensen & Knudsen (2005). Furthermore, introduced species, including microalgae but excluding zooplankton, associated with mussels are listed in Jensen (2008), and information on bloomforming or toxic species are listed in reports on mussel screening (Fødevarestyrelsen, 2006). There is little consensus about which species of microalgae should be considered non-indigenous, and the present list has not been verified by experts. For zooplankton and fish there are no recent reviews and observations are scattered in monitoring reports, student theses and faunistic articles, mostly in Danish. New definitions and criteria for identifying introduced species (Wolff, 2005) has transferred a number of species to be considered as cryptogenic rather than native. The species thus considered cryptogenic have been included in this report, as also seen in official lists from Germany (Gollasch & Nehring, 2006) and the Netherlands (Wolff, 2005). Taxonomy has been verified using World Register of Marine Species (WORMS at http://www.marinespecies.org/) and for macroalgae also in Algaebase (http://www.algaebase.org/). The few species of freshwater fishes that have been found in brackish water have been checked in Fishbase (http://www.fishbase.org/).

Phytoplankton species

Odontella sinensis (Greville) Grunow, 1884. First record is from 1903 in Skagerrak. It is now widespread in Danish waters.

Alexandrium tamarense (Lebour) Balech, 1995. Blooms have been recorded in 1968, 1981 and 1997 (Fødevarestyrelsen, 2006). The species is cryptogenic. According to the IGLOO-project (IGLOO, 2008) two other species of *Alexandrium, A. leei* Balech, 1994 and *A. margalefi* Balech, 1994, have been recorded a few times in the Limfjord in recent years.

Dinophysis sacculus Stein, 1883 from the Mediterranean has recently been found in the Limfjord and in the Isefjord (IGLOO, 2008).

Karenia mikimotoi (Miyake & Kominami ex Oda, 1935) G. Hansen & Moestrup, 2000. Occurs in most Danish waters except the Baltic proper. Has caused death of fish and benthic animals in several years since 1968 (http://www.dmu.dk/).

Peridinium quinquecorne Abé, 1927, a tropical species which now has been recorded in Kattegat (IGLOO, 2008).

Prorocentrum triestinum Schiller, 1918. Maybe a natural range extension. It was first observed in the North Sea in 1976.

Prorocentrum minimum (Pavillard, 1916) Schiller, 1931. Introduced status unknown. It has been observed in the Isefjord (NOVA 2003). It occurs in most Danish waters, but is more abundant in fjords. Blooms have been recorded in 1983 (Kolding Fjord) and 1999 (the Limfjord) (http://www.dmu.dk/).

Heterosigma akashiwo (Y. Hada, 1967) Y. Hada ex Y. Hara & M. Chihara, 1987 (previously known as *Heterosigma carterae* (Hurlburt) Taylor, 1992. Has been observed in Danish waters, but apparently not established (http://www.nobanis.org/speciesinfo.asp?taxa?ID=2515).

Verrucophora farcimen Eikrem, Edvardsen & Throndsen, 2007. Previously recorded as *Chattonella* aff. *verruculosa*. The taxonomic status of this species has been unclear until it was described as a new species of Dictyochophyceae (Edvardsen *et al*. 2007). Due to the recent description and previous problematic status, it is unknown whether the species is introduced. The first mass occurrences were recorded in Danish waters in 1998 and 2001. Later blooms have been recorded in 2006 and 2007 (IGLOO, 2008). Data for 2008 are not yet available.

Macroalgae

Rhodophyta

Bonnemaisonia hamifera Hariot, 1891. First recorded in Denmark around 1901. Now widespread. Only the *Traillella*-stage (tetrasporophyte) occurs in Danish waters.

Dasya baillouviana (Gmelin) Montagne, 1841. First recorded 1961 in northern Belt Sea and western Baltic. Now known to the harbour of Copenhagen.

Gracilaria vermiculophylla (Ohmi) Papenfuss, 1967. First recorded in 2003 in Horsens Fjord. In 2005 also found in nearby Vejle Fjord and in the Limfjord (Thomsen *et al.*, 2007b). It is rapidly spreading to the rest of Danish waters (http://cis.danbif.dk/cooperation/fol790500/gracilaria-vermiculophylla-brunlig-gracilaria).

Heterosiphonia japonica Yendo, 1920. First recorded in 2004 in northern Kattegat (Nielsen, 2005) and in 2005 in the Limfjord (Miljøcenter Aalborg, 2007). Now found in the Limfjord and northern Kattegat.

Mastocarpus stellatus (Stackhouse) Guiry in Guiry *et al*., 1984. The introduced status of this species has been debated. Køie *et al*. (2000) mention that it has probably been introduced with ships and Thomsen *et al*. (2007a) exclude it because it has been in Danish waters for more than 100 years. The first record was from Thisted in 1869. Next it was found near Aarhus in 1911-12, in both cases on artificial substrates. More recently it has been found at Strandby and Frederikshavn on the northwestern shores of Kattegat and in Hirtshals on the Skagerrak coast, again always on artificial substrates. It was found in 2008 at the ferry-harbour of Læsø in northern Kattegat (Ruth Nielsen, pers. comm.).

Neosiphonia harveyi (Bailey) Kim, Choi, Guiry & Saunders, 2001). First recorded 1986 in the Limfjord (as *Polysiphonia fibrillosa*). Now found in the Limfjord and northern Kattegat.

<u>Phaeophyta</u>

Colpomenia peregrina Sauvageau, 1927. First recorded 1940 (drifting) and 1943 (attached) in the Limfjord (R. Nielsen, pers. comm.). Now found in the Limfjord and northern Kattegat (Thomsen *et al*., 2007a).

Dictyota dichotoma (Hudson) J.V. Lamouroux, 1809. First recorded 1939 in the Limfjord. Today it still occurs only in this area (Nielsen, 2005). This may be a natural range extension.

Fucus evanescens C. Agardh, 1820. First recorded 1948. Its dispersal in the Sound (Øresund) has been described by Wikström *et al*. (2002). It is now widespread in Danish waters (Thomsen *et al*., 2007).

Sargassum muticum (Yendo) Fensholt, 1955. First recorded in 1984 in the Limfjord. Now very abundant in the Limfjord (Stæhr *et al*., 2000) and northern Kattegat; drift algae have been found further south in Kattegat and the Sound (Øresund). It also occurs in the Wadden Sea.

<u>Chlorophyta</u>

Codium fragile ssp. *fragile* (Suringar) Hariot. This species has caused considerable confusion about subspecific status. In Denmark it was first recorded in 1919 in the Limfjord as *C. tomentosum* (Huds.) Stackh. and at Hirsholm, northern Kattegat in 1920 as *C. mucronatum* J. Agardh. The former was later identified by Silva (1957) as *C. fragile* ssp. *tomentosoides* (van Goor) Silva, 1955 and the latter as *Codium fragile* ssp. *scandinavicum* Silva, 1957. The type locality of the latter is Hirsholm, northeastern Kattegat, and it was described on herbarium material (Trowbridge, 1998). Recent molecular studies have shown that ssp. *scandinavicum* belongs to ssp. *tomentosoides* and the correct name is *Codium fragile* ssp. *fragile* (Suringar) Hariot (Provan *et al*., 2008). *Codium fragile* is established in Danish waters and is locally common.

Flowering plants

Spartina anglica Hubbard. According to WORMS the correct name should be *Spartina townsendii* var. *anglica* C.E. Hubbard. This is a fertile species resulting from the chromosome dubling of an infertile hybrid between the North American *Spartina alterniflora*, which may have been introduced to Europe with ballast water, and *S. maritima*, which may be native to western Europe or may have dispersed naturally or been introduced from Africa (Nehring & Adsersen, 2006). It is not quite clear whether the plants that were originally introduced for planting in the Danish Wadden Sea in the 1930s were the infertile hybrid, referred to as *Spartina x townsendii* or the fertile *S.*

anglica, but at the present time *S. anglica* is found in several places in Denmark (Randløv, 2007).

Invertebrates

Cnidaria

Bougainvillea rugosa Clarke, 1882

A few records off Frederikshavn in northeastern Kattegat from the 1960ies. The species is not established (Jensen & Knudsen, 2005).

Cordylophora caspia (Pallas, 1771)

First recorded in Ringkøbing Fjord, a coastal lagoon on the North Sea coast now regulated through sluice gates, in 1895 (Jensen & Knudsen, 2005). It has been found in several other brackish water localities. It is probably established in brackish water areas though no recent records (after 1960's) exist, probably because nobody has looked for it.

Gonionemus vertens Agassiz, 1862

Only a single record from northeastern Kattegat in 1960 (Jensen & Knudsen, 2005). The species is not established.

Ctenophora

Mnemiopsis leidyi A. Agassiz, 1865

This highly invasive ctenophore made its first appearance in Danish waters in 2005, although it was not correctly identified. In 2006 it was also found, though not identified, in a few places. In 2007, however, it spread rapidly throughout Danish waters (Tendal *et al*., 2007). Densities reached more than 800 m^{-3} in the Limfjord (Riisgård *et al*., 2007) whereas they were rather low in the Danish part of the Baltic Sea (Huwer *et al*., 2008). In 2008 *M. leidyi* appeared later in the year and in lower densities (Tendal *et al*., 2008).

Platyhelminthes

Pseudodactylogyrus anguillae (Yin & Sproston, 1948)

First recorded in Danish eels in 1985, but its abundance indicates that it had been present earlier (Jensen & Knudsen, 2005). It is established and common in Denmark.

Pseudodactylogyrus bini (Kikuchi, 1929)

Only found in eels from Esrom Lake, a freshwater lake. They have probably been introduced when an eel farm closed down and released its stock into the lake (Jensen & Knudsen, 2005).

Nematoda

Anguillicola crassa Kuwahara, Niimi & Itagaki, 1974

First recorded in Denmark in 1985, but had probably established some years earlier. It is widespread and abundant in eels in Danish waters (Jensen & Knudsen, 2005).

Annelida

Aphelochaeta marioni (Saint-Joseph, 1894) (fam. Cirratulidae). Synonym: *Tharyx marioni*

This polychaete species is considered a cryptogenic alien species in Germany (Gollasch & Nehring, 2006) and the Netherlands (Wolff, 2005). It occurs in the Limfjord (Hedeselskabet, 2003), but nothing is known about its first appearance. There is a chance that this and the following species have been mixed up in Danish studies (Jensen, 1992), as the systematics of this family seems rather confused.

Caulleriella killariensis (Southern, 1914) (fam. Cirratulidae). Synonym: *Tharyx killariensis*

This species is also considered non-native in Germany (Gollasch & Nehring, 2006), but not in other European countries (Fauchal, 2007). An unidentified species of *Caulleriella* has been recorded from the Limfjord (Hedeselskabet, 2003). It occurs also in the Danish Wadden Sea, although it was unknown prior to the 1980ies (Jensen, 1992).

Ficopomatus enigmaticus (Fauvel, 1923)

This polychaete occurs only in the southern harbour of Copenhagen (Jensen & Knudsen, 2005). It was first recorded in 1953, and was still present in 1997 and 1998. No sampling has been done since then.

Marenzelleria viridis (Verrill, 1873). Synonym: *Marenzelleria* cf. *wireni* (auctt., see Sikorski & Bick, 2004)

This polychaete was first found in Ringkøbing Fjord in 1990 and presently forms dense populations in a few localities (Jensen & Knudsen, 2005). More recently it has been identified from the southern coast of Denmark near the offshore windmill farm at Nysted (DONG, 2006), and unconfirmed observations from the Isefjord also exist (Olsen *et al*., 2008). Other species of the genus have not been definitely identified. *M. viridis* appears to be established and spreading.

Alitta succinea (Frey & Leuckart, 1847), previously known as *Neanthes succinea* or *Nereis succinea*.

In Danish waters this species is considered a cryptogenic species. It was first recorded in 1940 in Kattegat (Jensen & Knudsen, 2005). It is now one of the most abundant species in several localities, e.g. the Isefjord and the Limfjord (Rasmussen, 1973; NOVA, 2003, Hedeselskabet, 2003).

Alitta virens (Sars, 1835), previously known as *Neanthes virens* or *Nereis virens*.

This is not considered an alien species in Danish waters, but has been considered alien in the Netherlands, where it was first found in 1915 (Wolff, 2005). However, it was described from Norway in 1835 and could fairly easily have dispersed by its own means. The population in the Isefjord has been considered a distinct species *N. southerni* Abdel-Moez & Humphries, 1955, but this is presently not recognized (Rasmussen, 1973; Fauchald, 2007). In the Isefjord the species only became common in the late 1940s (Rasmussen, 1973).

Proceraea cornuta (A. Agassiz, 1862)

This is considered a possibly alien species in the Netherlands (Wolff, 2005). It has been found a few times in the Limfjord (Hedeselskabet, 2003) and the Isefjord (Rasmussen, 1973). Due to its small size it may have been overlooked or misidentified. It probably should be considered cryptogenic.

Syllidia armata Quatrefages, 1866

This species is considered alien, but not established in the Netherlands (Wolff, 2005). It seems to be fairly common in the Limfjord (Hedeselskabet, 2003) and in the Isefjord (Rasmussen, 1973), and has not been considered an introduced species in Danish waters.

Mollusca

Potamopyrgus antipodarum (Gray, 1853), previously known as *Potamopyrgus jenkinsi* or *Hydrobia jenkinsi*.

First record in Denmark is either 1897 or 1914 (see Jensen & Knudsen, 2005 for discussion). A few surveys of its occurrence have been carried out (Bondesen & Kaiser, 1949; Lassen, 1978), but it also appears to be rather common in many low salinity areas (Jacobsen & Forbes, 1997).

Crepidula fornicata (Linnaeus, 1758)

This species was first recorded from the Limfjord in 1934, the same year it was discovered in the Danish Wadden Sea. Its present distribution includes the Wadden Sea, North Sea, Skagerrak, Northern Kattegat and the Limfjord (Jensen & Knudsen, 2005). In soft bottom stations it occurs in low densities (about 30 ind/m²), but occasionally up to 160 ind/m², e.g. in Løgstør Bredning in 1998 (Hedeselskabet, 2003). There is some indication that densities in certain areas in the Limfjord are increasing, and quantitative sampling is planned for 2009.

Gibbula cineraria (Linnaeus, 1758)

This species is considered introduced and recently established in the Netherlands (Wolff, 2005). It is not considered exotic in Danish waters and occurs from the North Sea to the northern Belt Sea and the Sound (Køie et al., 2000) and in the Limfjord (Hedeselskabet, 2003). It is not known when it was first recorded.

Ocenebra erinacea (Linnaeus, 1758)

This muricid gastropod has been introduced with oysters to the Limfjord a couple of times, but has not been established (Jensen & Knudsen, 2005). It was found again in 2006 with egg capsules, and thus it seems to be established, though this time it has probably extended its natural distribution due to higher temperatures and presence of food (Jensen & Hoffmann, 2007). Possibly it should be considered cryptogenic.

Crassostrea gigas (Thunberg, 1793)

This species was first recorded in the Danish Wadden Sea in 1999 (Diederich et al., 2005). However, this was interpreted as settling of larvae from nearby culture areas at the German island Sylt. In the following years it became increasingly abundant and since 2004 or 2005 it has been reproducing in the Danish Wadden Sea (Kristensen & Pihl, 2008). A separate population occurs in the Limfjord (Christensen & Elmedal, 2007, Davids et al., 2007), and recently also a very small population has been identified in the Isefjord (Wang et al., 2007). Both these localities have been used for culture of imported Crassostrea gigas in the 1980s, and apparently some escapees have been able to breed and form local populations. Recently a few small specimens have been found at two localities between the Wadden Sea and the Limfjord (Mortensen et al., 2007), but whether the larvae have come from one or the other populations is unknown. C. gigas may also occur in Horsens Fjord, where culture also took place in the 1980ies, (http://www.tvsyd.dk/stillehavs%C3%B8sters-i-%C3%B8stjyske-fjorde); shells sometimes wash up on the beach in Horsens Fjord (http://obsnatur.dk/index.php?content_id=7131). C. gigas impacts Mytilus edulis by settling on the mussels. In some parts of the Wadden Sea mussel beds seem to be replaced by oyster reefs (Kristensen & Pihl 2008). C. gigas occurs in shallower water than the native oyster, Ostrea edule (Christensen & Elmedal 2007), so the two species do not compete for space. The biomass of C. gigas in the Wadden Sea was estimated to be 3300 tons in 2006 and had increased to about 6300 tons in 2007 (Kristensen & Pihl, 2008). C. gigas is established and appears to be spreading as well as increasing in density in Danish waters.

Crassostrea virginica (Gmelin, 1791)

This species was introduced for culture in the 1880s, but it was never successful (Jensen & Knudsen, 2005). It does not occur in Danish waters at the present time.

Dreissena polymorpha

This species occurs only in freshwater habitats in Denmark (Jensen & Knudsen, 2005)

Ensis americanus (Gould in Binney, 1870). Synonym: Ensis directus auctt. (Non Conrad, 1843)

This species was first recorded from the Danish Wadden Sea in 1981. The first record from the Limfjord was from 1984 (Knudsen, 1989). It has only been found as empty shells at the mouth of the Isefjord (Rasmussen, 1996; Knudsen, 1997), but larvae have been identified in the plankton (Larsen et al., 2007). This species is very difficult to collect alive because it retracts deeply into the sediment when disturbed. However, the amounts of shells that are washed up on the Danish shores indicate that the species is very abundant both in the North Sea, Kattegat and the Limfjord (Jensen & Knudsen, 2005).

Mya arenaria Linnaeus, 1758

This species was apparently introduced to Europe by Vikings (Petersen et al. 1992) and is now considered completely naturalized. However, it's spread in the Limfjord in the years after 1978 bears resemblance to that of an invasive species. Prior to 1952 it was rare in most places except the brackish Lovns Bredning, but after 1978 (sampling was interrupted between 1952 and 1978) it was common in many places, and in the following years it spread to most of the Limfjord. During the same period (1910-1952), the congeneric, native Mya truncata decreased and has been very rare after 1978 (Christiansen et al., 2006). In Ringkøbing Fjord an "invasion" was also observed following a change in the regulation of salinity (Laursen et al., 2004).

Petricola pholadiformis Lamarck, 1818. In some studies it is listed as Petricolaria pholadiformis, but WORMS gives Petricola as the accepted genus name.

This species occurs in the North Sea, Skagerrak, the Limfjord and in Kattegat where substrate and salinity are suitable (Hedeselskabet, 2003; Jensen & Knudsen, 2005). It requires a hard substrate such as calcareous cliffs or hardened marine peat or clay. This is only found in a few places in Danish waters. It was first recorded in Denmark in 1905 and in the Limfjord in 1934. In 2003 this species constituted 88% of the biomass in Lovn's Broad and 50% of the biomass in Skive Fjord, both in the Limfjord (Hedeselskabet, 2003). It should be mentioned that the native piddock, Barnea candida, has not been recorded in recent studies, although it was recorded as common in previous times (Collin, 1884).

Teredo navalis Linnaeus, 1758

The origin of this species is uncertain, and also whether it has arrived through natural dispersal on driftwood or by human interference (in ships' timber) is unknown. Until recently it was not considered alien in Danish waters, but after Baltic scientists noticed it spreading eastwards and also reproducing east of the Darsser Ort - Gedser threshold (Sordyl et al., 1998), it has been included in lists of alien species (Jensen & Knudsen, 2005). This would also result from applying the criteria of Wolff (2005). Although settling of competent larvae has occurred intermittently following inflow of saltwater, the species has not been capable of reproducing in water below a salinity of 10-12 ppt. However, following a spatfall in 1993 the Baltic population is now apparently able to reproduce (Sordyl et al., 1998). T. navalis is the only wood-boring species that can tolerate salinities below 30 ppt. The other species of teredinids, Psiloteredo megotara (Hanley in Forbes & Hanley, 1848) and Nototeredo norvagica (Spengler, 1792) occurring in Danish waters are only found in the North Sea and Skagerrak. Viking sagas from Iceland mention boring organisms in their ships, but it is not possible to determine whether these were shipworms or the boring isopod Limnoria lignorum (Rathke, 1799). Wood that has been preserved in the Zoological Museum in Copenhagen from a Dutch dike that was broken around 1730 contains bore-holes that have been positively identified as those of T. navalis, but this is the earliest certain identification.

Arthropoda

Penilia avirostris (Dana, 1852)

This cladoceran species may have arrived in Danish waters through natural range expansion due to increased water temperature. It was first observed in the North Sea in 1990 (Johns et al., 2005), and the first observations in Kattegat are from 2001 (Ærtebjerg et al., 2003). In 2002 the density in Kattegat was very high (4000 m^{-3}). It now also occurs in the Limfjord where it was first found in 2002 (Bio/consult 2004).

Acartia tonsa Dana, 1849

In 1921 A. tonsa was found in Ringkøbing Fjord, and by examining plankton samples from previous years it was shown that this species did not occur prior to 1919. It is now established and common in Danish waters.

Mytilicola intestinalis Steuer, 1902

This species is parasitic in blue mussels. In Danish waters it occurs only in the Limfjord (Theisen, 1964, 1966). Apparently only mussels close to or on the bottom are infected (Theisen, 1987).

Balanus improvisus Darwin, 1854

This species was first recorded from the harbour of Copenhagen in 1880 (Jensen & Knudsen, 2005). It is common in all Danish waters, especially in lower salinity.

Elminius modestus Darwin, 1854

The first record of this species is from 1978, when it was found in the Wadden Sea on Mytilus edulis and stones (Theisen, 1980). The population has been wiped out during cold winters, but seems to be permanently established at the present time (Jensen & Knudsen, 2005). In the summer of 2007 it was found at the eastern entrance to the Limfjord for the first time (B.F. Theisen, pers. comm.).

Caprella mutica Schurin, 1935

A few specimens identified as this species were recorded in 2005 during the monitoring program for the offshore windmill farm at Horns Rev in the North Sea (DONG Energy, 2006). So far this is the only record from Danish waters.

Platorchestia platensis (Krøyer, 1845). Synonym: Orchestia platensis

This species has been overlooked as an alien species by previous authors (Knudsen, 2001; Jensen & Knudsen, 2005), probably because it is "terrestrial" rather than marine. It was originally described from La Plata, Argentina (Wolff, 2005) and may have been introduced to the Sound (Øresund), Denmark directly from there. It is established and locally common in Danish waters (Rasmussen, 1973).

Callinectes sapidus Rathbun, 1896

The blue swimming crab from the east coast of the USA has been found only two times in Danish waters (Tendal & Flintegaard, 2007). It is not established.

Eriocheir sinensis Milne-Edwards, 1854

The Chinese mitten crab is regularly found in most Danish waters, but very few egg-bearing females have been seen, and most had partly decomposed eggs, so it is unlikely that it is reproducing in Danish waters (Rasmussen, 1987; Tendal, 2003, 2008).

Rhithropanopeus harrisii (Gould, 1841)

This tiny crab that has been established as an alien in most countries surrounding Denmark, was first recorded in 1953 in the harbour of Copenhagen (Jensen & Knudsen, 2005). The second specimen was found on a beach south of Copenhagen in the summer of 2008 (J. Olesen, pers. comm.).

Homarus americanus H. Milne Edwards, 1837

This has only been captured alive once in December 2006 in the northern Sound (Øresund) (http://politiken.dk/indland/article230229.ece). It had most likely escaped or been released from a restaurant or fish-shop, or it could have migrated from Norway where several specimens have been caught (van der Meeren et al., 2006).

Limulus polyphemus (Linnaeus, 1758)

The American horseshoe crab has been found on several occasions in Danish waters, but only as single specimens, probably released from passing vessels or from aquaria (Jensen & Knudsen, 2005).

Telmatogeton japonicus

This giant Japanese chironomid was first found in 2003 in connection with the monitoring of the offshore wind farm at Horns Rev in the North Sea (DONG Energy, 2006).

Bryozoa

Bowerbankia imbricata (Adams, 1798) and Bowerbankia gracilis (Leidy, 1855)

Wolff (2005) discusses the status of these two species of the Bryozoan genus Bowerbankia. They are at best cryptogenic, but possibly not alien at all. Both have been recorded a few times from the Isefjord (Rasmussen, 1973), but it is uncertain whether they are established.

Ascidiacea

Molgula manhattensis (De Kay)

There is some discussion about the identity of this species. Some authors consider it a synonym of Molgula tubifera (Ørsted) (Rasmussen, 1973), whereas others consider them different (Hayward & Ryland, 1995). This species has been recorded from several localities and appears to be established in Danish waters.

Styela clava Herdman, 1882

This species was first recorded from the Limfjord in 1978, but may have arrived there a few years earlier (Jensen & Knudsen, 2005). It occurs throughout the Limfjord and also in the Wadden Sea. It is a fouling species, forming dense growths on mussels, seaweeds and stationary fishing gear, including mussel culture facilities (Jensen & Knudsen, 2005).

Fishes

Aristichthys nobilis (Richardson, 1845) (Bighead carp). In FishBase this species is known as *Hypophthalmichthys nobilis*

This species has been introduced to Denmark and has been caught in the wild a few times; the first record is from 1987 (http://www.nobanis.org/speciesInfo.asp?taxaID=687). It occurs in brackish water, but is not established in Denmark.

Neogobius melanostomus Pallas, 1914 (Round goby)

The first specimen of this highly invasive species was caught in Danish waters near Bornholm in the Baltic in September 2008 (http://zoologi.snm.ku.dk/ZM-nyhedsliste/121108/).

Oncorhynchus mykiss (Walbaum, 1792). Previously known as *Salmo gairdneri*. (Rainbow trout).

The rainbow trout has been introduced for aquaculture in Denmark. It is the most widespread aquaculture species. It often escapes to the wild and is established and breeding in Danish waters (Jonsson, 2006).

Oncorhynchus gorbuscha (Walbaum, 1792) (Pink salmon)

A single record from saltwater in Vejle Fjord in 1976, and one record from freshwater (Ribe Vesterå) in 2007. The species is not established in Danish waters (http://www.fiskeatlas.dk/download/Pukkellaks.pdf).

Salvelinus fontinalis (Mitchill, 1814) (Brook trout or brook char)

This is a freshwater species, intentionally introduced to Denmark for aquaculture. It is now an established alien species, but only found in a few streams. It may migrate to saltwater and has been caught for instance in Ringkøbing Fjord (on the North Sea coast of Denmark).

Table 1. Established alien species in Danish waters (Jensen & Knudsen, 2005; Jensen, 2008).

Taxon	First record	Present status
Diatoms		
Odontella sinensis	1903	Widespread
Dinoflagellates		
Alexandrium tamarense	?	Regularly occurring
Karenia mikimotoi	?	Regularly occurring
Prorocentrum minutum	?	Regularly occurring
Porocentrum triestinum	?	
Rhodophyta		
Bonnemaisonia hamifera	1901. Limfjorden	Sublittoral, widespread
Dasya baillouviana	(1961) 1988	W Limfjord, Samsø area, Little Belt, Great Belt, the Sound
Gracilaria vermiculophylla	2003, Horsens Fjord	Spreading
"Heterosiphonia japonica"	2004, N Kattegat; 2005, W Limfjord	Limfjord, northern Kattegat
Mastocarpus stellatus	1869, Thisted (Limfjord)	Limfjord, northern Kattegat
Neosiphonia harveyi	1986, W Limfjord	Limfjord, northern Kattegat
Phaeophyta		
Colpomenia peregrina	(1940) 1943	Limfjord, Nordlige Kattegat
Dictyota dichotoma	1939	W Limfjord
Fucus evanescens	1948	
Sargassum muticum	1984 (Limfjord)	Limfjord, Kattegat, northern Belt Sea
Chlorophyta		
Codium fragile ssp. *fragile*	1919, Limfjord	
Tracheophyta		
Spartina anglica	1930ies? Wadden Sea	Established Kattegat, northern Belt Sea
Cnidaria		
Cordylophora caspia	1895, Ringkøbing Fjord	Brackish water (and freshwater?)
Platyhelminthes		
Pseudodactylogyra anguillae	Before 1985	widespread
Pseudodactylogyra bini	Before 1985	Freshwater only (Esrum Lake)
Nematoda		
Anguillicola crassa	Before 1985	widespread
Polychaeta		
Ficopomatus enigmaticus	(1939, dead, on ship); 1953	Copenhagen Harbour
Marenzelleria viridis	1990 Ringkøbing Fjord	Ringkøbing Fjord, Nissum Fjord, Isefjord, western Baltic
Gastropoda		
Crepidula fornicata	1934, Limfjord, Wadden Sea	North Sea, Wadden Sea, Limfjord, northern Kattegat
Pomatopyrgus antipodarum	(1897?) 1914 Randers Fjord	Brackish water (and freshwater)
Bivalvia		
Crassostrea gigas	(1972 culture, Limfjord) 1999 Wadden Sea	Wadden Sea, Limfjord, Isefjord; spreading

(Dreissena polymorpha)	(1843)	Freshwater only
Ensis americanus	1981	North Sea, Wadden Sea, Limfjord, Kattegat, northern Belt Sea
Mya arenaria	ca. 1290	widespread
Petricola pholadiformis	1905	North Sea, Limfjord, Kattegat
Teredo navalis	Before 1730	widepread
Cirripedia		
Balanus improvisus	1880, Copenhagen harbour	widespread
Elminius modestus		Wadden Sea; spreading
Copepoda		
Acartia tonsa	1921, Ringkøbing Fjord	Established
Mytilicola intestinalis	1964	Limfjord
Amphipoda		
Platorchestia platensis	1860? Øresund	Established
Ascidiacea		
Styela clava	1978, Limfjord	Limfjord
Pisces		
Oncorhynchus mykiss	?	Established

Table 2. Alien species that are not established, cryptogenic, or established but unknown whether the species is alien or not.

Taxon	Status	Observations
Dinoflagellates		
Alexandrium leei	?	Few records, Limfjord
Alexandrium margalefi	?	Few records, Limfjord
Dinophysis sacculus	?	Few records, Limfjord and Isefjord
Peridinium quinquecorne	?	Limfjord and Kattegat
Cnidaria		
Bougainvillea rugosa	Not established	Few records 1960ies
Gonionemus vertens	Not established	?Single record
Polychaeta		
Alitta viridis	widespread	?
Alitta succinea	cryptogenic, locally common	1940
Aphelochaete mariona	Cryptogenic?	?
Caulleriella killariensis	Cryptogenic?	?
Procereae cornuta	Cryptogenic?	?
Syllidia armata	Cryptogenic?	?
Gastropoda		
Gibbula cinerea	cryptogenic?	?
Ocenebra erinacea	cryptogenic?	(1873, Hirtshals) 2006 Limfjord
Bivalvia		
Crassostrea virginica	No recent records	1880, Lillebælt
Psiloteredo megotara	cryptogenic?	North Sea
Amphipoda		
Caprella mutica	established?	2005, Horns Rev
Decapoda		
Callinectes sapidus	not established	First record 1951, Øresund
Eriocheir sinensis	common, but not reproducing	First record 1927, Skagerrak
Rhithropanopeus harrisii	not established	1953, Copenhagen; 2008 south of Copenhagen
Insecta		
Telmatogeton japonicus	established?	2003, Horns Rev
Xiphosura		
Limulus polyphemus	not established	First record 1968, Læsø
Bryozoa		
Bowerbankia gracilis	cryptogenic?	?
Bowerbankia imbricata	cryptogenic	?
Ascidiacea		
Molgula manhattensis	cryptogenic?	?
Pisces		
Aristichthys nobilis	not established	Few records, brackish water
Neogobius melanostomus	not established	one record 2008
Oncorhynchus gorbuscha	not established	one record, 1976
Salvelinus fontinalis	not established	Few records

Species not yet seen:

Several species have been regularly recorded from neighbouring countries. The following list may not be exhaustive.

Table 3. Species not yet recorded from Danish waters.

Species	Current distribution	Remarks
Polychaeta		
Marenzelleria neglecta	Baltic	All Danish records have been identified as *M. viridis*
Mollusca		
Rapana venosa	S North Sea	No records in Danish waters
Mytilopsis leucophaeta	Baltic	No records in Danish waters
Ruditapes philippinarum	Norwegian waters	
Mercenaria mercenaria	Southern UK	Larvae have been identified by K.W. Ockelmann, Helsingør
Arthropoda		
Cercopagis pengoi	Baltic	No records in Danish waters
Balanus/ Megabalanus spp.	Netherlands	Windmill farms may be stepping stones
Gammarus tigrinus	Baltic	No records in Danish waters
Hemimysis anomala	Baltic	No records in Danish waters

Pathogens and parasites:

Metazoan parasites have been listed above.

The Fish pathology laboratory at DTU Aqua is the National reference-lab for shellfish diseases. They screen oysters from the Limfjord twice a year for *Bonamia ostreae* and *Marteilia refringens*. These parasites have not been found in Danish oysters (*Ostrea edule*), and in 2004 the Limfjord was declared disease-free zone. Neither Microcytosis nor Iridovirosis have been recorded in Denmark. Unfortunately only the native oyster, *Ostrea edulis*, has been screened, at least in the most recent report covering 2006 (available at http://gl.foedevarestyrelsen.dk/FDir/Publications/2008091/Rapport.pdf).

Broodstock fish in aquaculture facilities often show infections with bacteria and/or virus. In Denmark cod broodstock has been infected with *Vibrio anguillarum, Aeromonas salmonicida* and species of *Mycobacterium* and *Francisella* (Dalsgaard *et al*., 2008). Broodstock of Baltic cod are nearly always infected by protozoans and/or metazoan parasites. Buchman (2008) found 12 different species, and between 12 and 100% of the fish investigated were infected. Most of these parasites are not contagious in culture systems, but three species may be problematic: *Spironucleus torosa, Loma branchialis* and *Gyrodactylus* sp., which may infect other species. Also, a parasite of unknown taxonomic affinity, *Ichthyophonus* sp. may be problematic, but no data is available (Buchmann, 2008).

Renibacterium salmoninarum which causes bacterial kidney disease occurs in Danish aquaculture farms. Natural outbreaks occur only in salmonid fish. It was first detected in a Danish rainbow trout farm in 1997 and has proved difficult to eradicate.

IPN (infectious pancreatic necrosis) virus was first described in North American freshwater trout in the 1950ies and later in European cultured rainbow trout in the

1970ies (Ruane *et al.*, 2007). It occurs in aquaculture farms in Denmark, but only eggs and fingerlings from IPN-free farms can be exported or transferred to IPN-free zones

Denmark has been declared EU-zone free of IHN (infectious haematopoietic necrosis). This pathogen has never been detected in Denmark (http://www.fiskepleje.dk).

VHS (viral haemorrhagic septicaemia) is believed to be native in Europe and introduced to North America. Only a small part of Denmark is outside the EU-approved VHS-free zone, and fish from this zone cannot be exported or transferred to zones approved as VHS-free (http://www.fiskepleje.dk).

Meetings:

A miniworkshop on marine invasive species was organized during the 14th national marine science meeting (Dansk Havforskermøde) in January 2007 at the University of Southern Denmark, Odense, Denmark. The reason was the perceived need for monitoring in Danish waters based on recent publications on *Mnemiopsis leidyi* from neighbouring seas. The session was so well attended that other meetings were planned and an informal network was established. The first meeting concerning invasive species in aquatic environments was held at the Institute of Biology, University of Copenhagen in August 2007. Since then a few other national meetings have been held, usually covering both aquatic and terrestrial species. Besides this, the present author has presented data on alien marine species at several national and one international meeting and given guest lectures about marine invasive species.

Første Symposium om Danske Marine Bioinvasioner, Institut for Biologi, Københavns Universitet, **17 August 2007**. Abstracts available at: http://www.fbl.ku.dk/pastahr/Danish%20MNIS%20Symposium%20Review.pdf .

Marint fagmøde, **20-21 November 2007**, Svendborg, Denmark. Presentation on invasive species by present author available at: http://www.dmu.dk/NR/rdonlyres/806BBFA9-2999-481F-9789-A9A70433FCDF/0/KatheJensen.pdf .

Invasive arter i havet. Guest lecture at the Marine Biological Laboratory, Helsingør (University of Copenhagen), **13 February 2008**.

En illustreret, webbaseret identifikationsguide til invasive arter i nordiske farvande. Seminar presentation, **26 February 2008** at the Agency for Spatial and Environmental Planning, Copenhagen.

Alien molluscs in Danish waters. Oral presentation at international symposium "60+ years in Malacology: Global imprints and foresight in taxonomy" **6-7 March 2008**, University of Copenhagen.

An illustrated, web-based identification guide to invasive species in Nordic waters. Oral presentation at NOBANIS meeting in Bonn, Germany, **19-20 May 2008**.

Danish YPEP Seminar on Marine Invasive Species **1-3 September 2008**, Brorfelde Observatory, Denmark. A brief summary of the meeting is available at: http://www.dancore.dk/files/newsletters/2008/Encora_Dancore_Enews_September08.htm#47d00af3bb3b1ad4cc750ab218a206d9.

Workshop: Status for viden om invasive arter i Danmark, **9 December 2008**. Presentations and abstracts are available at: http://cis.danbif.dk/cooperation/fol195769/archive/workshop-status-viden-om-invasive-arter-i-danmark .

Tema session: Invasive arter, 15. Danske Havforskermøde, **27-29 January 2009**, Helsingør, Denmark. Program available at: http://www2.bio.ku.dk/havforsker/program/onsdag1.asp .

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Estonia, 2008

Prepared by: Henn Ojaveer and Jonne Kotta, Estonian Marine Institute, University of Tartu, Estonia

Overview

The current report describes recent findings of two new aquatic alien species in Estonian marine waters: the mysid shrimp *Paramysis intermedia* (Czerniavsky) in 2008 and the cladoceran *Evadne anonyx* G. O. Sars in 1999. Both species have formed permanent populations.

Regulations

According to Nature Protection Act (2004) article 57, the Minister of the Environment has established a regulation with a list of species whose import into Estonia is forbidden. The first version of the regulation entered into force in 2004 and was updated in 2007. In addition to three alien crayfish species who were entered into the list in 2004 (*Astacus leptodactylus, Orconectes limosus and Pacifascatus leniusculus),* 11 fish species were entered in 2007: *Umbra pygmaea, Pseudorasbora parva, Opsariichthys uncirostris, Ameiurus nebulosus, Ameiurus melas, Lepomis auritus, Lepomis gibbosus, Lepomis macrochirus, Perccottus glenii, Neogobius fluviatilis, Neogobius gymnotrachelus.* Most of the fish species are not yet found in Estonia and were included for preventive reasons. The list is updated regularly and species could either be removed or added to the list in the future.

In 2007 EC regulation No 708/2007 concerning use of alien and locally absent species in aquaculture entered into force. As the regulation is directly applicable, it is not integrated into Estonian legal acts. Newly formed Environment Agency (1st of February 2009) will be designated as competent authority for issuing permits.

During 2004 – 2006 a Nature Protection Development Plan (NPDP) was drafted, but mainly due to political reasons it was not adopted. It will be updated during 2009 and will hopefully be submitted to Government for approval end 2009. NPDP contains several targets concerning fisheries and will be a connecting document between the Environmental Strategy (adopted in 2007) and its action plan (also adopted in 2007). The Environmental Strategy is very general and gives general objectives while NPDP is more detailed, giving background information, listing main problems and setting objectives. This will be used as a basis for composing of action plans.

Intentional Releases

Estonia continues live fish imports from various countries. The statistical nomenclature categories doesn't allow the identification of the species, rather it lists fish by origin or taxonomic groups. During the past two years, only salmonids (salmon and sea trout) were released to the natural water bodies in order to enhance fishery resources.

Live Imports

2007

Country	Fish	Quantity (kg)
Indonesia	Ornamental freshwater fish	485.3
Peru	Ornamental freshwater fish	189
Poland	Ornamental freshwater fish	534
Singapore	Ornamental freshwater fish	1795.4
Finland	Ornamental freshwater fish	34.2
Indonesia	Ornamental marine fish	78.2
Lithuania	Ornamental marine fish	100.1
Latvia	Ornamental marine fish	11.8
Singapore	Ornamental marine fish	41
Latvia	Oncorhynchus apache and O. chrysogaster	117
Lithuania	Oncorhynchus apache and O. chrysogaster	441.1
Latvia	Unidentified salmon	49526
Unknown	Unidentified salmon	2
Latvia	carp	3610.5
Lithuania	Thunnus maccoyii	610.8
Latvia	Thunnus maccoyii	173.0
Lithuania	Oncorhynchus nerka, O. gorbuscha, O. keta, O. tschawytscha, O. kisutch, O. masou, O. rhodurus, Salmo salar, Hucho hucho	146
Unknown	Oncorhynchus nerka, O. gorbuscha, O. keta, O. tschawytscha, O. kisutch, O. masou, O. rhodurus, Salmo salar, Hucho hucho	14150
Israel	Unidentified fish	0.5

Poland	Unidentified fish	4160
Finland	Unidentified fish	3000

2008 (January-October)

Country	Fish	Quantity (kg)
Indonesia	Ornamental freshwater fish	470.3
Latvia	Ornamental freshwater fish	0.5
Peru	Ornamental freshwater fish	105
Singapore	Ornamental freshwater fish	1769.3
Sri Lanka	Ornamental freshwater fish	175.8
Indonesia	Ornamental marine fish	713.2
Lithuania	Ornamental marine fish	56.1
Singapore	Ornamental marine fish	14.7
Sri Lanka	Ornamental marine fish	53.8
Lithuania	Oncorhynchus apache and O. chrysogaster	1494.2
Latvia	Oncorhynchus apache and O. chrysogaster	908
Latvia	Unidentified salmon	125672,8
Latvia	carp	9169,7
Lithuania	Thunnus maccoyii	217,2
Latvia	Thunnus maccoyii	148
Lithuania	Oncorhynchus nerka, O. gorbuscha, O. keta, O. tschawytscha, O. kisutch, O. masou, O. rhodurus, Salmo salar, Hucho hucho	300,5
Unknown	Oncorhynchus nerka, O. gorbuscha, O. keta, O. tschawytscha, O. kisutch, O. masou, O. rhodurus, Salmo salar, Hucho hucho	21542
Israel	Unidentified fish	720
Latvia	Unidentified fish	269.1
Finland	Unidentified fish	2080

Live Exports

2007

Country	Fish	Quantity (kg)
Latvia	Oncorhynchus nerka, O. gorbuscha, O. keta, O. tschawytscha, O. kisutch, O. masou, O. rhodurus, Salmo salar, Hucho hucho	14600
Russian Federation	Unidentified fish	2500

2008 (January-October)

Country	Fish	Quantity (kg)
Latvia	Oncorhynchus nerka, O. gorbuscha, O. keta, O. tschawytscha, O. kisutch, O. masou, O. rhodurus, Salmo salar, Hucho hucho	17150
Russian Federation	Unidentified fish	5000

Official data on fish releases of Estonia for 2007 and 2008 (in thousands)

Species/year	2007	2008
Salmon (Salmo salar)	240,759	253,513
Sea trout (Salmo trutta trutta)	64,401	75,783

Unintentional Releases

New Sightings:

During an extensive mapping campaign, *Paramysis intermedia* (Czerniavsky) was recorded for the first time in the Baltic Sea in 2008. The species was recorded in the eastern Gulf of Finland and in the central Gulf of Riga. It is plausible that the species invaded the Gulf from adjacent rivers. The species have formed permanent population in the Gulf of Finland, but not in the Gulf of Riga (Herkül *et al*. 2009, in press).

Previous sightings:

Re-analysis of earlier collected samples revealed that the Ponto-Caspian cladoceran *Evadne anonyx* was first present in the Gulf of Finland in 1999. In the Gulf of Riga, the first specimens were found in 2000. The observed distribution pattern, together with the recorded increase in the population density of the species of ca. 10 times during the years 2000–2006 indicate the recent successful establishment of *E. anonyx* in the low-salinity conditions (5 psu) of the NE Baltic Sea. *Evadne anonyx* and the native *E. nordmanni* are present in mesozooplankton community from May to October. In the seasonal cycle, the maximum abundance of *E. anonyx* may occur later in the season than that of *E. nordmanni*. As the fecundity of the alien *E. anonyx* significantly exceeds that of the native *E. nordmanni*, we suggest that population abundance of *E. anonyx* will very likely increase in future and the species may colonize new areas in the recently invaded ecosystem (Põllupüü *et al*. 2008).

Pontogammarus robustoides (Sars) was found in the eastern Narva Bay (southern coast of the eastern Gulf of Finland) in 2008. The species has previously been found only at Sillamäe Port area in the Gulf of Finland. The species have formed permanent and abundant populations in both areas.

Gammarus tigrinus Sexton was found in the central and eastern Gulf of Finland. In both cases the species was found in the vicinity of harbour areas but not further away. The species has not yet formed permanent populations at these sites.

Chelicorophium curvispinum (Sars) was found in the eastern Narva Bay in 2008. The species has been previously found only at Sillamäe Port area in the Estonian coastal sea. The species have formed permanent and abundant populations in both areas.

The round goby *Neogobius melanostomus* continues to colonise new areas and increase in population abundance in the Gulf of Finland. The center of the distribution area is Port of Tallinn in Muuga Bay. In other parts of the southern coast of Gulf of Finland, the species was not observed. For the first time, one specimen of the species was found in the coastal area of the NE Baltic Proper (Väinameri Archipelago area) in 2008.

The predatory cladoceran *Cercopagis pengoi* (present in the system since the early 1990s) continues to hold an important position in pelagic fish feeding in the Gulf of Riga in the warm season. In the diet of the adult herring *Clupea harengus membras*, the share of *C. pengoi* (wet weight basis) was around 27% and by frequency of occurrence ca 24%. The share of the alien species in the diet of the non-commercial three-spined stickleback *Gasterosteus aculeatus* was 17.3 and 18.0 %, respectively. Other more abundant pelagic fish in the gulf (juvenile smelt, juvenile herring, sprat) were generally feeding on other food than *C. pengoi* with the share of the alien in stomachs generally less than 5% Both adult herring and three-spined stickleback exhibited positive electivity for *C. pengoi* (Ivlev index of 0.3 and 0.6, respectively) while other fish and young herring tended to avoid the alien species (Lankov *et al*. in prep.).

Not Seen Species Yet:

Two species of Ponto-Caspian origin found recently in the eastern Gulf of Finland – the tubenose goby *Proterorhinus marmoratus* and the cladoceran *Cornigerus maeoticus* (Antsulevich 2007, Panov *et al*. 2007) – were not yet detected in Estonain waters of the Gulf of Finland which situate west of the first finding-sites of these species.

Meetings

Planned attendance (H. Ojaveer) at the 6th Marine Bioinvasions Conference, Portland, Oregon, August, 2009.

Organising (H. Ojaveer and S. Olenin) Euro-CoML alien species workshop in 2009. Agenda and venue of the meeting to be decided later.

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Finland, 2008

Prepared by: Lauri Urho

Regulations

No information.

Intentional introductions:

Deliberate releases into the Baltic Sea (including rivers draining into the Baltic) for fisheries and fish stock enhancement purposes in 2008 (for whitefish year 2007) were as follows:

- million newly hatched and 2.7 million older salmon (*Salmo salar*),
- 1.1 million newly hatched and 1.7 million older sea trout (*Salmo trutta* m. *trutta*), and
- something around 40 million newly hatched and 8.4 million older whitefish (*Coregonus lavaretus*).

Unintentional:

Gibel carp, *Carassius auratus* m. *gibelio* was caught in several places along the south coast of Finland; however the northernmost observation is still as far as the Archipelago Sea. The biggest individuals caught weighed over three kg, though the possibility of hybrids has not yet been excluded. In 2008, several dozen Russian sturgeons, *Acipenser gueldenstaedtii*, were caught along the coast of Finland. Some information on escapes from an Estonian fish farm was received.

The arctic comb jelly *Mertensia ovum* was recorded for the first time from the Baltic Sea in September 2008. The species was found in open sea stations in the Gulf of Finland, the Åland Sea and the Bothnian Sea. It is not known whether the species is an invasive alien species or a relict species that has not been identified from the Baltic Sea before. The observed individuals have been small, less than 8 mm. Most of the populations occur below 30 m depths. (Ref: Gorokhova G., Lehtiniemi, M., Viitasalo-Frösén, S.: Molecular evidence for the occurrence of ctenophore *Mertensia* sp. in the northern Baltic Sea and its vertical distribution. Submitted manuscript)

It is now under research to study whether the invasive American comb jelly (*Mnemiopsis leidyi)* has occurred earlier in the northern Baltic Sea, although the comb jelly community was formed of only *Mertensia* individuals in September 2009, or if it has been misidentified and mixed up with *Mertensia ovum.*

The invasive predatory cladoceran *Evadne anonyx* was recognized for the first time in Finnish waters (Helsinki sea area) in July 2008. However, when looking back at preserved samples, the species was found for the first time in the samples from September 2000. The species was also observed in August 2008 in coastal areas of the Gulf of Finland as well as at open sea stations of the Gulf of Finland, the northern Baltic Proper and the Bothnian Sea.

Meetings

16th International Conference on Aquatic Invasive Species (ICAIS), Montreal, Canada, 19.-23.4.2009

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Germany, 2008

Prepared by S. Gollasch and M. Rolke

Overview:

- The invasive ctenophore ***Mnemiopsis leidyi*** was first recorded in the Kiel Bight (western Baltic Sea) in October 2006. Investigations on its presence, distribution and spread are ongoing in Germany with an emphasis on its potential impact.
- The EU-funded project "Environmental impacts of alien species in aquaculture" (**IMPASSE**) was completed with several reports. The key objectives include to review and assess the impact of alien species in aquaculture and also to provide recommendations on e.g. containment facilities for alien species in aquaculture use.
- The Institute for European Environmental Policy (IEEP[1]) is currently undertaking a comprehensive initiative regarding alien species in Europe. One task is to assess the **financial impact of alien species including terrestrial species**. A rough estimation results in an impact of at least EUR 12 billion Euro annually (see below).
- A recently published summary of all alien aquatic species in the North Sea documents in total 166 species[2].

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[1] Shine, C., Genovesi, P., Gollasch, S., Kettunen, M., Pagad, S. & Starfinger, U. (2008).

[2] Gollasch, S., Haydar, D, Minchin, D., Wolff, W.J. & Reise, K. (2009).

- The free journal of applied research on biological invasions in aquatic ecosystems, ***Aquatic Invasions***, is now issuing its 3rd volume (http://www.aquaticinvasions.net/). Contributions to the journal from WGITMO members are more than welcome. Please submit manuscripts to Vadim Panov at vpanov@aquaticinvasions.ru or vpanov@mail.ru.

Regulations:

EU Council Regulation on Aliens in Aquaculture

The new EU Council Regulation (EC) No 708/2007 of 11 June 2007 Concerning the Use of Alien and Locally Absent Species[3] in Aquaculture is in place since Jan. 1st 2009. This instrument deals "only" with species imports from outside the Europe Union member states.

Intentional introductions:

No major changes to last year's National Report are known. The species which were reported earlier include Sturgeons, salmonid species, rainbow trouts, carps, *Crassostrea gigas, Homarus americanus* and *Palmaria palmate*.

Unintentional introductions:

No new sightings were reported.

Previous Sightings

Hemigrapsus penicillatus first found in Europe in 1993 in hull fouling samples (Gollasch 1999[4]). In 1994 it was found in the Bay of Biscay (France) and thereafter in Spain, Le Havre (France), The Netherlands. In 2007 *H. penicillatus.* was found for the first time in German waters (southwestern Wadden Sea) (Gehrmann *et al*. 2007[5], Markert & Wehrmann in prep.[6]). Other studies in 2007 also documented the presence of ***H. takanoi*** *and* ***H. sanguineus*** from the area (Obert *et al*. 2007[7]).

As reported before, in October 2006 the invasive ctenophore ***Mnemiopsis leidyi*** was first recorded in the Kiel Bight and is today found in all Baltic countries. *M. leidyi* also invaded the North Sea. However, this invasion may have been overlooked as the species was misidentified as a native comb jelly (Faasse & Bayha 2006)[8]. In September 2008 a field study was undertaken to determine vertical distribution of *Mnemiopsis* in the northern Baltic (outer part of the Gulf of Finland, Åland Sea and Bothnian Sea) and in conjunction with this study, specimens were collected for genetic analysis to confirm species identity. These specimens were sequences and turned out to be not *Mnemiopsis*, but another ctenophore belonging to the family Mertensiidae (order Cydippida), most probably *Mertensia ovum*. It is quite possible that *M. ovum*, which is

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[3] locally absent species = species being absent from a zone within its natural range

[4] Gollasch S (1999) The Asian decapod *Hemigrapsus penicillatus* (de Haan, 1833) (Decapoda, Grapsidae) introduced in European waters, status quo and future perspective. Helgol Meeresunters 52: 359-366

[5] http://www.nordseefauna.de/Brachyura_Trox.htm, assessed March 4th 2008

[6] Markert. A & Wehrmann, A. (in prep.) The Asian crab *Hemigrapsus penicillatus* (de Haan 1835) invades new established Pacific oyster reefs in the Wadden Sea, German Bight (North Sea).

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common in Arctic Seas and has wide boreal distribution, has always been here. However, the species identity has to be confirmed yet, as well as its origin and time of appearance in the Baltic Sea (Gorokhova pers. com.). During a cruise with the German research vessel "ALKOR" in the Baltic in November 2008 the results approved that *M. leidyi* is now established there. The estimated abundances of *M. leidyi* correspond to the values found in October 2007. An west-east gradient with higher numbers of individuals in Kiel Bight and Mecklenburg Bight and smaller numbers east of Darß Sill could be verified (Cruise Report No. 06AK/08/05; r/v "ALKOR" - www.io-warnemuende.de/tl_files/forschung/pdf/cruise-reports/cr06ak0805.pdf.

Gracilaria vermiculophylla, first recorded along the German North Sea coast in 2002 and along the German Baltic coast in 2005, continues to spread. Preliminary results from the Baltic show that *G. vermiculophylla* may have a potential to compete with the native *Fucus vesiculosus* in shallower and less exposed areas. The authors conclude that this alga has a very high potential to spread and that it may especially colonize shallower areas (Weinberger *et al*. 2008). The funding of the investigations on the development of *Gracilaria vermiculophylla* in the Baltic is prolonged for 2009.

Pathogens

No new records of pathogens are known. One of the most impacting parasites is the eel nematode *Anguillicola crassus*.

Projects

German "Rapid assessment" - project

With the objective to fill gaps in the knowledge about the presence of non-indigenous organisms in German harbours, a project for a so called "rapid assessment" was launched for the German North – and Baltic Seas. The project comprises of field investigations for sampling fauna and flora for selected harbours and marinas along the usual shipping routes taking salinity gradients into account. Contact: Christian Buschbaum, Alfred Wegener Institute, Hafenstraße 43, D-25992 List.

German "Early warning" – project

Another project dealt with artificial substrates in form of plates mounted on buoys and other fixed installations. The aim is to measure the settlement of hard bottom organisms with the aim to recognize non-indigenous species early after arrival. Contact: Martin Wahl, Leibniz Institute of Marine Sciences, IFM-GEOMAR, West Shore Campus, Duesternbrooker Weg 20, D-24105 Kiel, Germany.

Meetings

Past year

The project *IMPASSE* "***Environmental impacts of alien species in aquaculture***" was completed with a scientific conference (*MALIAF*, see below) meeting and an end-user workshop. The IMPASSE consortium delivered its reports and it was shown that more than 100 alien species are either in use in aquaculture in Germany or were unintentional introduced associated with target species movements. As a dissemination event the international conference **"Managing Alien Species for Sustainable Development of Aquaculture and Fisheries" (MALIAF)** was to be hosted by the University of Florence (Italy) between **5 and 7 November 2008**. Its main objective was to present IMPASSE's results to the scientific community, administrators, and stakeholders, but also to extend the discussion on the strategies needed to develop sustainable and profitable aquaculture and fisheries across the world.

The Institute for European Environmental Policy (IEEP[9]) is currently undertaking a comprehensive initiative regarding alien species in Europe. One task is to assess the **monetary impact of alien species, including terrestrial species**. When including all species, i.e. including terrestrial alien species, a tentative calculation, which needs to be updated and revised, results in an impact of at least EUR 12 billion Euro annually. This cost statement includes documented costs for control and damage.

Future meetings

The ICES Annual Science conference will be held this year be held in Berlin, Germany (Sep. 21th - 25th). For details visit: http://www.ices.dk/iceswork/asc/2009/

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Ireland, 2008

(Compiled by Francis O'Beirn with input from Dan Minchin, Marine Organism Investigations and John Kelly, Invasive Species Ireland).

Highlights

Freshwater systems: Reproductive swarms of *Hemimysis anomala* were found in a sheltered inlet of a 114km^2 lake, Lough Derg, the lowest lake on the Shannon River in April 2008. They were recovered from the same locality in October and December 2008. It was also found associated with *Mysis relicta* over depths of 36m. In March 2009 it was found in abundance in the lower region of Lough Ree (also on the Shannon River system but upstream of Lough Derg). Presently there is no explanation for its arrival.

In this same lake the amphipod *Gammarus tigrinus* was found to depths of 36m, and occurs in varying abundance at all depths, and *Crangonyx pseudogracilis* and *Chelicorophium curvispinum* to 20m.

The North American pondweed *Elodea nuttallii* is invasive in Lough Derg is expanding its range upriver but has not as yet been found in the next upstream lake, Lough Ree. This plant has become invasive in a shallow water area on the River Lee that drains into Cork Harbour.

The South African pondweed *Lagarosiphon major* was eliminated from a pond of ~0.4 hectare near the Shannon River but continues to expand its range in one large lake, Lough Corrib on the west coast of Ireland.

The freshwater snail *Ferrisia wauteri* has been found for the first time in Ireland. Further details will be available for next years report.

Marine Systems: The marine bryozoa *Bugula neritina* and *Tricellaria inopinata*, have been found for the first time in Ireland. Further details will be available for next years report. Recruitment of the Pacific oyster, *Crassostrea gigas*, has been confirmed in a number of sites in Ireland. A series of studies are currently being conducted by the Marine Institute, Galway, University College, Dublin and Queens University, Belfast to investigate the dynamics of *C. gigas* recruitment reproduction and ecological interactions. The presence of tunicate *Didemnum vexillum*, has been confirmed at a wide range of sites (predominantly marina sites) on both the east and west coasts of Ireland. Additional sightings of *Styela clava* have also been confirmed at a number of locations in Ireland throughout 2008. The presence of *S. clava*, appears to coincide with shellfish culture operations or significant boat movements.

The Pacific oyster, Crassostrea gigas: Settlement of the Pacific oyster, *Crassostrea gigas*, which has been cultured in Ireland since 1974, has recently been confirmed from a number of bays in Ireland. These bays include, Strangford Lough, Loughs Foyle and Swilly, Inner-Donegal Bay and Inner Galway Bay. Varying levels of recruitment have been observed with multiple year classes being observed in Strangford – Lough and in Loughs Swilly (see Figure 1) and Foyle.

Crassostrea gigas – **Reports 2008**					
Identified By	**Collector**	**Date**	**Locality**	**Longitude**	**Latitude**
Francis O'Beirn	Francis O'Beirn, Judith Kochman, Ciaran McGonnigle	November 27, 2008	Lough Foyle	7 12.643	55 6.274
Francis O'Beirn	Francis O'Beirn, Judith Kochman	November 27, 2008	Lough Swilly	07 33.742	55 2.875
Francis O'Beirn	Francis O'Beirn, Judith Kochman	November 28, 2008	Lough Swilly	7 33.549	55 02.611
Francis O'Beirn	Francis O'Beirn, Judith Kochman	November 28, 2008	Lough Swilly	7 34.953	55 01.283

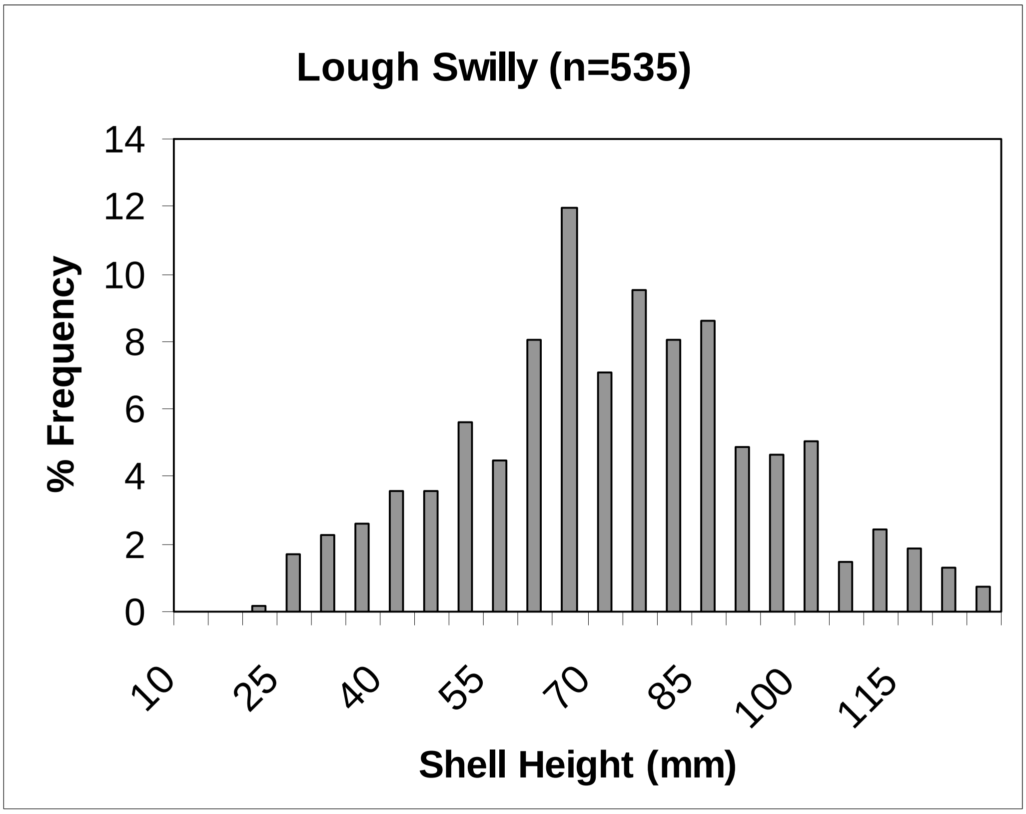

Figure 1: *Crassostrea gigas*, shell height frequency distribution from Lough Swilly, Ireland (November 2008).

***C. gigas* Research**

Current research will focus upon documenting the extent of recruitment around Ireland (focusing upon areas where culture is concentrated. A standardised sampling protocol is currently being developed whereby multiple survey teams can increase the geographic area surveyed with a view to surveying much of the country in 2009.

Recruitment studies are also being conducted in Lough Swilly and Foyle in order to document extent and identify habitat preference. Genetic analysis will be conducted comparing culture stock with wild stock in order to determine if there is any differentiation between the two. Quantitative reproductive (histological) analysis is also being conducted to identify difference in culture methods and to differentiate between triploid and diploid stocks- with a view to recommending risk mitigation measures

***Didemnum vexillum* Current Known Distribution in Ireland:** The colonial tunicate *Didemnum* sp., following recent genetic studies may now be referred to as *Didemnum vexillum.* This species has been reported from Westport Bay on the west coast of Ireland, kindly identified by Gretchen Lambert. This makes for three known localities in Ireland. However, the marina pontoons at Malahide were devoid of *D. vexillum.* It appears that these may have been purged by reduced salinity. The species still remains in Carlingford but was not found to be abundant.

Marina Sites (Carlingford Lough and Malahide)

In 2008 there were further reports of the occurrence of *Didemnum vexillum* colonies on boat hulls, pontoons, and other substrates in two marinas in eastern Ireland.

Clew Bay

Tunicate colonies of *Didemnum vexillum* overgrowing bottom of oyster bag; note long tendrils lying on bag surface. Clew Bay at Murrisk, County Mayo, Ireland (53 deg 47.43 min N, 09 deg 37.02 min W). Water depth, low intertidal oyster trestles. Nov 9, 2007. Identified by J. Kelly (QUB).

South Galway Bay

Tunicate colonies of *Didemnum vexillum* (pale orange color) hanging from two middle bars of oyster bag trestle above the seabed. South Galway Bay at Carrowmore, Shanmullen Channel, County Galway, Ireland (53 deg 12.75 min N, 08 deg 58.25 min W). Water depth, low intertidal. Sep 30, 2007. Identified by J. Nunn (NMNI).

Styela clava – historical reports					
Identified By	**Collector**	**Date**	**Locality**	**Longitude**	**Latitude**
John Bishop	John Bishop	21/09/2004	Dingle Marina	-10.337247	52.129189
Olwen Ager	Olwen Ager	06/2002	Fenit Harbour	-9.903271	52.226873
John Bishop	John Bishop	15/11/2005	Dun Laoghaire marina	-6.204307	53.217129

Styela clava – new records since 2008					
Identified By	**Collector**	**Date**	**Locality**	**Longitude**	**Latitude**
Joe Breen/ Hugh Edwards	Joe Breen/ Hugh Edwards	Unknown	Larne Lough	n/a	n/a
Julia Nunn	Julia Nunn	25 May 2008	North Water Mulroy Bay 14 m	7º42.20′	55º12.7′
Ascidian Workshop	Ascidian Workshop	03 Aug 2008	North Water Mulroy Bay 6 – 14m Approx	7º42.20′	55º12.7′

Current Known Distribution of *Botrylloides violaceous* in Ireland					
Identified By	**Collector**	**Date**	**Locality**	**Longitude**	**Latitude**
Dan Minchin	Dan Minchin	2006	Malahide marina	06º09.21'	53º27.26'
Dan Minchin	Dan Minchin	2006	Carlingford Marina	06°11.27'	54°03.01'

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Training and Public Understanding of Science

http://news.bbc.co.uk/2/hi/uk_news/northern_ireland/7544157.stm

Didemnum report a sighting leaflet. "Have you seen this invader? Report all sightings"

Poster guidelines for boat owners. "Protect against Invasive Alien Species"

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Meetings

2008 Second Annual Invasive Species in Ireland Forum. National Botanic Gardens, Dublin.

Italy, 2008

Prepared by Anna Occhipinti-Ambrogi, University of Pavia

Overview:

Three new alien species have been recorded in the Italian waters: the red alga *Osmundea oederi*, the calcareous sponge *Paraleucilla magna* (which represents the first alien sponge recorded in the Mediterranean), the cephalaspidean mollusc *Haminoea cyanomarginata.* Studies on the biology and ecology of species that had been introduced previously have continued, with special emphasis on the invading algae (*Caulerpa racemosa* var. *cylindracea*) and the toxic microalgae (*Alexandrium*, *Coolia* and *Ostreopsis*)

Range expansion of some thermophilic species is reported together with new records in neighboring Countries, among which the presence of *Styela clava* in the Lagoon of Thau is of special concern.

Regulations

No information

The Council Regulation (EC) N° 708/2007 concerning the use of alien and locally absent species in aquaculture has entered in force and the commission regulations, including the implementing rules, have been adopted by Italy.

Intentional introductions

No new intentional introductions have been reported.

Unintentional introduction

<u>New Sightings</u>

The red alga *Osmundea oederi,* known from the NW Atlantic, was recorded for the first time in the Mediterranean in February 2007 in the Mar Piccolo of Taranto. Specimens held in the Biological Station collection since 1987 have been reassessed as *O. oederi* (Serio *et al*., 2008).

The calcareous sponge *Paraleucilla magna* was detected at several Mediterranean sites (Taranto, Porto Cesareo, Brindisi and Naples). It is especially abundant since 2001 in the enclosed basin Mar Piccolo di Taranto. Its record in well studied areas where several benthic surveys have previously been carried out suggests a recent introduction of the species into the Mediterranean Sea. Until now this sponge has only been recorded from the Brazilian coast (Longo *et al*., 2007).

In September 2007 several specimens (both adults and juveniles from 6 to 20 mm in length) and several egg masses of the cephalaspidean mollusc *Haminoea cyanomarginata* were detected by SCUBA diving at Saline Joniche (Reggio Calabria), 37º55'34"N 15º44'26"E (Crocetta & Vazzana, 2008). *H. cyanomarginata* is considered one of the recent Erythrean species entering the Mediterranean Sea through the Suez Canal; it was reported in 2001 from only Korinthiakos Gulf, Greece, where it is now abundant, as well as in some places of the Turkish coast (see CIESM Atlas). This new finding represents the first record along the Italian coasts and the second outside the Eastern basin (in 2006 it was found in Malta), probably due to natural dispersal, considering the distance of Saline Joniche from any commercial route and major port.

Previous Sightings

Algae & higher plants

For several years, the Mar Piccolo, a brackish basin near Taranto has been constantly monitored by means of periodic surveys aiming to detect changes in the floristic composition, with particular attention to the presence of non-indigenous species. *Undaria pinnatifida* was not found for a period of two years, following its introduction ten years ago, while *Grateloupia turuturu* and *Hypnea cornuta* are expanding, each in two different basins (Cecere and Petrocelli personal communication).

Caulerpa racemosa has been found in two other protected areas in Sicily, Capo Gallo-Isola delle Femmine and Saline di Trapani e Paceco (Mannino *et al*., 2008).

The response of the introduced *Caulerpa racemosa* var. *cylindracea* to the local thermal regimes of the Gulf of Naples has been studied through laboratory experiments in order to explain some physiological traits that can be related to its invasion success. Growth and photosynthetic response of a shallow-water population was studied in two seasons (early winter and early summer). While temperatures higher than 22°C stressed early winter thalli, as reflected in the decrease in growth rates and optimal quantum yields, both increased with temperature in early summer plants. A difference between the two seasonal samples also occurred in the high-temperature sensitivity of respiration rates, which was enhanced in early winter plants. As changes in a number of the traits considered occur in advance of seasonal minima and maxima, *C. racemosa var. cylindracea* may behave as a season anticipator (Flagella *et al*., 2008).

The occurrence of the tropical seagrass species *Halophila stipulacea* (Hydrocharitaceae) was reported in the harbour of Palinuro (Salerno, Central Tyrrhenian Sea, Italy). The species of Erythrean origin apparently remained restricted to the eastern Mediterranean for several decades, but then showed a progressive colonization towards the western areas through Malta (Lanfranco, 1970) and the Ionian coast of Sicily (Biliotti & Abdelaad, 1990; Alongi *et al*., 1992). In the western basin, it was first observed in 1995 at the island of Vulcano in the Aeolian Archipelago, southern Tyrrhenian Sea (Acunto *et al*., 1997; Procaccini *et al*., 1999). For more than 10 years the species was not reported north of this latter location: thus, these record documents a displacement of about 180 km north of the previously documented limit in the western Mediterranean, likely mediated by pleasure boat traffic and anchoring, and favoured by climate change (Gambi *et al*., 2008).

Toxic microalgae are increasingly causing health problems not only in Italy, but also in other Mediterranean countries. The difficulties in taxonomic issues have prevented a clear recognition of whether the toxic strains are introduced or not.

A recent paper (Penna *et al*., 2008) revises the taxonomic, biogeographic and phylogenetic status of all the *Alexandrium* species (Dinophyceae) recorded in the Mediterranean Sea. The papers by Penna *et al*. (2005a, b) provide further details on some species of *Alexandrium*, *Coolia* and *Ostreopsis*. We summarize here some of the information related to the species more likely to have been introduced in the Mediterranean.

The dinoflagellate genus *Alexandrium* was established as a monospecific genus based on *Alexandrium minutum* Halim, a species responsible for a red tide in Alexandria harbour, Egypt (Halim, 1960). The genus remained monospecific until several species of *Gonyaulax* (Claparède et Lachman) Diesing and *Gonyodoma* Stein, known as the '*tamarensis* or *catenella* group' were transferred to *Alexandrium* and many new species were added to the genus (Balech, 1985). The different species of *Alexandrium* are phenotypically very similar, so that discrimination of the morphological characters used to distinguish the individual species is not a simple task. Morphological differentiation can be decisive in discriminating a toxic species from a harmless one. Finally, although the genus *Alexandrium* has been reported all around the world, the Mediterranean Sea appears to be the region with the highest number of reported *Alexandrium* species (Fraga *et al*., 2004), possibly a result of the intensive studies carried out in this area. The phylogenetic analysis of the 5.8 S rDNA and ITS sequences provided adequate information to discriminate the different Mediterranean *Alexandrium* species (Penna *et al*., 2008). The study assesses if clades of highly similar sequences occur, and if the phylogenetic structure within these clades links with different regions in the Mediterranean Sea. Therefore, monoclonal Mediterranean strains of *Alexandrium* were established from single cells isolated from samples obtained from several coastal areas throughout the Mediterranean basin. All strains were identified morphologically and characterized genetically. Sequences obtained from Mediterranean strains were aligned with ones from Genbank (including sequences of both Mediterranean and extra-Mediterranean strains) to assess biogeographical patterns in a broader context, and to infer geographical origins of the Mediterranean populations. The study has also extended the known range of some taxa, e.g. *A. andersoni* was known to be present as resting cysts in Mediterranean sediments (Ciminiello *et al*., 2000), but has now been detected in Aegean waters.

It has been hypothesized that *A.* cf. *catenella* could have been introduced into the Mediterranean from temperate Asia by human assisted pathways (Lilly *et al*., 2002). Although many phytoplankton studies have been carried out in the Mediterranean Sea, there is a lack of information on the presence of *A. catenella* before 1983. Then, there was a lack of information until 1994, when an expansion of this species, affecting several localities in the NW Mediterranean basin, such as the Valencia Harbour (since 1994), several Catalan harbours (since 1996), Thau Lagoon (1998) and Olbia Bay (1999) has been documented. At the same time, there is only one reference to this species in the Eastern Mediterranean basin: the eutrophic Alexandria Harbour in Egypt (Mikhail, 2001). The harbours affected by this species (Barcelona, Tarragona, Valencia and Olbia) are characterized by high commercial shipping traffic. In addition, aquaculture activities are present in Valencia Harbour, Olbia Bay and Thau Lagoon. The transfer of mollusc stocks is known to be another vector of alien phytoplankton species introduction. Once the *A. catenella* species has been introduced, especially in closed areas such as harbours, bays or lagoons, sediments become full of cysts. Thus, when the species has been successfully established, natural or anthropogenic ways of dispersion could facilitate the expansion to other areas (Masò *et al*. 2003). The paper by Penna *et al*., 2005a concludes that *A. catenella* was probably introduced into the

Western Mediterranean from Japanese waters via anthropogenic pathways. This can be supported by either the high genetic similarity between the Mediterranean isolates and a Japanese strain, as shown by the phylogenetic analyses based on the ITS-5.8S rDNA gene and the absence of *A. catenella* before 1983 in historical data followed by its detection in different sites in the Western basin of the Mediterranean. Fast evolving molecular markers, such as microsatellites, will soon be available to determine more certainly whether the Mediterranean *A.* cf. *catenella* isolates are indigenous or introduced.

Ostreopsidaceae can be considered as organisms potentially harmful to human health.Mediterranean occurrence of Ostreopsidaceae in summer periods may be associated with human respiratory problems and massive invertebrate mortalities. *Ostreopsis* spp. blooms in the Tyrrhenian and southern Adriatic Sea (Mediterranean Sea) have been related to human health problems, such as fever and breathing and skin irritation, in tourists attending the beaches and inhaling marine aerosols (Sansoni *et al*.,2003). These noxious events are not originated through the food chain via toxic bloom-forming phytoplankters, but via benthic and epiphytic toxic microalgae. Toxic harmful algal bloom (HAB) occurrence is becoming more frequent and problematic in highly urbanized coastal zones. In summer 2005 along the urbanized Genoa coastline, about 200 people were treated, who all showed similar symptoms following exposure to marine aerosols. The link with proliferation of *Ostreopsis ovata* was made. Subsequently, a specific monitoring plan was designed and implemented in the same area in July 2006. Maximum values (both of concentration in the water and of number of cells on macrophytes) were recorded on July 26th ($87 \times 10^3 \pm 27 \times 10^3$ cell/l; mean ± SE) and on July 27th ($2541 \times 10^3 \pm 588 \times 10^3$ cells/g of fresh macrophyte; mean ± SE) Mangialajo *et al*., 2008).

Concerning the origin of Ostreopsidaceae in the Mediterranean basin, two alternative scenarios can be envisaged, endemic versus introduced. In the paper by Penna *et al*., (2005b) the morphological studies were supported by phylogenetic analyses; all western Mediterranean isolates of *O.* cf. *siamensis* showed ITS and 5.8S rDNA sequences identical to each other and so did those of *O.ovata,* whereas high genetic diversity was detected between the western Mediterranean and Asian isolates of *O. ovata*. It could be inferred that because *Coolia* (non toxic) isolates from the Mediterranean/northwest Europe are phylogenetically well differentiated from Asian isolates, the introduction seems much less plausible. The same holds for *O. ovata* (toxic), even if in this case the differentiation between Asian and Mediterranean isolates is less pronounced.

Invertebrates

The crab *Percnon gibbesi* and the mollusc *Aplysia dactylomela* have been recorded for the first time from the Taranto Gulf (Italy, Ionian Sea) (Crocetta & Colamonaco, 2008).

Several specimens of an Anthuroidea Isopod Crustacean, belonging to the genus *Mesanthura*, previously found only in Egypt and in Salerno port, have been recently found also in the Taranto port. Although its identity remains to be determined, the ecological attributes of the present species suggest an introduced origin (Lorenti *et al*., 2008).

Several living specimens of the Gastropod Mollusc *Cerithium scabridum* were collected in August 2007 in the harbour of Otranto (Lecce) South Western Adriatic Sea. The present record extends the distribution of this termophilic Erythrean species into a new basin of the Mediterranean Sea (Albano & Trono, 2008).

The invasive brackish water mytilid *Xenostrobus securis*, already reported in the Northern Adriatic lagoons, was found in August 2006 at the outlet of an artificial canal flowing close to the Leghorn harbour (Giusti *et al*., 2008) in the proximity of a dock for large commercial ships, suggesting ballast waters as the most likely vector of introduction. This is the first finding of the species in the Tyrrhenian Sea. The site is close to the Orbetello lagoon, calling for immediate monitoring in order to control the possible spread of this species, highly invasive and able to smother the infauna by covering soft sediments.

New findings in the Gulf of Naples and Taranto of three mollusc species (*Brachidontes faraonis, Anadara demiri* and *Fulvia gracilis*), already found in Italy, are reported in the paper by Crocetta *et al*. (2008).

Fishes

The bluespotted cornetfish *Fistularia commersonii* was found in several additional locations around Sardinia (Follesa *et al*., 2008), Latium (Psomadakis *et al*., 2008), on the Ligurian coast (Laigueglia - Occhipinti-Ambrogi & Galil, 2008) and in the Adriatic Sea (Southwestern-Tricase Porto, Italy and Southeastern - Sveti Andrija, Croatia) (Dulčić *et al*., 2008). This thermophilic species of Erythrean origin has so far rapidly crossed the Mediterranean reaching the Northwestern Ligurian Sea after only 9 years since its first appearance in 2000 along the Israeli coasts, undoubtedly favoured by the warming trend recorded.

<u>Species not yet seen</u>

Two non-native ctenophores: *Mnemiopsis leidyi* and *Beroe ovata* were observed in October 2005 in the Bay of Piran (Slovenja, Gulf of Trieste). The validity of the Mediterranean species *Beroe ovata* is discussed and the authors state that the Mediterranean native species is not *Beroe ovata* but rather *Beroe cucumis* sensu Mayer, 1912 (Shiganova & Malej, 2009).

The solitary ascidian *Styela clava* Herdman, 1882, native to the north-west Pacific, was found for the first time in the Mediterranean region in the Bassin de Thau (France), near Sète; in June 2005. The presence of a stable population within the Sete lagoon was confirmed in 2007 (43°25.6'N 03°39.5'W). The proximity of commercial shellfisheries to the discovered populations, and the absence of *S. clava* from other harbours and marinas along the French and Italian coasts, suggests that the species may have been introduced by shellfish transfer. (Davis and Davis, 2008). This very likely vector should call for special attention due to the active exchange of aquacultured products between Thau and Venice lagoons.

In August 2007, a female *Selene dorsalis* was caught by means of a traditional trammel net at a depth of 18 m on the Munxar Reef, in shallow waters off the southeastern coast of the island of Malta. This is the first finding in the Mediterranean Sea of this species, whose native range consists of tropical and subtropical waters of the east Atlantic, from the Cape Verde Islands and Senegal to South Africa. The single individual could simply constitute a vagrant (occasional adult visitor) but it could also be indicative of a northward range expansion of the species, spurred in part by the recent warming trend observed in the Mediterranean Sea (Vella and Deidun, 2008).

<u>Pathogens</u>

Different developmental stages of 91 parasite specimens belonging to Arthropoda (Gnathiidae) and Nematoda (Anisakidae, Cystidicolidae and Philometridae) were found in mouth and gills, and body cavity, respectively of this single individual of *G.*

granti. Myxozoan spores were found in the gallbladder. Male and female nematodes of the genus *Ichthyofilaria* are reported for the first time from the Mediterranean Sea, and a very rare male of this genus is reported for the second time in the world. Parasitological results indicated that this Atlantic migrant probably entered the Mediterranean as an adult, suggesting for a non-indigenous species the possibilities of entering with natural parasites and/or acquiring native parasites in the introduced range (Pais *et al*., 2008).

The parasite fauna *of F. commersonii* has been recorded from specimens caught in Tunisia and Lybia: *Rachelobdella lubrica* and *Hysterothylacium. aduncum* are reported for the first time in this host species, while the Indo-Pacific *Neoallolepidapedon hawaiiense* represents a new record for the Mediterranean. Native generalist species are usually predominant in this species but two Indo-Pacific digeneans are able to complete their life cycle in the Mediterranean Sea (Merella *et al*., 2008).

Meetings

The final international conference of the *IMPASSE* EU funded Project "*Managing Alien Species for Sustainable Development of Aquaculture and Fisheries*" (*MALIAF*) was held in Florence in November 2008 with the aim of presenting to the scientific community the results of the of the project IMPASSE"*Environmental impacts of alien species in aquaculture*".

In the framework of the Italian project VECTOR (Vulnerability of shores and Italian marine ecosystem to climatic changes and their role in the Mediterranean carbon cycles, funded by the Ministry of Education, University and Research, MIUR) (*http://vector-conisma.geo.unimib.it/*), the Benthic Research Group of the Stazione Zoologica A. Dohrn has focused its researches on pluriannual variations of the invasive species *Caulerpa racemosa* var. *cylindracea* in relation to the adaptative features of this alga to environmental factors and the effects on the animal associated communities. Some results have been presented at national and international meetings.

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Poland, 2008

Prepared by Aldona Dobrzycka-Krahel and Anna Szaniawska, University of Gdansk

Regulations

Nothing new recorded, still in force: CBD Convention (05 June 1992), Act on Fishery (19 February 2004) and Nature Conservation Act (16 April 2004).

Intentional

No data

Unintentional

Invertebrates

Dikerogammarus villosus (Sowinsky, 1894) was recorded for the first time in the Vistula River near Wyszogród – in the autumn of 2007 (Bącela at el. 2008).

Fish

In April 2008, *Proterorhinus marmoratus* (Pallas, 1814) was recorded for the first time in Poland (Grabowska et. al., 2008). Six individuals (five females and one male) of tubenose goby (total length 52-58 mm) were found in the Vistula River near the bridge at Płock (52 32′05′′N, 19 41′12E′′) at the down-stream and of the Włocławski Reservoir.

Tubenose goby was reported in August 2007 for the first time in the upper and middle parts of the Pripyat River (Belarus), very close to the Pripyat-Bug canal (Rizevsky *et al*. 2007), which suggests that the species reached Poland and the Vistula basin via the Pripyat-Bug canal.

Parasites, pathogens and other disease agents

The first record of *Paratenuisentis ambigous* Van Cleave, 1921 from Lake Łebsko (central Polish coast) (Morozińska-Gogol J., 2008) was recorded in eels, since 2002. *Paratenuisentis ambiguous* is a specialist parasite of the American eel *Anguilla rostrata* (Lesueur, 1817) along the east coast of the North America from Labrador to Florida (Samuel & Bullock, 1981). This acanthocephalan was introduced into Europe with its sole intermediate host, the euryhaline amphipod *Gammarus tigrinus* Sexton, 1939 (Bullock & Samuel 1975, Kennedy 2006, Taraschewski 2006). Because of the spread of the intermediate host and the appearance of new adults in eels along the southern Baltic Coast, it is clear that *P. ambiguus* can complete its life cycle in Baltic coastal waters.

Gregarines (Apicomplexa, Gregarinidae) were recorded in digestive tracks of invasive *Pontogammarus robustoides* (Uradiophora ramose (Balcescu-Codreanu 1974) and *Cephaloidophora mucronata* (Codreanu-Balcescu 1995) from the Vistula deltaic system and in digestive system of native *Gammarus pulex (Cephaloidophora gammari* (Franzius 1848)) from Stradanka River, an affluent of the Vistula Lagoon. Microsporidia were found also only in two above gammarid species: *Pleistophora muelleri* (Pfeiffer 1895) in *G.pulex* from Piaśnica river, and *Nosema pontogammari* (Ovcharenko and Kurandina 1987) from the Vistula deltaic system. All the above microparasites are new to Poland (Ovcharenko M, at el., 2008).

Meetings

September 15-18, 2008 “Aquaculture Europe 2008” KRAKOW POLAND – organized by the European Aquaculture Society and hosted by Polskie Towarzystwo Rybackie (the Polish Fisheries Association).

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Spain, 2008

Prepared by Gemma Quilez-Badia

The interest on the AIS topic in the Iberian Peninsula, although it is increasing, it only started recently. Different administrations, NGOs and academic and research entities have been carrying out investigations and campaigns. In addition, the Ministry of Environment, some regional governments and local authorities have established their own AIS management plans to eradicate nonnative species (i.e. the Program for the Control of Alien Invasive Species in Andalucía, running since 2001). These actions, however, have usually been very isolated and specifically when the importance of the invasion was evident. Such is the case for the zebra mussel (*Dreissena polymorpha*), the *Caulerpa* algae, the American mink (*Mustela vison*) or the Ruddy duck (*Oxyura jamaicensis*).

Examples of the growing interest in the subject can be seen in the carrying out of the following conferences: the First (in 2003) and the Second (in 2006) National Conference on Alien Invasive Species, as well as the European Conference on Invasive Alien Species (in 2008) held in Madrid. The publication of: ‘Top 20: The most harmful alien invasive species present in Spain’ (GEIB, 2006) and the ‘Alien Invasive Species: Diagnose and bases for its prevention and management’ (Capdevila Argüelles *et al.*, 2006).

Even more encouraging is the recently published law 42/2007, concerning the Spanish Natural Heritage and Biodiversity, particularly, Chapter III Prevention and Control of Alien Invasive Species. Art. 61, deals with the AIS Spanish Inventory, which is run by the Ministry of Environment (Ministerio de Medio Ambiente).

Most of the studies, however, focus on terrestrial or freshwater introduced species and usually in catalogued protected areas. In freshwater ecosystems, the majority of the studies are related to the impact of certain arthropods, such as the American red swamp crayfish, *Procambarus clarkii* , the signal crayfish, *Pacifastacus leniusculus,* and the Australian common yabby, *Cherax destructor,* on the population of the native crayfish *Austropotamobius pallipes*. The consequence of introducing exotic fish species in epicontinental aquatic systems has also been studied. Now we know that in the last 60 years at least 26 fish species have been introduced in our rivers, lakes and reservoirs (PHORON, 2002), many of them have proved to be voracious predators.

A worth noting initiative in the AIS subject is the program InvasIBER (http://hidra.udg.es/invasiber/presentacion.php). This project is directed by Dr. Garcia-Berthou and it is funded by the Ministry of Science and Technology (Special Action REN2002-10059-E). Its main objective is to establish a data base of the main invasive species in the Iberian Peninsula. Up until now, it is composed of 36 animal and plant species, from these, only 4 are marine.

With regard to AIS in marine and brackish environments, the number of studies conducted is very scarce. Most of the research in this field has focused on sea weeds in the Mediterranean coast, especially on the impacts and damage caused by the 'killer algae' *Caulerpa taxifolia* on the native and productive *Posidonia oceanica* ecosystem.

Of particular interest and solely marine, are the two studies carried out in the Basque Country (North of Spain).They were funded by the Biodiversity Direction of the regional Basque Government to investigate the problem caused by AIS on the coastal ecosystems of Gipuzkoa (Martínez and Adarraga, 2005) and Bizkaia (Martínez and Adarraga, 2006).

The growing interest on AIS in Spain is palpable. The subject is being introduced in education. But a lot more needs to be done, mainly in terms of marine organisms. Even in the legal case, there isn't a specific chapter for the marine environment.

Even though Spain was one of the first signatories of the IMO Convention for the Control and Management of Ships Ballast Water and Sediments, in national legal terms, we lack coordination and the possibility of achieving fast decisions, as there is not a national strategy (although, it should be in place before 2010, according to Cristina Narbona, the then Spanish Environment Ministry). Furthermore, even though the law prohibits the possession, transport and trade of live or dead organisms, there are some gaps regarding the Precaution principle.

The present study shows the first records of nonnative marine and brackish species in Spain (excluding Canary Islands) (Table I). This list is based on the previous lists compiled by Cabal (2006; 2007) and modified based on records confirmed from the bibliography and information given by experts .

To date 132 marine and brackish species have been identified as nonnative. This list could be increased if the 49 not yet confirmed species are found to be also alien. From the currently identified as nonnative, 45 (i.e. 34.09 %) are seaweeds, 29 (i.e. 21.97 %) crustaceans and 16 (i.e. 12.12 %) mollusks. In 2007-2008 7 new records (or newly cited, although previously recorded) (* from Table I) were found: 2 seaweeds and one annelid from the Mediterranean coast of Spain and one seaweed, one protozoan and two mollusks from the Atlantic coast of Spain.

Table I. First records of nonnative marine and brackish species in Spain (excluding Canary Islands)

Species	Location	First record	Native Region	Invasion status	References
PHYTOPLANKTON					
Alexandrium cf. *catenella*	Balearic-Catalan sea, Mediterranean sea	1983	NW Pacific	established	(Margalef and Estrada, 1987) (as *Gonyaulax catenella*)
Alexandrium taylori	Catalonia, Mediterranean coast	1982		established	(Garcés *et al.*, 1999)
Gymnodinium catenatum	Galicia, Atlantic coast	1976	SW Pacific/debatable	established	(Estrada *et al.*, 1984)
Pseudo-nitzschia australis	Muros Ria, Galicia, Atlantic coast	1994	S Atlantic, New Zealand and California		(Miguez *et al.*, 1996)
PROTOZOA					
Marteilia refringens	Muros Ria, Galicia, Atlantic coast	1975		casual, spreading	(Alderman, 1979 ; Gutierrez, 1977a; b)
*Bonamia exitiosa**	Cambados, Galicia, Atlantic coast	2007	SW Pacific		(OIE, 2007)
Bonamia ostreae	Galicia, Atlantic coast	1981	NE Pacific	casual, spreading	(Alderman, 1979 ; Polanco *et al.*, 1984)
Photobacterium damselae subsp. *piscicida* (formerly *Pasteurella piscicida*)	Arosa Ria, Galicia, Atlantic coast	1990	NE Atlantic		(Toranzo *et al.*, 1991)
SEAWEEDS					
Acetabularia calyculus	Mallorca, Balearic Islands, Mediterranean sea	1957	Pantropical and subtropical	established	(Ribera Siguán, M.A. and Gómez Garreta, 1985; Valet, 1969)
Acrochaetium (Rhodothamniella) codicola / Audouinella codicola	Santander, Cantabria, Atlantic coast	1926	Atlantic (Canary Islands) (from Verlaque 1994)	established	(Miranda, 1931)
Acrothamnion preissii	Mallorca, Balearic Islands, Mediterranean sea	1994	W Pacific	spreading	(Ferrer *et al.*, 1994)
Anotrichium furcellatum	Minorca, Balearic Islands, Mediterranean	< 1983	NW Pacific	rare	(Pérez-Cirera *et al.*, 1989; Ribera Siguán, M.A. and Gómez Garreta, 1984)

Antithamnion algeriense = amphigeneum	Alboran Island, Mediterranean sea	1990	Indo-pacific	spreading	(Aranda, A. and Solano, 1999; Ballesteros, E. *et al.*, 1997; Gómez Garreta, A. *et al.*, 2001; Ribera Siguan and Soto Moreno, 1992; Verlaque, 1994)
Antithamnion densum	A Coruna Ria, Galicia, Atlantic coast (43º 22' N, 8º 23' W)	1984-1995	E Pacific		(Bárbara and Cremades, 1996; Veiga *et al.*, 1998)
Antithamnionella spirographidis	San Juan de Nieva, Cantabria, Atlantic coast	1927	NW Pacific	rare	(Ballesteros, E., 1981; Ballesteros, E. and Romero, 1982)
Antithamnionella ternifolia = A. sarniensis	Aviles Ria, Asturias, Atlantic coast	1927	S Pacific	established	(Miranda, 1931; 1936) (as *Antithamnionella sarniensis*)
Asparagopsis armata = Falkenbergia rufolanosa	Pontevedra Ria, Galicia, Atlantic coast	1933	SW Pacific	established	(Miranda, 1936; Seoane-Camba, 1965; Valenzuela and Pérez-Cirera, 1982)
Bonnemaisonia hamifera = Asparagopsis hamifera = Trailliella intricata	Torrequebrada, Benalmadena, Alboran sea (Mediterranean sea) and Catalan Sea (Mediterranean sea)	1975-80	Pacific	established	(Breeman *et al.*, 1988) (as *Bonnemaisonia hamifera*); (Ballesteros, E. and Romero, 1982) (as *Trailliella intricata*)
Caulerpa racemosa	Balearic Islands, Mediterranean sea	1998	Indo-Pacific	established	(Aranda, A. *et al.*, 1999; Ballesteros, E. *et al.*, 1999)
Caulerpa taxifolia	Mallorca, Balearic Islands, Mediterranean sea	1992	Caribbean and Indo-Pacific	established	(ICES-WGITMO, 1999; Pou *et al.*, 1993; Riera *et al.*, 1994)
Centroceras clavulatum	Bizkaia, Basque country, Atlantic coast	2004	SE Pacific	established	(Gorostiaga *et al.*, 2004)

Codium fragile ssp. *atlanticum*	Guipuzcoa, Basque country, Atlantic coast	1978	NW Pacific		(Casares-Pascual and Seoane-Camba, 1988a; Gorostiaga *et al.*, 2004)
Codium fragile	Spain	1957	NW Pacific	spreading	(ICES-WGITMO, 1999; Silva, 1957)
Codium fragile ssp. *tomentosoides*	Tossa de Mar, Catalonia, Mediterranean coast	1981	NW Pacific	established	(Ballesteros, E., 1981; Gómez *et al.*, 1981; Pérez-Cirera *et al.*, 1989)
Colacodictyon reticulatum	Arousa Ria, Galicia, Atlantic coast (42° 32.9' N, 8° 55.2' W)	1995-1997	NE Atlantic		(Bárbara *et al.*, 2004)
Colpomenia peregrina	Arousa Ria, Galicia, Atlantic coast	<1923		established	(Van Goor, 1923) (as *C. sinuosa*); (Ballesteros, E., 1983; Donze, 1968)
Dasya sessilis	Pontevedra Ria, Galicia, Atlantic coast	1989	NW Pacific		(Peña and Bárbara, 2006)
Dasysiphonia sp.	Port of Vigo, Galicia, Atlantic coast	1994	Pacific		(Bárbara *et al.*, 2002; Peña and Bárbara, 2002)
Dictyota ciliolata = *D. ciliata**	Palamos, Catalonia, Mediterranean coast	1987	Atlantic and Indian Ocean	established	(Rull Lluch *et al.*, 2007) (as *D. dichotoma*)
Dipterosiphonia dendritica	Barbate, Cadiz, Atlantic coast	1961-62	Pantropical		(Seoane-Camba, 1965; Soto, J. and Conde, 1987)
Gelidiella calcicola	Arousa Ria, Galicia, Atlantic coast (42° 32.9' N, 8° 55.2' W)	1995-1997	NE Atlantic		(Bárbara *et al.*, 2004)
Gracilaria vermiculophylla	A Coruna, Galicia, Atlantic coast	2003	NW Pacific		(Bárbara *et al.*, 2005; Rueness, 2005)
Grateloupia turuturu = *G. doryphora*	El Cantal, Malaga, Mediterranean coast	1988	NW Pacific		(Rull Lluch *et al.*, 1991) (as *Grateloupia doryphora*) ; (Cremades Ugarte, 1995) (as *Grateloupia doryphora*)

Grateolupia doryphora	Galicia, Atlantic coast	1990			(ICES-WGITMO, 1992)
Grateolupia filicina	Galicia, Atlantic coast	1990			(ICES-WGITMO, 1992)
Grateloupia luxurians	Arousa Ria, Galicia, Atlantic coast	1990	Indo-Pacific		López Rodríguez *et al.*,1991; Goulletquer *et al.*, 2002; Gorostiaga *et al.*, 2004
Grateolupia filicina var. *luxurians*	Guetaria, Guipuzcoa, Basque country, Atlantic coast	1978	Indo-Pacific		(Casares-Pascual and Seoane-Camba, 1988b; López Rodríguez *et al.*, 1991)
Heterosiphonia japonica = *Dasysiphonia* sp.	A Coruna Ria, Galicia, Atlantic coast (43º 22' N, 8º 23' W)	1990s	NE Pacific		(Bárbara and Cremades, 1996) (misidentified as *H. crispella* var *laxa*); (Bárbara *et al.*, 2002; Maggs and Stegenga, 1999)
Heterosiphonia crispella var. *laxa*	Coruna Ria, Galicia, Atlantic coast (43º 22' N, 8º 23' W)	1984-1995			(Bárbara and Cremades, 1996)
Hypnea spinella = *H. cervicornis*	Portals Nous, Mallorca, Balearic Islands, Mediterranean coast	1977			(Gómez Garreta, M. A. *et al.*, 1979) (as *H. cervicornis*)
Lomentaria hakodatensis	A Coruna Ria, Galicia, Atlantic coast (43º 22' N, 8º 23' W)	1992	NW Pacific		(Bárbara and Cremades, 1996; Bárbara *et al.*, 2005; ICES-WGITMO, 1992 ; Peña and Bárbara, 2002)
Lophocladia lallemandii	Cabo Cope, Aguilas, Murcia, Mediterranean coast	1987	Indian Ocean	spreading	(Patzner, 1999 (1998); Soto, J. and Conde, 1990)
Neosiphonia harveyi = *Polysiphonia harveyi*	Vigo Port, Galicia, Atlantic coast	1994	NW Atlantic	established	(Bárbara and Cremades, 1996) (as *Polysiphonia*); (Veiga *et al.*, 1998) (as *Polysiphonia harvegi*); (Bárbara *et al.*, 2003) (as *Polysiphonia*)

Petalonia zosterifolia	A Coruna, Galicia, Atlantic coast	1989	NE Atlantic		(Bárbara and Cremades, 1990)
Pikea californica	Galicia, Atlantic coast	1991	NEP, NWP		(Goulletquer *et al.*, 2002; ICES-WGITMO, 1992)
Pleonosporium caribaeum	Fuenterrabia, Gipuzcoa, Basque country, Atlantic coast	1986	Caribbean		(Casares-Pascual and Seoane-Camba, 1988b) (as *Mesothamnion caribaeum*); (Soto Moreno, 1991) (as *Mesothamnion caribaeum*); (Conde *et al.*, 1996) (as *Mesothamnion caribaeum*)
*Plocamium secundatum**	Mediterranean coast		SW Pacific	established	Rodriguez Prieto, unpublished (within (Zenetos *et al.*, 2008))
Sargassum muticum	Guetaria, Basque Country, Atlantic oast	1985	NW Pacific	spreading	(Casares Pascual *et al.*, 1987; Fernández *et al.*, 1990; Peña and Bárbara, 2002)
Scytosiphon dotyi	Ferrol Ria, Galicia, Atlantic coast	1988	Pacific		(Perez-Cirera *et al.*, 1991)
*Ulva pertusa**	A Coruna Bay, Galicia, Atlantic coast	1990	NW Pacific	established	(Baamonde López *et al.*, 2007)
Undaria pinnatifida	Arousa Ria, Galicia, Atlantic coast	1990	NW Pacific	spreading	(Fletcher and Farrell, 1999; ICES-WGITMO, 1999; Santiago Caamaño *et al.*, 1990)
Vaucheria erythrospora	A Coruna Ria, Galicia, Atlantic coast (43º 22' N, 8º 23' W)	1984-1995			(Bárbara and Cremades, 1996)
Womersleyella setacea (=Polysiphonia setacea)	Alboran Island, Mediterranean sea	1988/1992	NE Pacific	established	(Ballesteros, E. *et al.*, 1997; Rindi and Cinelli, 1995)
PLANTS					
Carpobrotus edulis	Minorca, Balearic Islands, Mediterranean sea	1824	South Africa		(Fraga i Arguimbau *et al.*, 2004; Fraga *et al.*, 2005)

Spartina alterniflora	Bidassoa estuary, Basque country, Atlantic coast	1806	NW Atlantic	established	(Chevalier, 1923)
Spartina densiflora	Gulf of Cadiz, Atlantic Coast	XVI century	SW Atlantic-SW Pacific	established	(Castillo, J. M. *et al.*, 2000; Castillo, Jesús M. *et al.*, 2005; Nieva *et al.*, 2005; Nieva *et al.*, 2003; Nieva *et al.*, 2001)
Spartina patens = S. versicolor = S. juncea	Estany del Remolar, Barcelona, Catalonia, Mediterranean coast	1947	NW Atlantic		(Bolós, 1947) (as *S. juncea*)
CNIDARIANS					
Actinothoe sphyrodeta	Mediterranean coast		SW Atlantic		(Williams, 1997)
Cordylophora caspia	Guadalquivir estuary, Gulf of Cadiz, Atlantic Coast	2001	Ponto-Caspian		(Escot *et al.*, 2003; García-Berthou *et al.*, 2007)
Eudendrium carneum	Spain	1986	W Atlantic-E Pacific	established	(Zenetos *et al.*, 2008)
Eucheilota paradoxica	Alboran sea, Mediterranean sea	1981	tropical and subtropical seas	established	(Dallot *et al.*, 1988; Zibrowius, 1991)
Forskalia edwardsi	Alboran sea, Mediterranean sea	1981	NW Atlantic, NE Pacific and Gulf of Mexico	established	(Dallot *et al.*, 1988)
Haliplanella lineata	Guadalquivir estuary, Gulf of Cadiz, Atlantic Coast	1996	NW Pacific		(Cuesta, J.A. *et al.*, 1996; García-Berthou *et al.*, 2007)
Oculina patagonica	Alicante, Mediterranean coast	1972	SW Atlantic	established	(Zibrowius, 1991; Zibrowius and Ramos, 1983)
ANNELIDS					
Boccardia proboscidea	Mompas, San Sebastian, Basque country, Atlantic coast	1996	Pacific		(Martínez and Adarraga, 2006; Martínez *et al.*, 2006)
*Branchiomma luctuosum**	Valencia, Mediterranean coast	2005	Indo-Pacific		(Haddad *et al.*, 2007)
Desdemona ornata	Bidassoa (43º 21'20" N; 01º47'40"W) and Pasajes (43º 19'32" N; 01º 55' 25" W), Bay of Biscay, Atlantic coast	1998	South Africa		(Ceberio *et al.*, 1998; Martínez and Adarraga, 2006)

Erinaceusyllis serratosetosa	Fornells, Menorca, Balearic Islands, Mediterranean sea	2003	SW Pacific	casual	(San Martín, 2003; Zenetos *et al.*, 2008)
Ficopomatus enigmaticus	Gandia, Alicante, Mediterranean coast	1924	SW Pacific	established	(Rioja, 1924) (as *Mercierella enigmatica*); (Fischer-Piette, E., 1937; 1951; 1955) (as *Mercierella enigmatica*)
Hesionura serrata	Barcelona (from 41º 28' N, 2º 19' E to 41º 20'N, 2º 10'E), Mediterranean coast	1990	Red sea	casual	(Cardell and Méndez, 1996; Zenetos *et al.*, 2008)
Novafabricia infratorquata	Ibiza Island, Mediterranean sea	1999	Caribbean sea	established	(Bick, 2005)
Pseudopolydora paucibranchiata	A Coruna, Galicia, Atlantic coast	1982	NW Pacific	established	(López-Jamar *et al.*, 1995; Parra and López-Jamar, 1997)
Spirorbis marioni	Port de la Selva, Girona, Catalonia, Mediterranean coast	1979	E Pacific	established	(Zibrowius, 1983; Zibrowius and Bianchi, 1981)
Streblospio benedicti	Foz Ria (43º 34'N; 7º 14'W), Galicia, Atlantic coast	1984-1985	NW Atlantic	established	(Aguirrezabalaga *et al.*, 1990; Junoy and Viéitez, 1990)
Syllis pectinans	Galicia (Atlantic coast) and Murcia (Mediterranean coast)	1982	S Pacific - Indian Ocean	rare	(Campoy, 1982) (as *Opisthosyllis* sp.); (San Martín, 2003)
MOLLUSKS					
Chaetopleura angulata	Galicia, Spain	Early 1900s	South America	established	(Hidalgo, 1917) (as *C. fulva*); (Kaas and Belle, 1987; Rolán *et al.*, 1985)
Chlamys lischkei	Alboran Sea, Mediterranean sea	1985	SW Atlantic	rare	(Zenetos *et al.*, 2004)
Corbicula fluminea	Guadiana River basin (37º 27' N, 7º 27'W), Andalucia, Spain	1988	SE Asia	spreading	(Araujo *et al.*, 1993; Pérez-Quintero, 1990)

Crassostrea gigas	Cadiz, Atlantic coast	1877	NW Pacific	frequent	(Hidalgo, 1839-1923; 1917) (as *Ostrea angulata*); (Poutiers, 1987; Rolán Mosquera *et al.*, 1989) (*as C.* virginica)
Crepidula aculeata	Alicante harbour, Mediterranean coast	1973	Tropics and subtropics.	established	(Zibrowius, 1991) (as *Crepidula calytraeiformis*); (Zibrowius, 2002) (as *Crepidula calyptraeiformis*)
Crepidula fornicata	Aldan Ria, Galicia, Atlantic coast	1977	NW Atlantic	established	(Blanchard, 1997; Rolán, 1983; Rolán *et al.*, 1985)
Crepipatella dilatata	Aldan Ria, Galicia, Atlantic coast	2005	SW Atlantic and SE Pacific	frequent	(Rolán and Horro, 2005)
Dreissena polymorpha	Ebro estuary, Catalonia, Mediterranean coast	2001	Black and Caspian Seas	spreading	(Altaba *et al.*, 2001); C. Altaba (ICES/IOC/IMO SGBOSV, 2002)
Fulvia fragilis	Valencia, Mediterranean coast	1991	Indian Ocean	rare	(Gofas and Zenetos, 2003)
Haminaea callidegenita	Arousa Ria and Eo Ria, Galicia, Atlantic coast	1992	Pacific	established	(Alvarez *et al.*, 1993)
Mytilopsis leucophaeta = Congeria leucophaeta	Guadalquivir estuary, Gulf of Cadiz, Atlantic coast	1993	Gulf of Mexico		(Escot *et al.*, 2003; García-Berthou *et al.*, 2007)
Potamopyrgus antipodarum	Galicia (Atlantic coast) and Barcelona (Mediterranean coast)	1950	SW Pacific		(Boettger, 1951) (as *P. jenkinsi*); (Vidal-Abarca and Suárez, 1985) (as *P. jenkinsi*)
*Rapana venosa**	Cambados (42º 31’43”N, 08º 50’52”W), Galicia, Atlantic coast	2007	NW Pacific		(Rolán and Bañón Díaz, 2007)
Ruditapes (Tapes) philippinarum	Atlantic coast	1980	NW Pacific		(Cigarría *et al.*, 1997; Goulletquer *et al.*, 2002)
Urosalpinx cinerea	Basque Country, Atlantic coast		NW Atlantic		(Martínez and Adarraga, 2005a)
*Xenostrobus secures**	Arcade, Vigo Ria, Galicia, Atlanctic coast	2002	SW Pacific	spreading	(Garci *et al.*, 2007; Santaclara *et al.*, 2007)

CRUSTACEANS					
Acartia tonsa	Veta la Palma (36º 57' N, 6º 14' W), Andalucia, Spain	1994	IP, NW Atlantic		(Frisch *et al.*, 2006)
Ampelisca cavicoxa	Bakio and Elantxobe, Basque Country, Atlantic coast	2005	W Africa and Red Sea		(Martínez and Adarraga, 2006; Martínez *et al.*, 2007)
Ampelisca heterodactyla	San Sebastian, Atlantic coast	1993	W Africa		(Borja *et al.*, 2000; Martínez and Adarraga, 2003)
Artemia franciscana	Huelva, Andalucia, Atlantic coast	1995	North, Central and South America	spreading	(Amat, F. *et al.*, 1995; Amat, Francisco *et al.*, 2005)
Balanus amphitrite	San Sebastian, Atlantic coast	1934	SW Pacific and Indian Ocean	established	(Goulletquer *et al.*, 2002)
Balanus eburneus	Port of Pasajes, Basque Country, Atlantic coast	1954	NW Atlantic		(Fischer-Piette, E and Prenant, 1956)
Balanus improvisus	Galicia (Atlantic coast) and La Bidassoa, Basque Country (Atlantic coast)	1955	NW Atlantic		(Fischer-Piette, E and Prenant, 1956)
Balanus trigonus	Bay of Biscay, Atlantic coast	?	SW Pacific, cosmopolitan of tropical and warm temperate seas		(Martínez and Adarraga, 2006)
Calappa pelii	Chafarinas Islands, Mediteranean sea	1991	E Atlantic		(Galil *et al.*, 2002)
Callinectes sapidus	Guadalquivir estuary, Gulf of Cadiz, Atlantic coast	<2002	NW Atlantic		(Cabal *et al.*, 2006; WWF, 2002)
Cryptosoma cristatum	Alboran Sea, Mediterranean sea	1987	Tropical easter Atlantic	one single record	(Galil *et al.*, 2002; García Raso, 1993)
Charybdis feriata	Barcelona (41º20' N, 2º13' E), Mediterranean coast	2004	Indo-Pacific	one single record	(Abelló and Hispano, 2006)
Elminius modestus	Bay of Betanzos, Galicia, Atlantic coast	1955	SW Pacific	established	(Crisp, 1958; Fischer-Piette, E and Prenant, 1956)

Eriocheir sinensis	Guadalquivir estuary, Gulf of Cadiz, Atlantic coast	1997	NW Pacific	established	(Cuesta, J. A. *et al.*, 2004; WWF, 2002)
Eocuma dimorpha	Zarautz, Guipuzcoa, Basque country, Atlantic coast		W African coast		(Martínez and Adarraga, 2005b; 2006)
Hemigrapsus takanoi (=H. penicillatus)	Laredo, Cantabria, Atlantic coast (43º25 'N, 03º20 'W)	1996	NW Pacific	spreading	(D'Udekem D'Acoz, 1999; Martínez and Adarraga, 2006; Noël *et al.*, 1997) (as *H. takanoi*)
Hexapleomera robusta	Atlantic coast	1996		spreading	(Martínez and Adarraga, 2006)
Hyale spinidactila	Fuenterrabia, San Sebastian, Atlantic coast (43º19,25' N, 01º54,08' W)	1992	Senegal coast (Atlantic)		(Arresti, 1996; Martínez and Adarraga, 2006)
Leptochelia dubia	Mar Menor, Murcia, Mediterranean coast	1984	Subtropical		(Pérez-Ruzafa and Sanz, 1993; Zibrowius, 1991)
Merhippolyte ancistrota	Alboran Sea, Mediterranean sea	1980	SE Atlantic	one single record	(d'Udekem d'Acoz and Ďuriš, 1996; Galil *et al.*, 2002)
Palaemon macrodactylus	Guadalquivir estuary, Gulf of Cadiz, Atlantic coast	1999	NW Pacific	established	(Cuesta, J. A. *et al.*, 2004; González-Ortegón and Cuesta, 2006)
Paracerceis sculpta	Gulf of Cadiz, Atlantic coast	1988	NE Pacific	spreading	(Castelló and Carballo, 2001; Drake *et al.*, 1997; Rodríguez and Arias, 1992)
Paradella dianae	Gulf of Cadiz, Atlantic coast	1988	NE-Pacific	spreading	(Castelló and Carballo, 2001; Drake *et al.*, 1997; Rodríguez and Arias, 1992)
Penaeus japonicus	Atlantic coast	1984	Indo-West Pacific	established	(FAO, 2000-2009)
Percnon gibbesi	Cap de Favaritx, Minorca, Balearic Islands, Mediterranean sea	1999	Indo-Pacific	established	(Galil *et al.*, 2002; Garcia and Reviriego, 2000)
Procambarus clarkii	Guadiana River, Gulf of Cadiz, Atlantic coast	1973	NE Mexico and South central USA.	spreading	(Habsburgo-Lorena, 1978)

Processa macrodactyla	Alboran Sea, Mediterranean sea	1980	SE Atlantic	one single record	(Galil *et al.*, 2002; Garcia-Raso and Salas Casanova, 1985)
Rhithropanopeus harrisii	Guadalquivir estuary, Gulf of Cadiz, Atlantic coast	1990	NW Atlantic		(Cuesta Mariscal *et al.*, 1991)
Scyllarus posteli	Cadiz, Atlantic coast	1974	Tropical and subtropical E Atlantic	established	(Galil *et al.*, 2002; Garcia Raso, 1982; Pozuelo *et al.*, 1976)
Sphaeroma walkeri	Mediterranean coast	1977	Indo-Pacific		(Jacobs, 1987)
Synidotea laevidorsalis = S. laticauda	Guadalquivir estuary, Gulf of Cadiz, Atlantic coast	1991	Indo-W Pacific	established	(Cuesta, J.A. *et al.*, 1996)
BRYOZOANS					
Tricellaria inopinata	Galicia, Atlantic coast	1996	Pacific		De Blauwe, H. and M.A. Faasse, 2001; Fernandez-Pulpeiro *et al.*, 2001
Watersipora subtorquata (= W. subovoidea)	Gibraltar, Atlantic coast	1905	SW Pacific		Barroso, 1917
ASCIDIANS					
Corella eumyota	Estrecho de Rande, Vigo Ria, Galicia, Atlantic Coast (42º17'42.9"N, 08º38'31.2"W to 42º17'41"N, 08º38'36"W)	2003	S Hemisphere (America, Africa, Australia, NZ, Antartida)		(Soto, S. *et al.*, 2006; Varela *et al.*, 2007)
Distaplia bermudensis	Ibiza, Balearic Islands, Mediterranean sea (38º49' N, 01º30'45'')	1953		established	(Pérès 1957; Zenetos *et al.*, 2008)
Microcosmus squamiger	Cubellas, Catalonia, Mediterranean coast	1976	Indo-Pacific	spreading	(Ballesteros, M., 1978) (as *M. claudicans*); (Turón, 1987) (as *M. exasperatus*); (Naranjo *et al.*, 1996)
Molgula manhattensis	Punta Nudillo, Ferrol Bay, Galicia, Atlantic coast (43º27'30"N, 08º13'14"W)	1903	NW Atlantic		(Hartmeyer, 1923; Vázquez and Urgorri, 1992)

Polyandrocarpa zorritensis	El Fangar, Ebro Delta, Mediterranean coast (37º49'40"N, 0º39'26"E)	1986	SE Pacific and SW Atlantic	established	(Turón and Perera, 1988; Zibrowius, 1991)
Styela canopus	Algeciras Bay, Mediterranean coast (36º13'N, 5º45'W)	<1989	W Pacific		(Naranjo *et al.*, 1996; Ramos Espla *et al.*, 1992)
Styela clava	Cambados, Arousa Ria, Pontevedra, Galicia, Atlantic coast (42º30' N 08º50' W')	1978	NW Pacific		(Ortea and Vizcaino, 1981)
Styela plicata	Ebro Delta, Mediterranean coast (41º12'N, 01º13'W)	1986	Unknown origin, Indo-Pacific putative native range		(Barros *et al.*, 2009; Perera *et al.*, 1990; Turón and Perera, 1988)
FISH					
Fundulus heteroclitus	Gulf of Cadiz, Atlantic coast	1857	NW Atlantic	established	(Fernández-Delgado *et al.*, 1986 ; Gutiérrez-Estrada *et al.*, 1998; Machado-Núñez, 1857)
Megalops atlanticus	Off coast of Asturias, Atlantic coast (43º28'N, 04º45'W)	2003	Tropical or subtropical Atlantic		(Arronte *et al.*, 2004)

*** New species since 2007**

References For sighting of new species

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Sweden, 2008

Prepared by Inger Wallentinus and Fredrik Nordwall

Highlights of the Swedish Report

The following introduced species were reported as new sightings:

- Round goby *Neogobius melanostomus* (a few caught in Karlskrona, S Baltic Sea)
- American lobster *Homarus americanus* (Swedish west coast, some with rubber bands on)
- The cladoceran *Evadne anonyx* (in small numbers in the Baltic Sea)
- The crab *Necora puber* (Swedish west coast, probably a range extension)
- The chironomid *Telmatogon japonicus* (on two offshore windmills in the S Baltic Sea)
- The diatom *Chaetoceros concavicornus* (Swedish west coast)

Changes for previously recorded organisms:

- The occurrences of the American comb jelly *Mnemiopsis leidyi* in the N Baltic proper and the Bothnian Sea have been questioned after genetic analyses in 2008-09, since the samples analyzed belonged to an Arctic comb jelly, *Mertensia* sp.
- The polychaete genus *Marenzelleria* is represented along the Swedish coasts of the Baltic Sea and Bothnian Sea by three species; *M. neglecta, M. arctica* and *M. viridis.*

A Swedish national strategy and action plan for alien species has been developed, but is not yet adopted.

1. Laws and Regulations

The Swedish government had commissioned the Swedish Environmental Protection Agency, the Swedish Board of Fisheries, the Swedish Forest Agency, and the Swedish Board of Agriculture to develop, in consultation with Swedish Customs, a national strategy and action plan in order to establish a system to manage the import, movement and release of alien species and genotypes. This project was coordinated by the Swedish EPA, and the national strategy and action plan for alien species and genotypes should generally show how Sweden should work nationally and internationally with alien species (Naturvårdsverket 2008).

There is at present no unified national legal framework for preventative work and eradication and control of invasive alien species in Sweden. Basic requirements should be that all animals, plants and microorganisms should fundamentally be covered by laws that regulate intentional and unintentional import and export, keeping, use, sale and release. It is proposed that an official study should be commissioned to investigate the possibilities to supplement existing regulations, as well as possibilities to create a comprehensive framework for alien species.

Present EU laws do not allow member states to unilaterally limit the trade and spread of invasive alien species that fall outside of regulations for plant protection, animal health and animal protection, as well as the use of alien species in aquaculture. At present, a unified regulatory framework at the EU level for the member states' management and regulation of invasive alien species is missing. Work is in progress to develop a common framework within the EU. The European Commission plans to develop a EU Strategy for invasive alien species in two steps. A communication on policy options for invasive alien species was presented in December 2008 (Council of the European Union 2008) and a proposal for a EU strategy is planned for April 2009. It is important that Sweden should actively participate in the development of this framework. A problem, however, is that this framework would not be applicable to movements of alien species within the EU.

2. Intentional Releases and Transfers

2.1 Finfish

Two permits to import Arctic char (*Salvelinus alpinus*) and rainbow trout (*Onchorynchus mykiss*) from Canada for farming purposes was given by the Swedish Board of Agriculture. However, the imports have not yet been conducted.

2.2 Invertebrates

A company has applied for permit to keep living red king crab, *Paralithodes camtschaticus*, from Norway in land-based facilities for the food market. However, so far (March 2009) their design of the facilities to be used have not been approved by the County Administration in Västra Götaland.

3. Unintentional Introductions

3.1 New sightings

Fish

A few specimens of the round goby *Neogobius melanostomus* were caught by an observant private person in Saltösund, in the outer part of the town of Karlskrona (N 56°9'52", E 15°34'10") in southern Sweden in July 2008. One specimen sent in for analysis was a 96 mm long male, about 2-3 years old (Gustaf Almqvist, Swedish Board of Fisheries, pers. comm.). So far these are the only records of the species reported from Swedish waters, despite its common occurrence in Gdansk Bay, Poland, at some sites in northern Germany, Estonia, Lithuania, and, a record from the Turku archipelago, Finland and a record near Bornholm in 2008 (see Denmark in this volume). The probable vector is shipping, since Karlskrona has intensive boat traffic with the Polish coast, including a ferry line to Gdynia.

A thesis on the ecology of the round goby in Polish waters was published a year ago (Almqvist 2008). At that time no Swedish record had been reported. The round goby was used as a case study for assessing the invasion process of an alien species into the Baltic Sea. Factors governing life history characteristics, traits that have enhanced the invasion, and ecological consequences for the Baltic Sea were assessed. Two diverging life history strategies of the round goby, related to habitat, were found: one towards early maturation and short population turnover time in sheltered areas, the other towards high growth rate and late maturation in exposed areas. During the spawning season females on average produced two batches. Lengths of spawning season and annual fecundity of round gobies in Gulf of Gdańsk were in the same range as in the donor region. The species was found to compete with juvenile flounder for space and food resources, and probably also other native species are affected in coastal areas. Round goby comprised a main food source for cod and perch, forming a new energetic pathway between mussels and predatory fish. It is predicted that the species must produce more than one batch per season to sustain a viable population. Low temperature in the northern Baltic Sea is expected to hamper the development of new round goby populations, however, the global climate change might change this situation. In the southern Baltic Sea a shortage of optimal reproduction habitats is suggested to moderate the rate of spread. Although round goby in the Gulf of Gdańsk seems to have passed abundance maximum, it is likely that the species will continue to be an important ecosystem component, at least in the southern Baltic Sea, in the future.

Invertebrates

In 2008 four American lobsters, *Homarus americanus,* were caught on the Swedish west coast, which all tested positively by genetic analyses carried out in Bergen, Norway (Øresland and Ulmestrand 2009). Another four analyzed specimens turned out to be European lobsters, as have previous suspicious records been. One of the four American ones was quite a large female (carapax length 105 mm) caught in May by trawling north of Skagen (N 58°23', E 10°41') at a depth of 80-100 fathoms. It can be assumed that this female had survived several changes of the exoskeleton. The other three, found just outside Smögen (N 58°21', E 11°14') in late September and October 2008, had a carapax length of 80-84 mm, about the normal size of American lobster imported live for the food market. Two of these also had their claws fixed by a red rubber band, implying they had been kept alive in the sea, further strengthened by the proximity to Smögen, where much shellfish is sold to the general public. According to Swedish rules it is illegal to keep American lobster alive in the sea, it can only be kept in closed saltwater systems. The annual import of American lobster to Sweden is around 150 metric tonnes, exceeding the catch of European lobsters. The Swedish Board of Fisheries announced they would pay 900 SEK for each proven American lobster, while a suspected one turning out to be European would be paid 500 SEK. The main reason is the risk of spreading the bacterial disease Gaffkemia, which might cause an extreme high mortality in European lobster (but cf. also the National Report from GB this year). Furthermore, the higher growth rate of the American lobsters could imply a greater risk of out-competing the European ones for food and hiding places. There is also a risk that imported living females already could be carrying spermatophores that a year later could be used for fertilizing the eggs.

The invasive Ponto-Caspian cladoceran crustacean *Evadne anonyx*, first recorded from the innermost part of the Gulf of Finland in 2000, was in 2008 occurring in large numbers in this Gulf (Anon. 2008). The same year it was also recorded for the first time in Sweden in small numbers at Swedish monitoring sites in the Baltic proper, from the Arkona Basin in the southern part (N 55° 00', E 14° 05') to the Landsort Deep and Askö in the northern part (N 58° 48', E 17° 37') as well as in the Bothnian Sea (Elena Gorokhova, Stockholm Univ., pers. comm.). A likely vector for its arrival in the Baltic Sea could be shipping on the rivers from the Caspian Sea. It is closely related to the native, cosmopolitan *E. nordmanni*, which has decreased in these areas during the last decade. This could be due to that the introduced *E. anonyx* has a higher reproduction rate. Both species have parthenogenesis as part of their life strategy.

A large male of the European velvet swimming crab, *Necora puber,* was first caught (Hansson 2009: 277) on the Swedish west coast in September 2007 in a Norwegian lobster trap at Måseskär (N 58°05', E 11°17'). Another male was caught in a lobster trap at Ramsö (N 58°50', E 11°05') in November 2008. In October 2008 two drifting cages, originating from Aberdeen, Scotland, with 15 live and several dead crabs in each, were spotted west of Hållö (N 58°20', E 11°13'). Since this species occur as far north as Scotland and is known to vary in abundance with winter temperatures, this is probably a range extension. It is not known if the ones caught alive in our waters also had come by drifting cages or as larvae.

All development stages of the marine chironomid *Telmatogon japonicus* were found in two offshore windmill parks (Utgrunden N 56°22'22'', E 16°14'55'', and Yttre Stengrund ca. N 56°10', E 16°0') south of the city of Kalmar in the southern Baltic Sea in 2007 (Brodin & Andersson 2008). There is a thorough discussion in the paper whether this is an alien species or not (cf. Kerckhof et al. 2007). However, since it here, as well as in many other areas, has been found not far from harbours, it was suggested that shipping has been a vector. The species was first identified in the Baltic Sea in Germany in the 1960s and in Poland in the 1970s (Brodin & Andersson 2008 and references therein). It was also found in the black zone at Kristineberg on the Swedish west coast in the early 1980s, but then not pointed out as an introduced species (Kronberg 1988: Table 1). Brodin & Andersson (2008) also suggested that the species might be both advantageous (e.g. food for birds in autumn and winter), but also disadvantageous by affecting native species.

Phytoplankton

The diatom *Chaetoceros concavicornis* was first seen on the Swedish west coast in 2007, when it was common in the eastern Kattegat all autumn from September, but was also present in the eastern Skagerrak (Karlson 2008). This species can be harmful to farmed fish due to the sharp long spines that can damage the gills. It was again seen in the autumn of 2008, but so far no damage has been reported from Sweden (Bengt Karlson, SMHI, pers. comm.).

3.2 Previous sightings

Invertebrates

In 2008 (Wrange 2008a) the Japanese oyster *Crassostrea gigas*, on the Swedish west coast has been found on many different types of substrate from living and dead *Mytilus edulis*, on two living *Ostrea edulis*, stones, rocks and gravels made up by shells, as well as on artificial substrates such as ropes, jetties, pontoons etc. They occur in an almost 300 km long area, from close to the Norwegian border and south to the city of Falkenberg (ca N 56°54', E 12°30'), province of Halland, and have also been reported from nearly all that area by the general public. The highest densities, exceeding 500 ind. m^{-2}, were seen on banks of blue mussels, especially in narrow sounds with rapid currents, where reefs had been formed. They are mainly seen between 0 and 1 m depth, but occasionally also occur down to 5 m and could have been underestimated in the sublittoral zone. The maximum size measured was 143 mm and samples from June showed that more than one size class was involved. The growth rate between November 2007 and June 2008 was estimated to on average 10-20 mm, while during an earlier 10-month period (October 2006 to July 2007) a maximum of 60-70 mm was measured. Reproduction *in situ* has been seen when the water temperature exceeded 20 °C, and settled larvae were observed in summer 2008. Very few dead shells were seen in June 2008, pointing to low winter mortality rates. The main areas with dead oysters were in very shallow areas, often exposed to air and low winter temperatures. According to Swedish law it is illegal for the general public to collect all kind of oysters (Wrange 2008b), which are the property of the owners to the water areas where they occur.

For the Swedish west coast (Tiselius & Friis Møller 2008), the comb jelly *Mnemiopsis leidyi* has been most common from August to October and had increased the maximimum abundances in 2008 compared to in 2007, from 2.2 ind. m^{-3} to 8.3 ind. m^{-3}. Biomass (estimated from length relationships) peaked around 20-25 g wwt m^{-3} in late August both years, however, in 2008 the main peak consisted of many small individuals, while in 2007 they were larger. The overall largest ones (> 50 mm) occurred in winter. The sampling was mainly carried out down to 20 m depth, but some additional net samples down to 30 m, revealed very few animals deeper down. Predation pressure by larger *Mnemiopsis leidyi* was mainly on calanoid copepods and it was estimated that the comb jelly population in 2007 could filter 5% and in 2008 15% of the water column each day in August, while that by larvae on microzooplankton was estimated to 11% and 8%, respectively. Thus there could be a regulating effect on copepods. Reproduction followed close after the period of maximum predation.

For the Baltic Sea, a research report on Internet from October 2008 (Lehtiniemi & Flinkman 2008) stated that Finnish and Swedish scientists on board the Finnish RV Aranda had studied the reproduction and nutrient consumption of *Mnemiopsis leidyi* in the northern Baltic areas. They concluded that the numbers of *M. leidyi* in September had increased considerably in both the Gulf of Finland and the Åland Sea, since the monitoring carried out in August, and were at the same level as the peak winter figures the year before. In September most animals occurred near the halocline layer at 30-90 m depth (maximum 4490 ind. m^{-2}). In the Bothnian Sea, however, the numbers had continued to decrease. Large quantities of ctenophore eggs were also found.

However, in later reports (Anon. 2009, Press release, Stockholm university 2009, Gorokhova et al. submitted), written when genetic analyzes of the individuals sampled in September 2008 and January 2009 had been performed by scientists from Stockholm University, it turned out that all comb jellies in these samples in fact belonged to an Arctic comb jelly, *Mertensia* sp., most likely *M. ovum.* It might be possible that *Mnemiopsis leidyi* does not occur in the northern Baltic Sea and the Gulf of Bothnia, and that *Mertensia* sp. was the one seen also in 2007 (Press release, Stockholm university 2009, Elena Gorokhova, Stockholm univ., pers. comm.). Thus it may take a while before it can be concluded how many species of comb jellies there are in the Baltic Sea. It was also concluded (Anon. 2009) that the number of comb jellies this winter had increased by 70% in the Gulf of Finland in comparison to the previous winter, while no increase was seen in the other areas. The species composition, however, could not yet be confirmed.

Since the polychaete *Marenzelleria* was established in the Baltic Sea there has been much confusion about which species of the genus are present in samples from this area, due to difficulties in separating them based on morphological characters. Blank et al. (2008) have used a newly developed PCR/RFLP protocol to discriminate between the species *M. viridis, M. neglecta* and *M. arctica*, which are known to be present in the Baltic area. This protocol was supplemented by analyses of mitochondrial DNA sequences. They concluded that only *M. viridis* occurs in the Öresund and the south-western part of the Baltic, as well as on the North Sea coast. Further east *M. viridis* could often be found together with *M. neglecta*, although at some sites in lower abundance. At one site in the Bothnian Sea, *M. viridis* co-occurred with *M. arctica,* the latter mostly was the species being found in the Bothnian Sea and the Bothnian Bay. *M. neglecta* occurred both in the southern, middle and northern part of the Baltic proper. The authors also discussed the possibility that the quite recent increases in abundance of *Marenzelleria* in some northern areas could be due to the establishment of *M. arctica.* They also suggested that *M. arctica* might have arrived by ship's ballast water from the European Arctic. In all they urged for more genetic analyzes to be used to unravel the current species distribution in the Baltic Sea.

The establishment of *Marenzelleria* in the Gulf of Bothnia, northern Sweden, coincided with a decline in abundance of the amphipod *Monoporeia affinis.* In a recent paper (Wiklund et al. 2008) it was shown experimentally that the reproductive outcome of *M. affinis* was not affected by the presence of the polychaete. Other studies have shown that bioturbation caused by the deep-burrowing of *Marenzelleria* spp. could cause releases of organic contaminants from sediments (Granberg et al. 2008), but the polychaete also both buried and remobilised cadmium, thus contributing to complex interactions between sediment and water (Hedman et al. 2008).

For the Swedish west coast, in 2008 low numbers (2-176 ind. m^{-2}) of *M.* cf. *viridis* were found in quite shallow areas (0.2-9 m depth) at a few sites from Kullavik, south of Göteborg, (ca. N 57°33', E 11°55') to Skanör (ca N 55°25', E 12°50'), in the southern part of the Öresund (Peter Göransson, Miljökontoret Helsingborg, pers. comm). As reported last year (WGITMO 2008) in those areas only the true *M. viridis* has been seen, as shown by genetic analyses.

For the Chinese mitten crab, *Eriocheir sinensis,* the trend of decrease in abundance continued in 2008 (cf. WGITMO 2008), and even fewer individuals were caught in the lakes of Vänern and Mälaren than the year before (Marcus Drotz, Vänermuséet, pers. comm.). There are several reports from single catches of this crab both from the coasts and from inland waters, but there have been NO reports of mass migrations.

The potential of the introduced predatory cladoceran *Cercopagis pengoi* to influence native zooplankton populations was studied in the Baltic Sea (Lehtiniemi & Gorokhova 2008). Feeding rates of different instars of *C. pengoi* on *Eurytemora affinis,* a dominant native copepod species, were determined experimentally. Based on the experimental results and long-term zooplankton abundance data from the Gulf of Finland, the *in situ* predation rates were estimated, implying that at maximum abundance, the *C. pengoi* population feeding in dense prey patches could consume as many as 10^5 *E. affinis* m^{-3} d^{-1}. This could, at least partially, explain the observed drastic decrease in copepod abundances in the eastern Gulf of Finland, the region with the highest *C. pengoi* abundance after the expansion of this species. Such a decline may strengthen food competition between other zooplanktivores, i.e. planktivorous fish and mysids, feeding on the same copepod prey in regions where *C. pengoi* may reach high abundances.

There are several recent publications on the introduced copepod *Acartia tonsa* (Calliari et al. 2008, Tiselius et al. 2008, Andersen Borg 2009). *A. tonsa* is a very euryhaline species that can withstand also high salinity fluctuations in comparison with the more salinity dependent native *A. clausi.* Populations of *A. tonsa* could also sustain the conditions in a shallow hypertrophic estuary despite adverse abiotic conditions and high predation rates on young stages by mussels.

<u>Macroalgae</u>

In the southern Bothnian Sea, the stonewort *Chara connivens* is now quite common in suitable bays, i.e. quite exposed shores with substrate of sand and gravel, in the northern part of the province of Uppland (northernmost locality N 60°38', E 17°40'; southernmost N 60°19', E 18°37'; Gustav Johansson, Hydrophyta Ekologikonsult, pers. comm.). There have, however, been some doubts that the Swedish records represent the "true" *C. connivens,* which occurs further south in Europe. Thus genetic studies will be carried out to compare these two, as well as comparing it with *C. globularis* from the same Swedish sites (Gustav Johansson, Hydrophyta Ekologikonsult, pers. comm.).

There are no reports of changed distributions for other introduced macroalgae. For *Bonnemaisonia hamifera* a recent paper (Nylund et al. 2008) describes how an isolated poly-brominated 2-heptanone inhibits bacterial colonisation on the algal surface. Tests with this compound coated on submerged panels showed significantly lower numbers of bacteria compared to controls.

3.3 Not Yet Seen Species

<u>Finfish</u>

The "Alert list" for risk species occurring or having been recorded in other North European countries, i.e. having a potential of reaching Swedish coastal waters, includes the following fish species (www.frammandearter.se):

Carassius gibelio	<u>*Neogobius fluviatilis*</u>	*Oncorhynchus kisutch*
<u>*Cyprinus carpio*</u>	<u>*Neogobius gymnotrachelus*</u>	<u>*Percottus glenii*</u>
<u>*Lepomis gibbosus*</u>	*Oncorhynchus gorbuscha*	<u>*Proterorhinus marmoratus*</u>

Underlined names are mainly occurring in lagoons and estuaries with low salinities

Invertebrates

Since first recorded in the Baltic Sea in 1975, the North American crustacean amphipod *Gammarus tigrinus* has since the late 1990s been increasing in abundance in many countries (Orav-Kotta et al. 2009 and references therein), including in rivers. These authors also reported that it substantially reduced the survival of the native species *G. salinus* in summer, when occurring together in the brown alga *Pilayella littoralis.* However, so far there are NO reports of this species from the Swedish coasts. It is not known if this is due to that species within this genus often are not separated, but lumped together as *Gammarus* spp. This may also be the reason for that here are NO reports of the Ponto-Kaspian aggressive predator *Dikerogammarus villosus*, which occurs in the Oder lagoon in the southern Baltic Sea as well as in many rivers in northern Europe, where it also may outcompete *G. tigrinus*.

Although the sea squirt *Styela clava* occurs in quite shallow waters in Denmark (Hansson 2009: 319), there are NO reports from the Swedish west coast.

There are NO reports from Swedish waters of the two *Hemigrapsus* crab species (Hansson 2009: 276-277), although they are increasing in the Netherlands and Belgium, and in northwestern Germany (see National Report from Germany, WGITMO 2008).

The blue crab *Callinectes sapidus* was found in Denmark at Skagen in January 2007, but there are NO records from the Swedish west coast (Hansson 2009: 277).

The "Alert list" for risk species occurring or having been recorded in other North European countries, i.e. having a potential of reaching Swedish coastal waters, includes the following invertebrates (www.frammandearter.se):

Mainly the Swedish west coast	Mainly the Baltic Sea	Mainly Baltic lagoons and estuaries
Bougainvillia rugosa	*Maeotias marginata*	*Lithoglyphus naticoides*
Rapana venosa	*Mytilopsis leucophaeata*	*Branchiura sowerbyi*
Ficopomatus enigmaticus	*Dreissena bugensis*	*Paranais frici*
Limulus polyphemus	*Dreissena polymorpha**	*Limnomysis benedeni*
Balanus amphitrite	*Boccardia redeki*	*Paramysis lacustris*
Elminius modestus	*Tuboficoides pseudogaster*	*Chaetogammarus ischnus*
Ameira divagans	*Cornigerius maeoticus*	*Chaetogammarus warpachowskyi*
Caprella mutica	*Corophium curvispinum*	*Dikerogammarus haemobaphes*
Corophium sextonae	*Dikerogammarus villosus*	*Obessogammarus crassus*
Callinectes sapidus	*Gammarus tigrinus*	*Pontogammarus robustoides*
Hemigrapsus takanoi	*Gmelinoides fasciatus*	*Orconectes limosus*
Hemigrapsus sanguineus	*Orchestia cavimana*	*Rhithropanopeus harrisii*
Paralithodes camtschaticus	*Victorella pavida*	
Tricellaria inopinata		
Styela clava		

*** Occurs in freshwater in Sweden**

Macroalgae

There has been NO record of the Japanese brown alga *Undaria pinnatifida* on the Swedish west coast (the Baltic Sea would be too brackish), although it occurs in Dutch waters. Nor has the red alga *Antithamnion japonicum*, recorded in western Norway in autumn 2007, been found in Swedish waters.

4. Parasites, Pathogens and Other Disease Agents

Sweden declared, to the European Commission, diseased free status from the two parasites *Bonamia ostrae* and *Marteilia refringens* in atumn 2008. A new form of *Yersinia rückeri* was observed in a rainbow trout farm in the coastal zone of northern Sweden (Köpmanholmen, ca N 63° 11', E 18° 40').

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United Kingdom, 2008

Prepared by Ian Laing, CEFAS

Overview:

Two marine invertebrate species were recorded for the first time in the UK in 2008. The invasive ascidian *Didemnum vexillum* was found in harbours at Plymouth, Devon and Holyhead, Anglesey. The bryozoan *Watersipora subtorquata* was also found at Plymouth and at Poole Quay, Dorset.

There have been records of new locations for freshwater fish species either not previously reported in the wild or in areas outside the species' previous distribution. For example, fathead minnow *Pimephales promelas* has been reported for the first time in waters other than private garden ponds. And the distribution of sunbleak, *Leucaspius delineatus*, previously believe to be limited to southwest England (i.e. not further East than the county of Hampshire), has been confirmed for sites in the counties of East Sussex and Kent.

There is increasing concern from statutory nature conservation bodies on the continuing natural recruitment of Pacific oysters in the wild.

Outbreaks of Bonamia have occurred in two new areas.

Regulations

During a debate on invasive non native species in the Scottish Parliament on 30 October 2008, Mr Richard Lochhead (Cabinet Secretary for Rural Affairs and the Environment) asked the Scottish Working Group on Invasive Non Native Species to "take forward work to complete a legislative review on invasive non native species for Scotland, to identify gaps in the legislative framework and how we might best resolve these". The Scottish Working Group on Invasive Non Native Species has started work on this issue and will report back to the Parliament with the findings.

The UK Government published a joint (England, Wales, Scotland) response to the consultation on its Invasive Non-Native Species Framework Strategy (Defra 2008a).

The Invasive Non-native Species Framework Strategy for the UK was launched on 28th May 2008 (Defra 2008b). It is intended to provide a strategic framework within which the actions of government departments, their related bodies and key stakeholders can be better co-ordinated. It focuses efforts via the three-pronged approach agreed under the Convention on Biological Diversity, emphasizing prevention measures, early detection and then carefully considered appropriate action. Its overall aim is to minimise the risks posed, and reduce the negative impacts caused, by invasive non-native species in Great Britain. A working group consisting of key stakeholders from industry, Non Governmental Organisations and government drafted this strategy. Final versions are available at http://www.nonnativespecies.org/02_GB_Coordination/08_Strategy_Working_Group.cfm

During 2008, the Scottish Government commissioned the 2nd phase of development of the Great Britain Non-native Species Risk Analysis Scheme, and this was completed in September 2008 but has not yet been published. However, the screening tool for identifying potentially invasive freshwater fishes is available for free download (http://www.cefas.co.uk/4200.aspx) following calibration and validation (Copp *et al.*

2009), with versions available in English and Spanish. A similar calibration exercise has been completed for pre-screening freshwater invertebrates (Tricarico *et al*. unpublished).

Intentional introductions:

<u>Fish</u>

Summaries of imports of salmonid eggs into the UK can be found in Finfish News (for England and Wales, http://www.cefas.co.uk/news-and-events/finfish-news.aspx) and FRS survey reports (for Scotland, http://www.marlab.ac.uk/Delivery/Information_resources/information_resources_view_documents.aspx?resourceId=23693). UK export statistics are also presented in these publications. Seventeen different live fish species were imported from 13 other EU member states, for farming or human consumption.

<u>Invertebrates</u>

Deliberate releases of Pacific oysters for cultivation continue at a similar level to that in previous years. Stock was imported from France (5 consignments), Ireland (2 consignments) and the Channel Islands (47 consignments). A study described by Syvret (2008) assigned regions around the British coastline as high, medium and low risk from natural recruitment, according to temperature profiles. Highest risk regions, where recruitment is likely in most years, are south and southeast England. There are already extensive beds of naturally recruited Pacific oysters in some of the estuaries of southeast England. Climate change predictions were applied into this assessment and it was concluded that the medium risk regions, including Northern Ireland, Wales and Southwest England, would become high risk by 2040.

Statutory nature conservation organisations are seeking to impose restrictions on cultivating Pacific oysters in designated areas. The shellfish industry is concerned that this will be a serious constraint to legitimate business. Discussions between the two groups are ongoing.

Imports of non-native species of live bivalve molluscs and crustaceans for human consumption continues, although apparently no new species were in trade. About 420 tonnes of live Canadian/American lobsters were brought in to the UK.

Unintentional introductions:

<u>New Sightings</u>

The invasive ascidian *Didemnum vexillum* was found in harbours at Plymouth, Devon (single colony) and Holyhead, Anglesey (several colonies). Two colonies of the bryozoan *Watersipora subtorquata* were also found at Plymouth and one on a settlement plate at Poole Quay, Dorset. Full details are on the ICES data sheet.

The only new fish species record in the UK reported in 2008 was for a dead specimen of giant snakehead *Channa micropeltes* (Cuvier, 1831), confirmed by R. Britz (Natural History Museum) from photographs. In March 2008, it came to light that in late February 2008, an angler had reported the capture by rod and line of a single specimen of giant snakehead from a stretch of the River Witham adjacent to the village of North Hykeham, Lincoln, Lincolnshire, England (Lat: 53°10′35″ N, Long: 0°34′27″ W). The angler stated that the giant snakehead took bait intended for northern pike *Esox lucius*, however it later transpired that this was a hoax (G.D. Davies, Environment

Agency, personal communication). The specimen had in fact been found dead, washed up on the bank, and is thus assumed to have been an abandoned aquarium pet fish.

Previous Sightings

Fish

No new records of have been received for topmouth gudgeon *Pseudorasbora parva*, which continues to be eradicated from waters in the UK that warrant special protection from this highly invasive species (Britton *et al*. 2008).

A few specimens of pumpkinseed *Lepomis gibbosus*, a North American centrachid sunfish, were reported for Ifield Brook (Latitude: 51°06′51″ N; Longitude: 0°13′22″ W), a small tributary of the River Mole to the east of Crawley (West Sussex). The Mole catchment was one of the first into which pumpkinseed were introduced in the late 19th or early 20th century, so this report is not exceptional.

The sunbleak, which was previously thought to have an introduced range extending westward from the River Test (Hampshire), has been found in East Sussex and Kent. In addition to an overlooked report of sunbleak in a still water near East Grinstead, West Sussex in 2003 (K.J. Wesley, personal communication), the species was confirmed during 2008 in still waters near Uckfield, East Sussex, and near Royal Tunbridge Wells, Kent (G. Zięba & G.H. Copp, unpublished).

Invertebrates

The Chinese Mitten crab (*Eriocheir sinensis*) is newly reported to be present in the Dee and Duddon estuaries in northwest England by the Environment Agency and a single specimen, a berried female, was caught by a fisherman off Littlehampton in southern England in November 2008. The Natural History Museum (NHM) has put up some web pages devoted to this species (http://www.nhm.ac.uk/nature-online/life/other-invertebrates/chinese-mitten-crabs/index.html). The NHM also produced a report that concluded that a commercial fishery for Mitten crabs in the River Thames was feasible. Publication of the report is pending results from further studies on food safety of crabs from the river.

The Asian Clam, *Corbicula fluminea* invaded British waters in 1998. It remained confined to an isolated network of rivers in Eastern Britain until 2004, when it was discovered in low densities in the River Thames, London. *C. fluminea* has now been discovered at three more sites on the tidal River Thames. Surveys indicate that the clam has now established dense populations at Ham, with evidence of annual recruitment. Given the substantial connectedness of the Thames to many of Britain's other rivers, it is likely that it will now continue to spread through Britain's waterways (Elliott and zu Ermgassen, 2008).

It has been confirmed by a recent re-examination of the specimens that the breeding population of alien crayfish first detected within the River Lee system of North London in 2004 is the virile crayfish (*Orconectes virilis*) and not the spiny-cheek crayfish (*Orconectes limosus*) (Ahern *et al*, 2008).

The Bangor Mussel Producers Association, in conjunction with the Countryside Council for Wales, as the statutory nature conservation agency, have developed a Code of Good Practice for mussel seed movements to prevent introduction or spread of alien species. This follows from the accidental introduction and subsequent successful eradication of slipper limpets (*Crepidula fornicata*) to the Menai Strait in early

2007. Eight species are specifically addressed in the Code. As well as slipper limpets these include Violet sea squirt (*Botrylloides violaceus*), Carpet sea squirt (*Didemnum vexillum*), Solitary sea squirt (*Corella eumyota*), American jack knife clam (*Ensis americanus*), Chinese mitten crab (*Eriocheir sinensis*), Veined rapa whelk (*Rapana venosa*), Wakame (*Undaria pinnatifida*).

It is reported that the hard shell clam (*Mercenaria mercenaria*) is recruiting from a cultivation site in the Rover Roach, Essex.

Joaquín Vierna, a PhD student from the University of La Coruña (NW Spain) has been supplied with specimens of American razor clam (*Ensis directus*) from the Wash. He is making a phylogeographic study of the species in Europe.

Algae and higher plants

Sargassum muticum is considered to be now widespread on the Scottish west coast.

Species Not Seen Yet

The Japanese oyster drill *Ocinebrellus inornatus* is causing major problems in oyster culture in several countries including France and might be introduced with consignments of oysters for ongrowing. The turbellarian flatworm *Pseudostylochus ostreophagus* is also a major predator of Pacific oysters, attacking primarily young spat. It has also become well adapted in various oyster-growing bays in France where it has been accidentally introduced.

Two of the best known of the Ponto-Caspian fishes, the round goby *Neogobius melanostomus* and the tubenose goby *Proterorhinus marmoratus*, have spread across much of Europe via rivers and canal connections between river catchments. Given that river ships do not employ ballast water systems, the dispersal of Ponto-Caspian gobies is believed to be as 'hitch-hikers' (hull fouling) of river ships. Both round and tubenose goby have been recorded in the lower sections of the River Rhein (van Beek 2006, von Landwüst 2006). As such, these species are amongst the most likely of the Ponto-Caspian gobies to disperse to the UK as boat 'hitch-hikers'. Species in captivity only but not yet reported in the wild (but likely to) are the red shiner *Cyprinella lutrensis*, an aquarium fish, and the silver carp *Hypophthalmichthys molitrix*, a species used in aquaculture to help control phytoplankton levels. A number of these species have been the subject of a horizon-scanning exercise, initiated in 2008, regarding potential future invasive species (Parrott *et al*. 2009).

Pathogens

Bonamia ostreae was confirmed in a new area off the North Kent coast. The original positive sample was taken in late 2007 from a private bed of native flat oysters in the River Thames estuary. These oysters were originally moved from wild beds in the public fishery in an adjacent area. It is not known how the pathogen may have been introduced but boats that fish in infected areas also visit this fishery. This pathogen was also detected in Strangford Lough, Northern Ireland, for the first time in 2008.

A survey of Gaffkaemia in European lobsters landed from fished areas around the coasts of England and Wales has shown that the causative organism, *Aerococcus viridans* is present in lobster samples from South Wales and off Selsey Bill.

There were three outbreaks of crayfish plague (*Aphanomyces astacti*) in native white-claw crayfish at Bristol, Colchester and Derbyshire in 2008.

Meetings

Past

A major event in 2008 was the "Expert Workshop on Best Practices for Pre-import Screening of Live Animals in International Trade", which was held in South Bend, Indiana, USA on 9–11 April 2008. The workshop addressed the complex inter-related fields of biological science, economics, social norms, and international laws and institutions, with discussion covering a range of tools, processes/procedures, regulations and their applicability to pre-import risk screening for species of live animals in international trade.

An equally major meeting was held in Florence, Italy, 5–7 November 2008 on '*Managing Alien Species for Sustainable Development of Aquaculture and Fisheries*' during which papers and discussions examined strategies needed to develop sustainable and profitable aquaculture and fisheries across the world with respect to invasive aquatic species.

The 5th European NEOBIOTA Conference ' Towards a Synthesis' was held in Prague, Czech Republic, on 23–26 September 2008.

Introduced and invasive species topics were addressed in a number of wider, more generic meetings during 2008, including: the EIFAC symposium in Antalya, Turkey, 21–24 May 2008 on '*Interactions between Social, Economic and Ecological Objectives of Inland Commercial and Recreational Fisheries and Aquaculture*'; the 3rd European Pond Conservation Network workshop in Valencia, Spain, 14–16 May 2008; the Annual Scientific Meeting of the Freshwater Biological Association in London on 15–16 June 2008; the annual conference of the American Fisheries Society in Ottawa, Canada, August 2008 '*Fisheries in Flux: How do we ensure our sustainable future?*'; EURECO-GFOE conference on 'Biodiversity in an Ecosystem Context', Leipzig, Germany, 15–19 September 2008; and the annual conference of the Ornamental & Aquatics Trade Association, OATA annual conference, Buxton, England, 27–28 October 2008.

RPS Environmental Consultancy ran a workshop "Keeping up with Non Native Species Event", 10-11th June 2008.

The Scottish Natural Heritage Sharing Good Practice event on controlling invasive non-native species in freshwaters and wetlands: tools for success was held on 11th November 2008.

A GB Non-native species Stakeholder Forum was held on May 29th. The GB Non Native Species Programme Board and Secretariat ran this event.

A Ballast water treatment technology Review Group was held during the Marine Environment Protection Committee 58 meeting on 6-10th October 2008.

Future

The 16th International Conference on Aquatic Invasive Species (www.icais.org) will be held from 19th - 23rd April 2008 in Montreal, Québec, Canada.

The Ornamental Fish International Conference on '*Invasive Alien Species*' will be held in Suntec, Singapore, Malaysia on 30 May 2009.

The Sixth International Conference on Marine Bioinvasions will be held in Portland, Oregon in August 2009 (http://www.clr.pdx.edu/mbic/index.html).

The 2009 International Conference on Ecology & Transportation, Duluth, Minnesota, USA, 13–17 September 2009, which has invasive species issues as a sub-topic of virtually all sessions.

BIOLIEF conference - World Conference on Biological Invasions and Ecosystem Functioning, Porto, Portugal, 26–30 October 2009.

Ecology of Insular Biotas II, Wellington, New Zealand, 1–5 February 2010, will focus on ecological patterns and processes of particular importance to isolated biotas, including true islands, natural habitat islands (e.g. ponds), and artificial habitat islands (e.g. reserves).

Island Invasives: Eradication and Management, Auckland, New Zealand, 8–12 February 2010, will continue to have 'islands' and 'eradication of invasive species' as the focus, with emphasis on the work done and results or learning achieved.

RPS (an international environmental consultancy) has a number of upcoming workshops related to non-native species (www.nsnuk.org). These are:

- Identification of non-native amphibians and reptiles.
- Identification of non-native freshwater invertebrates
- Keeping up with non-native species
- Identification of marine seaweeds and macro-invertebrates.

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United States, 2008

Prepared by: Paul Fofonoff and Greg Ruiz, Smithsonian Environmental Research Institution; and Judith Pederson, MIT Sea Grant College Program

New Legislation

No new legislation on introductions and transfers of marine organisms has been passed by the U.S. government in 2008. In early 2009, new legislation has been proposed in the U.S. House of Representatives and in the U.S. Senate, to address ballast water issues and intentional introductions; this legislation is under consideration by has not been enacted to date.

Although it is not a new law, the U.S. Environmental Protection Agency (EPA), which is responsible for permitting discharges into U.S. waters, has lost a law suit in California which has implications for ballast water management throughout the U.S. The U.S. EPA is now required to regulate ballast water and has issued a general permit to allow commerce to continue as they develop an approach for permitting ballast water discharges. It is likely that this will occur in conjunction with the U.S. Coast Guard who manages ballast water compliance for the U.S.

Intentional introductions

Currently pending is a proposal to the U.S. Army Corp of Engineers (USACOE) to release *Crassostrea ariakensis* into the Chesapeake Bay. Although the principles of the ICES Code of Practice were referenced in the Preliminary Environmental Impact Statement that the USACOE prepared, the USACOE did not request a formal response from ICES. Thus, although the Maryland Department of Natural Resources requested a response from the WGITMO, no response was prepared.

The options under consideration (alone or in combination) are to: 1. approve *C. ariakensis* releases, 2. approve restoration of *Crassostrea virginica* and release of *C. ariakensis*, and 3. restore *C. virginica*. Several states around the Chesapeake and further north (e.g. New York State) have objected to release of non-native oysters, the federal government can grant an individual state permission to release *C. ariaken*sis. The final Environmental Impact Statement will be released shortly.

Accidental introductions and transfers.

<u>Fish</u>

Atlantic/Gulf Coasts

Lionfish of the *Pterois miles/volitans* complex, native to the Indo-Pacific, continue to be reported through the Caribbean basin and on the southern Atlantic coast of the US. [Both species have been identified in US waters by genetic methods, but are not easily separated (Hamner *et al*. 2007)]. Lionfish were first seen in Biscayne Bay, Florida, in 1993, probably released from aquaria, and were discovered to be well-established in waters off North Carolina in 2000. In 2008, no major range extensions were reported in mainland US waters, but first sightings were reported in Puerto Rico, the US Virgin Islands, the Dominican Republic, Haiti, Jamaica, Belize, the Turks and Caicos Islands, the Cayman Islands, and Colombia (USGS Centre for Aquatic Resource Studies 2009). This species is becoming an important resident of tropical Atlantic waters. A field experiment in the Bahamas, using transplanted native reef fishes and lionfish on natural and artificial patch reefs showed that lionfish reduced native fish recruitment by 79% (Albin and Hixon 2008). Albin and Hixon suggest that, while eradication is impossible, control of this predator at strategic locations may be advisable.

A single specimen of another marine aquarium fish, Brushtail Tang, *Zebrasoma scopas*, was seen by a trained observer off Fort Lauderdale, Florida (USGS Centre for Aquatic Resource Studies 2009). An earlier sighting of this species, off Boca Raton, was reported in 2001 (R.G, Gilmore, personal communication)). This is one of at least 24 exotic marine aquarium species, mostly Indo-Pacific natives, which have been seen in Florida waters (Semmens *et al*. 2004**;** USGS Centre for Aquatic Resource Studies 2009) in the last two decades. Most of these records are single specimens. So far, only the lionfish is known to have established populations in US Atlantic/Gulf of Mexico/Caribbean waters.

Invertebrates

Atlantic/Gulf Coasts

Littorina littorea - The sometimes contested status of the Common Periwinkle, widely believed to be an early invader to the Northwest Atlantic, has been largely resolved by several published studies this year. *Littorina littorea* was collected in 1840 in Pictou, Nova Scotia. Its range subsequently expanded to reach Labrador by 1882 and Virginia by 1971. While many malacologists accepted its introduced status, the presence of a Pleistocene fossil shell from Nova Scotia, and the occurrences at archeological sites in Newfoundland (1000-1300 BP) raised doubts about the status of this snail in US and Canadian waters. A molecular study (Wares *et al*. 2002) suggested that western Atlantic populations had genotypes not found in European populations, and were native. More extensive studies (Blakeslee and Byers 2008; Blakeslee *et al*. 2008), involving broader sampling of *L. littorea* and native *Littorina* species (*L. obtusata, L. saxatilis*) with trans-Atlantic ranges, and parallel studies of their parasites have confirmed the introduced status of *L. littorea* and a closely associated digenean trematode parasite, *Cryptocotyle lingua*. Assuming a mutation rate of 3%, Blakeslee *et al*. (2008) found an estimated introduction date of 444 (± 88) years ago with 95% confidence intervals (CIs) between 344 (± 73) and 644 (± 137) years, based on genetic divergence between North American and European populations. For the trematode *C. lingua*, again assuming a 3% mutation rate, the estimated introduction date was 306 (± 114) years ago with CIs between 204 (± 82) and 460 (± 153) years ago (Blakeslee *et al*. 2008).

Dreissena polymorpha- The Zebra Mussel is currently established in two North American estuaries, those of the St. Lawrence and Hudson rivers. In 2001, an established population was discovered in a reservoir in New York State, near the headwaters of the Susquehanna River, the largest tributary of the Chesapeake Bay. Since then, there has been a gradual spread, with mussels reaching the New York-Pennsylvania border in 2007 (USGS Centre for Aquatic Resource Studies 2009). In November 2008, a single zebra mussel was found alive, inside an intake at the Conowingo Dam, just above the head of tide of Chesapeake Bay (Thomson 11/25/2008, USGS Centre for Aquatic Resource Studies 2009). In December 2008, a clump of mussels was found attached to a boat at Glen Cove Marina, just above Conowingo Dam. In November 2008, D. polymorpha was also found further upstream in Pennsylvania, in Muddy Run, a tributary near the Maryland border (Thomson 12/5/2008). This mussel appears to be established in the lower Susquehanna River and is likely to colonize tidal fresh and oligohaline regions of upper Chesapeake Bay The limited salinity tolerance of the Zebra Mussel is likely to limit its distribution, but the potential invaded areas are ecologically important to a variety of fishes, blue crabs (Callinectes sapidus), and waterfowl.

Mytella charruana-A single specimen of the South American mussel *Mytella charruana* was found in the Ashepoo River, Colleton County, South Carolina, on an abandoned crab pot float line (USGS Centre for Aquatic Resource Studies 2009**)**. This is the northernmost record for this mussel**.** It is native from Venezuela to Uruguay, and was first found in US waters in the St. Johns River estuary, at Jacksonville, Florida, in 1986, when a massive infestation fouled a power plant. The population in the Jacksonville area apparently died out, but this bivalve was rediscovered in the Mosquito Lagoon, Florida in 2004, and in 2006, found near St. Augustine, Florida, again at Jacksonville, and in the Medway River estuary, Georgia (USGS Centre for Aquatic Resource Studies 2009). This mussel can tolerate water temperatures as low as 6º C with stepwise transfers (Brodsky *et al*. 2009).

Eriocheir sinensis- In 2008, 22 specimens of the Chinese mitten crab were caught in US Atlantic Coast tributaries. Two of these captures were in New Jersey waters, the rest in the New York portion of the tidal Hudson River and its nontidal tributaries. Of the 20 Hudson drainage crabs, 13 were male, 7 female, and sizes ranged from 16 to 64 mm. The northernmost captures, in Catskill Creek, were 185 km upriver from the mouth of the Hudson, in New York Harbor. Seventeen of the crabs were caught in tributary streams, often in rocky areas near falls and rapids, while three were caught in fresh-oligohaline portions of the tidal river. Modes of capture included eel traps, fyke nets, crab pots, dip nets, and power plant screens. One of the New Jersey crabs, a large (74 mm) male was caught in Raritan Bay, a saltwater extension of the Hudson estuary (Carin Ferrante, personal communication; USGS Centre for Aquatic Resource Studies 2009). The size range and number of captures in the Hudson is suggestive of a reproducing population. The other of the New Jersey crabs was caught in Toms River, New Jersey, a small tributary of Barnegat Bay (USGS Centre for Aquatic Resource Studies 2009; Carin Ferrante, personal communication). Surprisingly, no Mitten Crabs were reported from Chesapeake or Delaware Bays in 2008, despite occurrences in previous years.

Penaeus monodon, Asian Tiger Shrimp- This Indo-Pacific shrimp is widely reared in tropical waters. In 1988, there was a mass escape of *P. monodon* from an aquaculture operation in South Carolina, which led to captures of more than 1000 Tiger Shrimp from North Carolina to Florida. However, there were no further captures until 2006 and 2007, when at least 9 specimens were caught from Louisiana to Pamlico Sound, North Carolina In 2008, at least 15 Tiger Shrimp were reported, from Mobile Bay, Alabama, to Pamlico Sound (USGS Centre for Aquatic Resource Studies 2009). Inquiries by Pam Fuller (US Geological Survey, Centre for Aquatic Resource Studies) indicate that this shrimp is no longer cultured in the United States. In the Caribbean and tropical West Atlantic, shrimp farmers have largely switched to the Pacific White Shrimp (*Litopenaeus vannamei*). However, a number of specimens of P. *monodon* were caught in Brazil in 2000-2002 (Santos and Coelho 2002), and breeding populations are reported in Venezuela (Perez *et al*. 2007). A discussion on a shrimp-growers website, 'Shrimp News International (Oct. 26, 2007) suggests that many more escapes have occurred, and that *P. monodon* may be breeding from Guyana to Colombia, and also entering and breeding in *L. vannamei* ponds. Most or all specimens recently captured in US waters appear to be adults, with reported sizes over 200 mm (USGS Centre for

Aquatic Resource Studies 2009). So far, there is no evidence for reproduction in US waters.

Didemnum vexillum- After extensive morphological study by Gretchen Lambert (Lambert 2009), and worldwide molecular sampling of genetic material (Stefaniak *et al*. 2009), the invasive forms of the colonial '*Didemnum* species A.', in the Northwest Atlantic, Northeast Pacific, and elsewhere, have been confirmed as a single species, for which the name is *D. vexillum* Kott 2002. *Didemnum vexillum* was first vouchered in US Atlantic waters in 1993, in the Damariscotta River, Maine, but had been seen there since the 1970s.(Lambert 2009). On the Atlantic coast, it ranges from Eastport Maine, on the Canadian border, to Shinnecock Inlet, New York, on the south side of Long Island. In the 'Proceedings of the 2nd International Invasive Sea Squirt Conference' published in the online journal 'Aquatic Invasions' (Vol. 4, No. 1). Recent genetic and taxonomic findings on this species, together with a number of ecological studies, were published in this symposium.

In 2002, *D. vexillum* was first discovered on Georges Bank, covering extensive areas of pebble-gravel bottom. In surveys done in 2003 and 2004, with dredges and phototransects, it was the most abundant epibenthic organism, ranging from 0-100% cover (Lengyel *et al*. 2009). The second-most abundant epibenthic group, hydroids, were inversely correlated in abundance with *Didemnum*, and were frequently overgrown by the tunicate. However, anemones appear to resist overgrowth, and were abundant in areas with moderately high coverage of *Didemnum*. The polychaetes *Nereis zonata* and *Harmothoe extenuata* were also abundant in *D. vexillum* zones, possibly because the tunicate mats protect the worms from predation (Lengyel *et al*. 2009). In the shallower waters of Long Island Sound, *D. vexillum* mats did not affect the density or diversity of infauna on pebble-gravel bottoms, but did affect species and functional group composition, with more infaunal and deposit-feeding species inside the mats than outside (Mercer *et al*. 2009). Again, this may reflect the mats' interference with mobile predators such as fishes and crabs. To our knowledge, studies on the effects of *Didemnum* on fish predation on these mobile predators have not been published.

Didemnum vexillum fouls the shells of the Sea Scallop *Placopecten magellanicus,* an important fisheries species on Georges Bank, and could potentially prevent recruitment of the scallop by covering settlement areas. Because of the difficulty of studying the latter species, Morris *et al*. (2009) conducted experiments with *Argopecten irradians, the* Bay Scallop, also an important commercial species, in shallower coastal waters. They found that larval scallops avoid settling on *Didemnum*, possibly because of the low pH (3.8) of the colonies' tunics, suggesting that expansion of *D. vexillum*'s cover could reduce recruitment of Bay and Sea Scallops.

In New England coastal waters, recruitment of *D. vexillum,* on fouling panels, begins at 14-20ºC in spring and ceases at 9-11 ºC. Recruitment could not be easily measured by fouling panels on Georges Bank, but the regions colonized by *D. vexillum* have a relatively narrow seasonal temperature range (4-17 ºC). Colonies in shallow water degenerate in fall, as temperature drops in shallow waters, but remain intact through the year on Georges Bank (Valentine *et al*. 2009).

The degree to which *D. vexillum* can penetrate estuaries has been unclear, although most estuarine collections have been from seaward locations. Bullard and Whitlach (2009) placed colonies at three depths, in three salinity regimes in Long Island Sound. Growth was highest in shallow water (1 m depth) and at the highest salinities (26-30 PSU). Growth rates decreased with depth (2 .5 and 4 m), possibly because of decreased phytoplankton concentrations, since temperature differences were small. Colonies died at the least saline location (10-26 ppt), while in the laboratory, colonies in aquaria died after a week at 20 PSU (Bullard and Whitlach 2009).

Transport of fauna on ships destined for scrapping- A direct study of the transport of fauna of many taxonomic groups from the Pacific Coast to the Atlantic Coast was published in 2008 (Davidson *et al*. 2008a). A fleet of obsolete cargo ships, moored in Suisun Bay, a brackish part of the San Francisco estuary, was towed through the Panama Canal to Brownsville, Texas, for salvage. The fouling communities on the ships were surveyed before and after the voyage. At least 3 Pacific species survived the voyage, notably the isopod *Gnorimosphaeroma oregonensis* (Davidson *et al*. 2008a). The potential for prolonged survival or reproduction of this and other northeastern Pacific species in the Gulf of Mexico is unknown and further monitoring has not been done (Ian Davidson, personal communication). This study underscores the high capacity of defunct vessels, with their rich fouling communities, as a potential vector for invasive organisms. Davidson *et al*. (2008b) studied the effects of in-water cleaning on the fouling community of another group of 'ghost ships', destined for scrapping, moored in the James River, Virginia (Chesapeake Bay). They found that mechanical cleaning reduced the amount and diversity of fouling organisms, but that more than 30 species remained on the cleaned ships (Davidson *et al*. 2008b).

Pacific Coast

Potmopyrgus antipodarum- The New Zealand Mud Snail, a freshwater hydrobiid gastropod tolerant of strongly brackish water, was introduced to Europe, probably in the drinking-water barrels of sailing ships, and is now widespread there. In 1996, it was found in the Columbia River estuary (Carlton, personal communication 1997, USGS Centre for Aquatic Resource Studies 2009**).** From 1996 to 2007, it has colonized 12 estuaries from Port Alberni, British Columbia, to the Rogue River, Oregon (Davidson *et al*. 2008), In California, *P. antipodarum* was first collected in Freshwater Lagoon, north of Humboldt Bay, in 2008, in the Sacramento-San Joaquin Delta in 2003, and in many other coastal streams since 2006 (USGS Centre for Aquatic Resource Studies 2009). Possible vectors include boots and gear of recreational fishers, recreational boats, and machinery used in building docks and other shore structures, etc.

Caprella mutica- The Northwest Pacific caprellid *Caprella mutica* is a widespread invader, known from European waters since 1995, and from the East Coast (2000), New Zealand (2004), and the Pacific Coast (1973) (Ashton *et al*. 2007). In surveys in 2001 2003, and 2007, *C. mutica* was found in Alaskan waters ranging over nearly 6 degrees of latitude, from Ketchikan (55.4 ºN) to Kachemak Bay (59.6 ºN), and Dutch Harbor (in the Aleutian Islands (53.9 N) (Ashton *et al*. 2008). *Caprella mutica* is the first introduced crustacean documented to be established in Alaskan waters (Ashton *et al*. 2008). It has been known from Puget Sound since 1998, but has not been reported from British Columbia, to our knowledge.

Algae and higher plants

Atlantic Coast

Mathieson *et al*. (2008) reviewed introductions of seaweeds in Northwest Atlantic waters. They documented 20 introduced species, 16 of which occur in US waters from Maine to North Carolina. These include species first reported in the 19th and early 20th century, and not initially recognized as invaders (*D contorta,*, *Lomentaria orcadiensi, Neosiphonia harveyi*) but also recently discovered species (*Rhodymenia delicatula*, *Porphyra katadae*, *P. suborbiculata*, *P. yezoensis* forma *yezoensis*, *P. y.* forma *narawensis,* all red algae). *Rhodymenia delicatula* is an East Atlantic native, found in Woods Hole in 1996, while the *Porphyra* are Northwest Pacific species, identified by molecular methods, some (*P.s, P. yezoensis*), first collected in the 1960s and misidentified. *Porphyra yezoensis* (Nori) was cultured in Cobscook Bay, Maine, in the 1990s, but molecular analysis shows that the 'wild' algae are genetically distinct from the cultured forms (Mathieson *et al*. 2008). *Porphyra katadae* has been collected from Buzzards Bay and Cape Cod Bay, Massachusetts, since 2005, *P. yezoensis* forma *yezoensis*, from Boothbay Harbor Maine to Long Island Sound, and *P. y.* forma *narawensis* from Buzzards Bay to Long Island Sound (Mathieson *et al*. 2008).

Pacific Coast

Spartina alterniflora- Two colonies of smooth cordgrass (*Spartina alterniflora*), native to the Atlantic coasts of North and South America, were discovered, and eradication programs begun, near Warrenton, Oregon, on the Columbia River estuary in September 2008, and in Mukkaw Bay, on the Olympic Peninsula, Washington, in October 2007 (USGS Centre for Aquatic Resource Studies 2009).

Parasites, pathogens, and other disease agents

East Coast

Bonamia spp.- The parasite *Bonamia* spp., previously known from triploid *Crassostrea araikensis* reared in North Carolina waters, was discovered in triploid *C. ariakensis* reared in Chesapeake Bay in 2004 and 2005. The parasites were found in two lots of oysters, one reared at Piney Point, Maryland (mesohaline) in 2004 (3% prevalence) and the other at Gloucester Point, Virginia (polyhaline) in 2005. Prevalences were low (3-10%, respectively). The occurrence of this parasite in Chesapeake Bay poses questions for the proposed introduction of *C .ariakensis*, and could be an additional threat to the native Eastern Oyster, *C. virginica* (Schott *et al*. 2008).

Meetings:

The 6th International Marine Bioinvasions Conference will be held in Portland, Oregon,

August 24-27, 2009. Visit the website (http://www.clr.pdx.edu/mbic/) for more information. Abstracts are due March 31, 2009.

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Annex 4. ICES WGITMO Report 2009

ICES WGITMO Report 2009

WGITMO Report to OSPAR report

Edited by Judith Pederson, Chair, WGITMO

Contributors:

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This document responds to three Terms of Reference requested by the Oslo and Paris Commission (OSPAR) to the Working Group on Introductions and Transfers of Marine Organisms (WGITMO). The request by the OSPAR Commission was to identify and report on changes in the distribution, population abundance, and condition of introduced marine species in the OSPAR maritime area in relation to human activities.

ABSTRACT

Over 160 established marine introduced species have been identified in the OSPAR region based on an analysis of data entered in the DAISIE databank, a database managed and compiled by European scientist, but this number under represents the total number of species. A list of references provides data on invasions collected over the past decade or more. We have selected four algal species, one higher plant, and 18 invertebrate species as problematic invaders that have human health, economic and ecological impacts of concern.

OSPAR Terms of Reference to WGITMO

ToR (a) Prepare an overview assessment of non-indigenous species in the OSPARmaritime area

ToR (b) To prepare an overview assessment as a contribution to the OSPAR QSR 2010 of information that is available within the ICES framework on:

- the distribution and abundance of non-indigenous species introduced into the OSPAR maritime area as a result of human activities, and;
- whether the presence of these species have adverse impacts on marine ecosystems.

ToR (c) Where possible, graphic material should be included e.g. illustration of trends in the number of detections of new indigenous species or the number of observed established non-indigenous species or equivalent material, would be welcomed. (Points a-c) relate to OSPAR request no. 3, 2009).

INTRODUCTION

The ICES Working Group on Introductions and Transfers of Marine Organisms was asked by OSPAR Commission to prepare an assessment of nonindigenous species whether the presence of this species has an impact on marine ecosystems. We have used information from annual National Reports as one source of information, but not all countries provide reports for all years and hence, this information is incomplete. To provide a more complete report we have used the expert knowledge of our WGITMO, and supplemented their insights with reports from the literature as references in the document. Additional information can be achieved from two reports from ICES (1999, 2007). In addition, many ICES countries have national databases for nonindigenous species.

As requested in the Terms of Reference we identified introductions within each OSPAR LME as the basis for categorizing the organisms (Figure 1). The OSPAR regions are I = Arctic, II = Greater North Sea, III = Celtic Seas, IV = Bay of Biscay and western Iberia, V = wider Atlantic. There are few reports in Region I (Arctic), most of the reports are from areas II (Greater North Sea), III (Celtic Seas), and IV (Bay of Biscay and western Iberia). We can contribute to the Azores that are in region V (wider Atlantic), but not from the deeper waters. Where appropriate, we also have included some data from the Mediterranean and Baltic Seas and other regions that may "supply" nonindigenous species through shipping routes or other vectors.

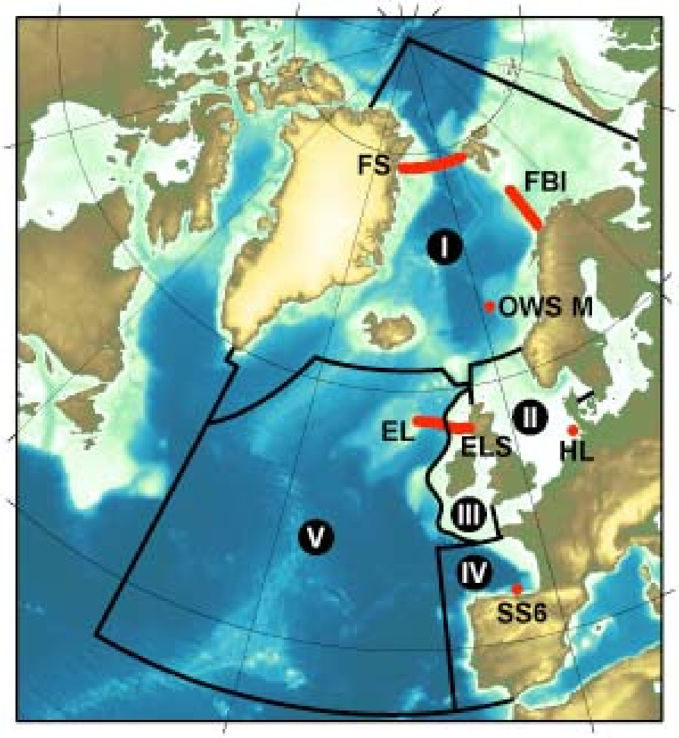

Figure 1. Location of selected hydrographic time series within the OSPAR sub-regions (stations in red, boundaries of sub-regions in black). In Region I (Arctic Waters) are time series at Fram Strait (FS), Fugløya-Bear Island (FBI) and Ocean Weather Station Mike (OWS M). Region II (Greater North Sea) is represented by Helgoland Roads (HR).

To identify changes that we observe in relation to human activities, we have applied some basic criteria to our discussion.

1) We identified likely vectors as reported in the National Reports, literature, and/or best estimates by the experts of the Working Groups (ICES 2005 a, Report 271).
2) We selected species that are likely to have a human health, economic and/or ecological impact.
3) We included species that have or are spreading and for which we have adequate data.
4) We focused on nonindigenous species whose presence is likely to be due to human factors, i.e. they are not likely to be there due to floating materials, as naturally migrating species, or other "natural" causes.
5) Where possible, we used the criteria that the presence of "new species" is not due to range expansion related to climate variability.

There are around 160 nonindigenous species in the OSPAR region reported in DAISIE database, but this number underestimates the total number of introduced species (Eno et al. 1997; Reise et al. 1999; Leppäkoski et al. 2002; Ashton et al. 2006; Boudouresque 2005; Wolff 2005; Gollasch 2006; Gollasch and Nehring 2006; Kerckhof et al. 2007; Minchin 2007a; Galil et al. 2009; Gollasch et al. 2009). Often missed are the many small species (e.g., bacteria, plankton, hydrozoans, bryozoans) that are difficult to identify to species level (Wyatt and Carlton 2002; Carlton 2009). In addition, taxonomy continues to change based on morphology and, more recently, molecular studies often resulting in several species within a complex (e.g., see *Marenzellaria* spp. paragraph below). The changes in taxonomy refine our understanding of distributions and origins as discussed below and allow us to better define impacts of invaders. For this document we have selected a few species that illustrate human-mediated vectors and impacts to human health, economics, and ecosystems (see also ICES 1999, 2007).

PLANKTON

The number of phyto- and zooplankton species reported in ICES and other countries relative to other marine organisms is disproportionately small. This is due to several factors:

1) Because of their small size, plankton are not seen and/or easily detected by non-scientists;
2) Laboratory facilities and equipment (e.g., microscopes, growth chambers, and equipment for molecular studies) are needed in order to study and identify them at the level of detail needed for identifying native and non-native species;
3) Some species are difficult to preserve and store;
4) Limited numbers of plankton taxonomists, particularly those who can identify native and non-native species, makes the identification (to the species level) process even more tedious and difficult;
5) Unless they are already an evident invasion, cause human health, and/or impact aquacultures or other resources, they are not perceived as important;
6) There is little interest in support by society for long-term monitoring programs, retention of voucher species, and historical information on native

species, thus limiting historical data as a basis for identifying introductions over time and changes in native populations;

7) The shorter life cycle of small organisms (e.g. hours to day to weeks) implies that species composition can vary significantly at short time frames reducing the probability of discovering them.

Because modifications of the plankton communities can have important impacts on human health and ecosystems structure and function and can also be impacted upon by non-native species, it is therefore necessary to include this issue in existing and new research and monitoring programs to investigate these 'invisible' yet important organisms.

Phytoplankton can be introduced into new areas in a variety of ways e.g. ballast water and sediments and the ability of some species to form protective cysts means that they are able to survive for long periods of time and can thus be transported considerable distances. Once there are suitable conditions the cysts may hatch and the motile cells become part of the phytoplankton community in a new area. However, phytoplankton species can be difficult to differentiate, often relying on specialized microscopy techniques to identify the cell features that are unique to a particular species. This means that in many cases it is difficult to know whether a "new" species has been introduced or has simply not been indentified accurately in previous work.

Large cells such as the diatoms *Coscinodiscus wailesii* and *Odontella sinensis* that are found in European waters are easier to identify because of their size and/or their distinct morphology and there is more confidence that the first records of the occurrence of these species in 1977 and 1889 respectively are correct.

Phytoplankton occur in large abundances in spring as daylight and temperature increases and these blooms can sometimes have adverse effects as they can lead to anoxic conditions, smothering of benthic organisms or can cause irritation of fish gills. Some species can also produce toxins, which can accumulate in shellfish and can therefore have adverse effects on the shellfish industry, which will be restricted from selling the shellfish when there are toxins present in the flesh.

Of the two diatoms mentioned above *C. wailesii* has caused some problems by producing mucilage during the bloom die off that has clogged fishing nets. However, as with all phytoplankton, the abundance of this species fluctuates depending on environmental conditions and the nuisance features of this diatom do not always occur. We did not include these species in the table, but they are worth noting.

Table 1. Non-native species identified as considered problematic based on reported impacts.

Taxonomic Group	OSPAR/other Region/s	Probable Vectors[a]	Location/date of 1st report	Current Range	Probable Impacts
ALGAE					
Sargassum muticum	Region I?, II, III, IV, Mediterranean	Oyster imports, escape, secondarily by drift range expansion	1973, UK; ICES 1999	W. Norway to Portugal, Skagerrak, Kattegat, UK, Ireland	Algal and seaweed competition, habitat modification; clogging nets, oyster and aquaculture; propeller interference; substrate for other species in barren areas
Undaria pinnatifida	Region II, IV, Mediterranean	Oyster imports, range expansion, hull fouling; ballast	Thau Lagoon, S France 1971, Brittany, N, France 1983; ICES 1999; 2007b	Netherlands, Belgium, France, UK, Spain, Italy, Portugal?	Space competition (being annual are less severe), oysters harvest interference, fouling on boats, jetties, etc.; grazed by invertebrates and ducks
Gracilaria vermiculophylla[3]	Region II, III, SW Baltic Mediterranean	Oyster import and transfers, drift range expansion, boats, dredges, fishing nets	Roscoff, France 1996, Rueness 2005	Sweden, Denmark, Germany, Netherlands, France, Spain, Portugal	Seaweed competition, forms mats that may smother benthic organisms (including eel grass), clogging nets, substrate for other species in barren areas
Codium fragile ssp. *fragile*	Region I, II, III, IV, V, Mediterranean	Shipping, oyster movements, range expansion	Netherlands ~1900; ICES 1999	Iceland to Portugal, Kattegat, Skagerrak, UK, Ireland, Mediterranean	Competition with seaweeds, forms "belt" and monoculture, habitat modification, attaches to bivalves

HIGHER PLANTS					
Spartina anglica	Region II, IIi, IV,	Intentional planting to stop erosion, range expansion	France 1906; ICES 2007b	Sweden (ICES WGITMO 2008), to France, Ireland, native in U.K	Habitat modification, rhizomes create monoculture stands, sediment trapping, alters water flow
CTENOPHORE					
Mnemiopsis leidyi	Region II	Ballast water	Faasse and Bayha, 2006 ; Javidpour et al. 2006 ; Hansson (2006)	North Sea, Baltic Sea and Kattegat, respectively	Trophic impacts, competition, fish stock recruitment
POLYCHAETE					
Marenzellaria spp. (complex)	Region II, III, Baltic	Ballast (3 separate incursions)	1979 Forth Estuary	North and Baltic Seas	Nutrient regeneration, outcompetes insects and oligochaetes, fish decline
MOLLUSCS					
Crepidula fornicata	Region II, III, IV	With *C. virginica*	1872, UK	Norway to Spain, UK	Competition; Habitat modification
Ensis directus	Region II	Ballast water	1979, Germany	Norway to France	Outcompetes native bivalves, habitat modification
Crassostrea gigas	Region II, IV	Escaped aquaculture	1980s, France	Norway to Portugal	Outcompetes native mussels (*Mytilus edulis*), habitat modification
Venerupis philippinarum	Region II, IV	Aquaculture, Suez Canal range expansion	1992, UK	France to Spain, Netherlands (wild populations)	Competition
Teredo navalis	Region I?, II, III, IV, V	Hull fouling (boring)	Before 1730, Netherlands	Cosmopolitan? (except polar?)	Destruction of wooden structures (Habitat destruction)
CRUSTACEANS					
Eriocheir sinensis	Region II, III, IV	Ballast, range expansion	1912, Germany	Portugal to Norway, Baltic Sea, UK,	Habitat modification, predation,

				Ireland	competition
Hemigrapsus sanguineus	Region II, IV	Ballast, hull fouling	1999, France	Germany to France	Competition, habitat modification
H. takanoi	Region II, IV	Ballast, hull fouling	1994, France	Germany to Spain	Competition, habitat modification
Paralithodes camtschaticus	Region I	Migration from early introduction	1976, Norway	Northern Norway	Competition, predation, habitat modification
FOULING COMMUNITIES					
Ficopomatus enigmaticus	Region II, III, IV	Fouling	1921, France; WGITMO 2009	Germany to France, Ireland, Denmark	Competition, habitat modification
Balanus improvisus	Region I, II, III, IV	Fouling	<1800	Norway to Spain, Baltic	Competition, habitat modification
Austrominius (=Elminius) modestus	Region II, IV III???	Fouling	1945 UK	Denmark to Portugal	Competition, habitat modification
Caprella mutica	Region II, III, IV	Fouling	1998 Belgium	Norway to Belgium	Competition, habitat modification
Telmatogeton japonica	Region II, III	Fouling	1963 Germany	Denmark to Belgium, Ireland, Baltic Sea	Competition, habitat modification
Bugula stolonifera	Region II, IV, V, III?	Fouling	1993 the Netherlands	Belgium to Spain, incl. Azores	Competition, habitat modification
Styela clava	Region II, III, IV	Fouling	1968, France	Germany to Portugal, UK , Ireland	Competition, habitat modification
Didemnum vexillum	Region II, III	Fouling	1991, the Netherlands	Netherlands, France, Ireland, UK	Competition, habitat modification

Seaweeds and Higher Plants

Many seaweeds and most higher plants have large importance for structuring the benthic communities in large, and function as shelter and substrate for other organisms. In many cases they may also be used as food by grazers, although many seaweeds and plants have chemical substances deterring grazers. In temperate areas, however, most of the organic material produced is not eaten, but enters the food chain as detritus. Several species are easily recognized also by amateurs, while for a large number of algal genera separating different species may be difficult. This complicates the task of identifying introduced species, especially those not having a history of being introduced anywhere else. Introduced seaweeds and higher plants may in many cases act as ecosystem engineers or habitat modifiers, being keystone species for the ecosystem. The effects could be both negative, e.g. on biodiversity, or positive, e.g. by providing substrate or shelter for other species (Wallentinus & Nyberg 2007).

Seaweeds have mainly been introduced as hitch-hikers on imported molluscs, but also as hull-fouling organisms or within ballast. Many of these have later spread secondarily, either by drifting or with ships, small boats and fishing equipment. Some few algal species have also been intentionally introduced for farming purposes, and several species of the salt-marsh grasses have been planted on mud flats as protection for erosion.

The species for which details are given below are among the most invasive in respective algal groups (Nyberg & Wallentinus 2005, Nyberg 2007). For any possible effect of "Climate change", see the individual species below.

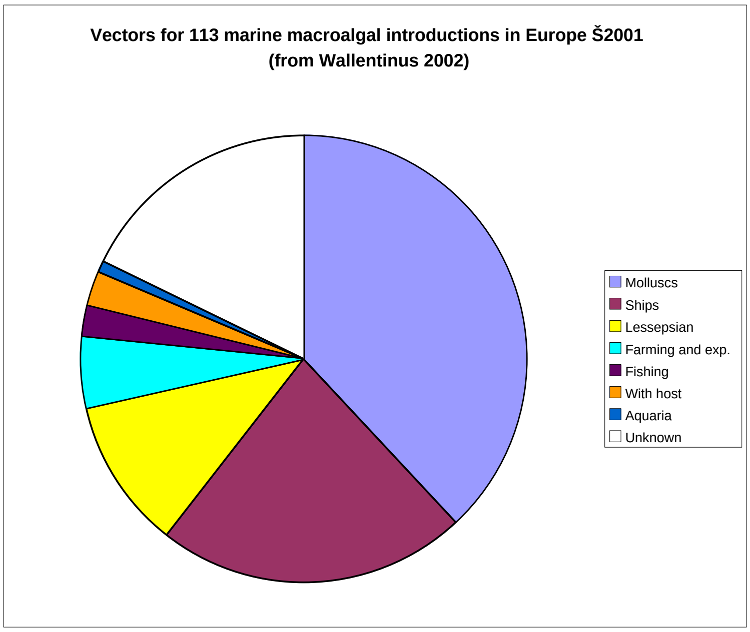

Figure 2. Percentage of seaweeds being introduced in Europe by various vectors until 2001. Compiled from data summarized by Wallentinus (2002: Appendix 2)

Brown algae (Class: Phaeophyceae; Phylum: Heterokontophyta)

Japanese kelp *Undaria pinnatifida* (Family: Alariaceae; Order: Laminariales)

Since the early 2000s, the Japanese kelp, *Undaria pinnatifida*, native to the northwest Pacific, occurs on all continents except – so far – Africa and Antarctica, and it has become one of the main target species for biosecurity. Information about the species was synthesized as an "Alien Species Alert" (Wallentinus 2007a), in which references for the details below are given. In an analysis ranking species traits of 113 introduced seaweeds in Europe, it was the third most invasive seaweed (Nyberg and Wallentinus 2005). There are several reasons for its success as an invader, especially its great ability to colonize artificial substrates and disturbed areas rapidly, as well as shells of oysters and mussels. Furthermore, this mostly annual plant can grow very fast, reaching lengths of up to 2–3 metres. Other reasons are its high tolerance for adverse conditions, such as high turbidity and eutrophication, and the nearly invisible gametophytes' ability to survive being out of water for more than a month and can then act as a "seed bank". The reproductive output from sporophytes is large, and zoospores may be released all year-round, which contributes to its colonization potential. As in other members of the Laminariales, the life cycle is comprised of a large sporophyte and microscopic gametophytes. Further, *U. pinnatifida* often develops into a fouling problem, which not only affects ships and boats, but also structures used in aquaculture and molluscs growing on the seabed. On the other hand, it has economic value as a source of food ("wakame"), which has motivated intentional introductions to some areas for farming.

In 1971, it made its first appearance on another continent as an unintentional introduction with oysters that were brought from Japan to the French Mediterranean coast. In 1983, it was intentionally introduced from the French Mediterranean coast to farms in Brittany, northwestern France, from where it later dispersed to other northern European countries. In 1987, it was recorded in New Zealand and in 1988 in Australia, having been brought by shipping from Asia, which also was the vector for its spread to Argentina in the early 1990s. Thus, the main vectors for unintentional introductions have been ships or small boats as well as oyster movements in aquaculture (including illegal ones). It can be assumed that, hitherto, we not have seen the final global distribution of *U. pinnatifida*. Areas most at risk are not yet colonized warm and cold temperate coasts of Europe, North and South America, Australia, New Zealand and Africa, where surface salinities are not too low (>18 psu). Disturbed areas, if not too exposed, seem to be more vulnerable then densely vegetated substrates. The prospect of controlling further dispersal is low, because of the extreme hardiness of the microscopic gametophytes. They can survive in a range of -1 - 30 °C, while growth optimum is around 20 °C and maturation at 10-15 °C. Growth rates of young sporophytes have an optimum at 20°C (a relative growth rate of ca. 25% per day), with an upper level of 27°C and a lower limit of less than 5°C (a relative growth rate of ca. 8% per day at 5°C). Thus, in northern Europe, this species might be favoured, if the temperature of the seawater increases by climate change.

Japweed *Sargassum muticum* (Family: Sargassaceae; Order: Fucales)

In 1973 the japweed, *Sargassum muticum,* was first recorded in southern U.K. , but had already in the early 1940s spread from Japan to the area around the Strait of Georgia, British Columbia. The vector has in most cases been movements of oysters, especially *Crassostrea gigas*. Oyster movements have also been a major way of its spread within Europe, including into the Mediterranean Sea. However, drifting has also played a major role in secondary introductions, especially in northern Europe, easily facilitated by the many small air vesicles on the long primary laterals, developed during the warm seasons. During favourable conditions these primary laterals can reach lengths even as large as 5-10 metres, while only the dm-sized base and holdfast of this pseudo-perennial species over-winter (for more details and references see Wallentinus 1999a, 2007b). As in other members of the Fucales, the life cycle is only comprised of one stage. At senescence (late spring/ summer/ early autumn, depending on temperature), the laterals detach, but they can survive and even grow while floating free and loose vegetative branches may even become reproductive. In the analysis ranking species traits of 113 introduced seaweeds in Europe, it ranked as eight in invasiveness (Nyberg and Wallentinus 2005).

Sargassum muticum exhibits several opportunistic characters such as rapid colonisation of free space, a large number of propagules, including cast off branches, rapid growth of young germlings, high photosynthetic rates, while respiration rates still are low. Being monoecious with self-fertilization and keeping the young embryos on the adults, highly increases the chances of establishment, and the perennial base secures the continued existence of the plant. Large plants with their high buoyancy often lift smaller pieces of substrate, including live molluscs, and drift away, colonizing new areas by release of germlings. It has in several cases been found to be a superior competitor and the large size of the plants during spring/ summer effectively blankets the light for understory species, especially when the summer "branches" are floating on the water surface. Accumulation of silt among densely branched specimens further reduces the possibilities for other species to survive. The large primary laterals also often clog fishing nets and get stuck in the screw of small boats. However, it is also often used as a shelter by small animals and fish, when growing on small stones and shells in otherwise barren sediments. Flourishing growth in mussel and oyster cultures points to nutrient enhancement and it also grows in polluted waters.

Further likely areas for colonisation in Europe: All the rest of the coasts of England, Wales and Ireland, Isle of Man, Scotland; the islands of Orkney, Shetland and the Hebrides; the Faroe Islands, the Danish North Sea coast; the Norwegian northwest and north coasts, southern Iceland as well as all the rest of Spain, Portugal, and the Mediterranean Sea. However, it will probably not go far into the brackish Baltic Sea because of the low salinities, causing reduced fertilization. The northern distribution limit is more difficult to predict depending on risks for ice scouring and low growth rate at low temperatures, which makes it less competitive. Thus the species may benefit from a climate change involving higher seawater temperatures. Also at risk are the cold and warm temperate Atlantic coasts of Canada and USA, South America, Africa, Australia and New Zealand.

Red alga (Class: Florideophyceae; Phylum: Rhodophyta)

Gracilaria vermiculophylla (Family: Gracilariaceae; Order: Gracilariales)

The Asiatic red alga *Gracilaria vermiculophylla* was first seen in Europe near Roscoff, NW France, in 1996, although being sterile it was difficult to identify (Rueness 2005, Wallentinus 2007b). The identity was later accomplished by genetic analyses (Rueness 2005). It was next recognized in the archipelago area of Göteborg in 2003, but had, however, already in the late 1990s, been sampled by Dr. H. Stegenga in the brackish Oostvoornse, close to Rotterdam, the Netherlands (Rueness 2005) and was seen in the German Waddensee in 2002, and in 2003 in Horsens Fjord, Denmark, (Thomsen et al. 2007), in all places correctly identified some years after sampling. It has also established in Spain and Portugal (Rueness 2005), in the Kiel Bight in the western Baltic Sea, as well as in the West Atlantic and East Pacific (Thomsen et al. 2007 and references therein). The possible vector for its introduction into Europe probably was oysters (often seen close to oyster farms), while for Sweden small boats or dredgers are more likely, since no oysters or mussels farms occur in the area, where it was first recorded. Boat projections, fishing nets etc. probably also act as a vector within the regions (Nyberg 2007, Thomsen et al. 2007).

The species often occurs as loose lying mats, which may cover many square-metres and individuals can reach a length of more than a metre. A highly invasive character is its capacity to have asexual reproduction by regrowth from small fragments, even when only being some millimetres long (Nyberg 2007). Furthermore, in Sweden all stages of the life cycle (i.e. tetrasporophytes, male and female gametophytes were found already the first year in contrast to in France. Since it could not be identified when first sampled in France in 1996, it was not included in the ranking of seaweeds when analyzing their risks (Nyberg & Wallentinus 2005). However, this analysis was performed later and then it scored highest among the red algae, but slightly lower than the two most invasive green algae and equal to the most invasive brown alga (Nyberg 2007). The species is extremely tolerant to darkness (months) as well as being out of water (while still humid) and start to grow when again getting benign conditions (Nyberg 2007). She also showed that it can tolerate very low salinities, growing in a very wide range of salinities, and that it can be a shelter and substrate to many organisms, especially when occurring on barren sediments, and quoted a study which showed that it can serve as food for some common invertebrates. Grazing also causes fragmentation, which may help dispersing the plants. If large mats are developed on the sediments in shallow areas, this may be a threat to species of *Zostera*, and in northern Europe *Z. noltii* is red-listed as vulnerable, thus it may suffer from large mats of *G. vermiculophylla*. It may also be clogging fishing nets and traps.

Growth rates are quite low at lower temperatures, maximum ca 7% per day at 11 °C, compared to 25% per day at 25 °C (Nyberg 2007 and references therein). This, in addition to that it occurs as far south as Vietnam in Asia (Guiry & Guiry 2009) and in North Carolina, US, (Thomsen et al. 2007) points to that it may spread further north if the water gets warmer by climate change. However, it has also survived in shallow bays under sea ice in Sweden (Nyberg 2007), thus tolerating a wide range of water temperatures.

Green alga (Bryopsidophyceae: Chlorophyta)

Codium fragile* ssp. *fragile (Codiaceae, Bryopsidales)

Codium fragile ssp. *fragile*, previously called *Codium fragile* ssp. *tomentosoides,* is a very invasive strain, which was the highest ranked of the algae analyzed for risks by Nyberg & Wallentinus (2005). It originates from Japan and Korea in the North Pacific and may reach a height of a metre, but is often much smaller. The vector of introduction is generally listed as hull fouling on ships, but it has also spread, especially within biogeographical regions by movements of molluscs. In North America it is indeed called the "oyster thief", a name with in Europe is used for the introduced brown alga *Colpomenia peregrina,* both species being able to drift away with oysters.

It was first recorded in Europe in the Netherlands in 1900 (Wallentinus 1999b, 2007b) and then spread to most European countries during the 20th century, where it now occurs in all countries all the way from Iceland in the north down to Portugal (except for the Faroe islands) as well as in the Azores (Wallentinus 2007b). Proven et al. (2005), based on genetic analyses and the occurrence of two separate haplotypes, argued that the introduction into the Mediterranean Sea was a separate event from the introductions into the Atlantic coasts of Europe and the Northwest Atlantic coasts, in the latter it was first recorded as late as in 1957. They also pointed out that the populations in the Mediterranean mainly reproduced parthenogenetically, while those in Europe were sexual. In a later paper (Proven et al. 2008) however, it was shown, by using herbarium material, that *C. fragile* ssp. *fragile* (as *C. fragile* ssp. *tomentosoides*) had been introduced outside its native range much earlier, in some cases almost 100 years before it was first recognized in an area. Differences in invasiveness were also described between the European and Northwest Atlantic populations by Chapman (1999), the North-American populations being more invasive. This is especially true for the Canadian Atlantic coast, where it was first recorded in 1991 and later has caused much nuisance (WGITMO 2003, Wallentinus 2007b and references therein) both as a fouling organism in aquaculture and wild fishery of bivalves, as well as replacing kelp canopies after disturbance and constituting poor food for fished sea urchins. Also in its native region in Asia it seems to be favoured of disturbance of more complex algal communities by over-harvesting of seaweeds, creating empty space, where *C. fragile* can establish (Chavanich et al. 2006).

Chapman (1999) reported it as growing in oligo- to eutrophic waters and having quite low light requirements. She also quoted other papers giving a temperature optimum for growth and reproduction as high as 24 °C, however, growth is also possible at around 12 °C and adults survive temperatures as low as -2 °C. This may point to that a climate change with warmer water may be favourable. Compared to opportunistic algal species, however, its growth rate is comparatively low.

Higher plant (Liliopsida: Magnoliophyta)

Common cord-grass *Spartina anglica* (Poaceae, Poales)

This cord-grass arose in southern U.K. after the native *Spartina maritima* had hybridized naturally with the introduced American *S. alterniflora* and produced the sterile *S. townsendii*, which later by chromosome doubling (a quite common event among many plants) resulted in the fertile *S. anglica*, first recorded by the end of the 19th century. It has a size of up to a metre or more, and is in salt marshes attached in the sediments by rhizomes. Today, in Europe besides the U.K., where it rapidly spread, it is found from Sweden and Denmark in the north, through the North Sea coasts of Germany, the Netherlands (first seen there in 1906, Wallentinus 2007b), Belgium and France, and is also introduced on Ireland as well as in the US (Wallentinus 2007b, WGITMO 2008). Nehring & Adsersen (2006 and references therein) noted that it was considered by IUCN as being among the 100 "World's Worst" invaders and described it to be very common in the Wadden Sea area and that the innermost site into the Baltic Sea is close to Haderslev, in the Belt Sea area. They also reported that some plants had been transplanted from the Kattegat to the Oslofjord, southern Norway, but that those had died after three years. Furthermore they stated that the populations on the Danish island of Læsø, the north-western Kattegat, had established in 1997, after spontaneous spread, a place from where the Swedish populations probably have arrived (WGITMO 2008). Although seed dispersal probably contributed to its appearance in Sweden, unintentional spread by humans cannot be ruled out.

Since it grows in the intertidal zone, it has been intensively used, and intentionally spread and planted especially during the 1920s-1930s, to protect the shores from erosion (Nehring & Adsersen 2006). From such areas it can also disperse by seeds (although seed-production might be irregular), by mud (although there are no long-lasting seed-banks), by fragments of rhizomes, or by tillers, and in the neighbourhood also by the clonal growth of the rhizomes forming large tussocks. These dense, often monotypic, belts can accumulate large amounts of sediments among the rhizomes, and hence the habitat structure and water movements are changed. According to Nehring & Adsersen (2006) it can affect biodiversity by invading mudflats of importance for benthic invertebrates, migrating shorebirds, and replace native plants such as species of *Salicornia*, *Halimione* and *Artemisia*. Furthermore, they also reported that nursery areas of fish can be negatively affected and in some regions also oyster fishery may suffer. Because of the dense belts recreation is impoverished, and once established the dense tussocks are almost impossible to get rid of, due to the growth of the rhizomes. However, diebacks have been observed in very old populations, especially in fine-grained sediments, where anoxia occurs.

Nehring & Adsersen (2006) reported that in the Wadden Sea low soil temperature can delay or suppress flowering, reducing seed production, while on the other hand during mild winters flowering may continue until next year, and during warm summers the ripening of seeds are enhanced. Thus a further spread to the north can be a result of a climate change, especially if severe frost no longer affects young plants.

Comb Jellies (Ctenophora: Tentaculata)

Mnemiopsis leidyi (Lobata, Bolinopsidae)

The natural distribution range of *M. leidyi* is in temperate to subtropical coastal waters along the Atlantic coast of Northern, Central and South America (Harbison et al., 1978). It was unintentionally introduced by ballast water to the Black sea in the early eighties (Vinogradov, 1989), and later extended its range to the Azov Sea, the Eastern Mediterranean and the Caspian Sea (Shiganova et al., 2001 a,b). The species was discovered almost simultaneously in fall 2006 in the southwestern Baltic Sea (Kiel Bight), the Skagerrak (W Coast of Sweden) and in high densities in estuaries of The Netherlands (Hansson, 2006; Javidpour et al., 2006; Faasse and Bayha, 2006). The species was shortly after also found in Norwegian Waters along the coast to Bergen (Hansson, 2006, Oliveira, 2007), and was detected to be widely colonizing Danish waters (Tendal et al., 2007).

The species usually dwells in coastal waters and estuaries. It is more abundant in surface water above thermocline, especially when transported offshore. *M. leidyi* is euryhaline and tolerates salinities from 2 to 38 ppt (Kremer, 1994). It is also eurythermic and occurs in temperatures ranging from 0 ºC to 32 ºC in its natural distribution area. When testing the Black sea population Shiganova et al.,, (2001a) found a die-off below 2 ºC, and in the Azov Sea, the entire population dies off when the temperature drops below 4 ºC in the fall/winter (Shiganova, Bulakova, 2000). *M. leidyi* is able to grow in oxygen levels down to 0.2 -0.3 mg l^{-1}. *M. leidyi* does only reproduce when temperature is between 19 ºC and 23 ºC and when food availability is good (GESAMP, 1997).

M. leidyi is a functional hermaphrodite (with ability to self-fertilize). The species is a carnivore (possibly omnivore) with a wide range of accepted food sizes and types. It will consume holoplankton as well as eggs and larvae of fish and benthic organisms. *M. leidyi* is bioluminescent and have superfluous feeding (continues food uptake even when gut is full. Surplus undigested and partly digested food is excreted encapsulated in mucus). Partly damaged and divided individuals are able to regain body integrity and regenerate to a full-grown animal (Coonfield, 1937). As typical for a successful non-indigenous species, *M. leidyi* has high fecundity. The full grown individual can produce approximately 10 000 eggs (Baker and Reeve, 1974).

Several characteristics of the species (high fecundity, rapid growth and a wide range of types and size of suitable prey food organisms) implies that the ecological impact of *M. leidyi* might be significant in invaded ecosystems by extending to several trophic levels. This assumption has been verified by showing that after invasion of *M. leidyi* pelagic fish (anchovy) have significantly decreased, possibly due to competition for food and preying upon fish eggs and larvae in the Black Sea (GESAMP 1997, Shiganova 1998; Shiganova et al, 2001a,2001b Kideys et al., 2001) while reversal of anchovy stocks occurred after invasion of another ctenophore *Beroe ovata* – an efficient predator of *M. leidyi* (Shiganova and Bulgakova 2000). Application of the coupled model of bioenergetic-based anchovy population dynamics and lower trophic food web structure study in the Black Sea suggests that dynamics of *M. leidyi* population over years was much more complicated than thought earlier and it could be accounted for a combination of direct and density-dependent effects of overfishing, eutrophication-induced nutrient enrichment, climate-induced over-enrichment and temperature-controlled *Mnemiopsis* spring production (Oguz et al. 2008).

Further spread of *M. leidyi* in OSPAR area should inevitably to be monitored. However, unfortunately, there is no known eradication strategy for *M. leidyi* when established in new ecosystems.

Polychaete (Polychaeta: Annelida)

Polychaetes are a large and complex group of organisms living in soft sediments as infauna and on hard surfaces as fouling organisms. Taxonomists usually specialize in families and thus, the identification of non-native species within many groups are largely unknown or not identified, especially small infaunal species. In this section, we identify one known invader and discuss the confusion in species identification which in turn makes identifying impacts difficult.

***Marenzelleria* spp**. (Spionidae, Canalipalpata)

Marenzelleria spp. are infaunal worms, which collect particles on their ciliated palps, either from the sediment surface or the near-bottom water. In its native range, on the Atlantic coast of North America, *M. viridis* ranges from 0 to 30 PSU, though in Chesapeake Bay and other estuaries, it is most abundant at oligohaline to mesohaline salinities (George 1966; Wass 1972). Planktonic larvae develop best at 5-10 ºC at 10 PSU (George 1966 - *M. viridis;* Bochert et al. 1997- probably *M. neglecta*), and spend 4-5 weeks in the plankton, creating the potential for considerable dispersal. The adult worms create densely branched networks of burrows down to 25-35 cm. in the sediment (Atkins et al. 1987; Hietanen et al. 2007). Dense populations of adult worms rework the sediment, bringing buried organic materials and nutrients to the surface, possibly increasing fluxes of NH4+ and P to the water column initially, but possibly promoting P retention and nitrification in the longer term (Hietanen et al. 2007). In the presence of *Marenzelleria* sp., the polychaete *Nereis diversicolor* (Atkins et al. 1987- Tay estuary, Scotland; Kotta et al. 2001, Baltic, Finland) and a community of oligochaetes and chironomids (Zmudzinski 1996, Vistula Lagoon, Poland) sharply declined, probably due both to competition and habitat change. However, *Marenzelleria* is out-competed by the native bivalve *Macoma balthica* and does not successfully invade *Macoma*-dominated communities (Kotta et al. 2001) Shifts in the benthic community due to the replacement of native fauna by *Marenzelleria* are likely to affect the feeding of fishes.

Worms of the genus *Marenzelleria* were first reported from temperate European waters from collections made in 1979 in the Forth estuary (these specimens are identified as *M. viridis*; Sikorski and Bick 2004). By the late 1980s, *Marenzelleria* were widespread in North Sea estuaries, and in 1985, they were collected in the Baltic Sea, at the mouth of the Oder River, Germany (Essink 1999; Bastrop and Blank 2006). By 1996, they had reached the Gulf of Bothnia and the Gulf of Finland (Leppakoski and Olenin 2000). Based on morphological and molecular surveys, *M. viridis* is the predominant species in North Sea estuaries (Sikorski and Bick 2004) and is common in the Baltic as far east as the Pomeranian Bight. One specimen was identified from the Gulf of Bothnia (Bastrop and Blank 2006; Blank et al. 2008). *Marenzellaria neglecta* was collected in the Elbe estuary (Sikorski and Bick 2004) and was abundant from the Pomeranian Bight to the Gulf of Riga (Blank et al. 2008). From the island of Askö north to the Gulf of Bothnia, *M. arctia* was the predominant species (Sikorski and Bick 2004; Bastrop and Blank 2006; Blank et al. 2008). From the 1970s to the 1990s, at least 3 separate contemporaneous cryptic invasions of *Marenzellaria* spp. into the northeastern Atlantic have occurred, probably through ballast water discharges (Sikorski and Bick 2004; Bastrop and Blank 2006).

The taxonomy of the genus *Marenzelleria* (Annelida) is confused; at least 5 species have been named in the genus. *Marenzelleria wireni* and *M. arctia* have an Arctic Ocean distribution, while *M. viridis* and *M. neglecta* are reported to have Northwest Atlantic native regions (*M. viridis* - Nova Scotia to Cape Henlopen; *M. neglecta* - Currituck Sound to Georgia) (Bastrop and Blank 2006; Sikorski and Bick 2004). As noted in the previous paragraph, at least three species of *Marenzelleria* have been introduced to the Baltic and North Seas, based on molecular and careful morphological studies (Sikorski and Bick; Bastrop and Blank 2006; Blank et al. 2008). Sikorski and Bick (2004) identify most North Sea estuary animals as *M. viridis* and Baltic animals as *M. neglecta*, a newly described Northwest Atlantic native species. Bastrop and Blank (2006) and Blank et al. (2008), using molecular methods, report occurrences of both *M. viridis* and *M. neglecta* in the Baltic, together with *M. arctia.* Morophological descriptions are given in Sikorski and Bick (2004), and a key to the genus is in Bick (2005).

Snails (Gastropoda: Mollusca:)

Crepidula fornicata (Calyptraeidae, Neotaenioglossa)

The slipper limpet (*Crepidula fornicata*) is a filter-feeding gastropod mollusc. It lives within sheltered coastal bays and estuaries and sometimes in deeper water. It attaches firmly to objects with its muscular foot. Individuals may attach to each other to form 'chains'. It was introduced to the UK in 1872 associated with imports of the oyster *Crassostrea virginica* from the USA and then spread to elsewhere in Europe where it now extends from the Mediterranean to southern Norway, including Ireland (Minchin et al. 1995). There are areas where population levels have exploded. Their abundance can change sediments to mud deposits of faeces, pseudofaeces and shell drifts. Such accumulating sediments on maerl beds reduce diversity and abundance of living plants. They may also reduce recruitment of some benthic commercial fishes. Shells may provide a refuge for predators. It is also widely viewed as a species that competes for space and food with native species. The main area of conflict is with commercially valuable beds of oysters and mussels and in some areas the limpets have to be actively removed to manage the situation. Slipper limpets are capable of spawning above 10°C with highly successful recruitment above 15°C. In addition winter minimum temperatures have been implicated as highly significant in terms of juvenile survival and therefore the overall level of mortality within the population. Range expansion may be limited by winter minimum temperatures. It is gradually expanding its range, possibly due to climate change.

Bivalves (Bivalvia: Mollusca)

Ship worm *Teredo navalis* Linnaeus, 1758 (Teredinidae, Myoida)

The origin as well as the time of introduction of *Teredo navalis*, the common shipworm have been debated. Some experts consider it a native of the Atlantic Ocean warm water region (NOBANIS 2007), whereas others consider its native region to be the Indo-West Pacific tropics (Främmande Arter, 2006). It has been introduced by hull fouling (boring into ships' timber). The earliest confirmed identification is probably from wood preserved from a Dutch dike that broke around 1730. This species caused much concern in the Netherlands between 1730 and 1735 due to massive damages to wooden coastal defense and harbor constructions. However, there are indications that the species was already present earlier in the North Sea, at least, from the 16ht century on. The earliest introduction into the Netherlands supports its Indo-West Pacific origin (Dutch colonial trade with Indonesia). There are records in Icelandic sagas that Viking ships were bored by living organisms, but it cannot be determined whether this was a species of shipworm (there are three species now living in the Northeast Atlantic) or the boring isopod *Limnoria lignorum* (Rathke, 1799).

Teredo navalis is the only shipworm species in the Northeast Atlantic that can tolerate the low salinities of Kattegat, the Belt Sea, and even the Baltic Sea. For many years there have been reports of *T. navalis* settling on wood pilings in the Baltic, usually after an inflow of saline water. However, they were not able to reproduce and would therefore disappear after 2-3 years. Also drift wood entering the Baltic Sea may contain live *T. navalis.* In less than 30 ppt it is permanently established in Kattegat, Little Belt (Lillebælt), Isefjord, the Sound (Øresund) to Copenhagen and the western Baltic Sea (west of Darsser Ort –Gedser threshold) (Kristensen, 1969, 1979; Jensen & Knudsen, 2005). Since 1993, however, apparently there has been a reproducing population in the Baltic proper (Sordyl et al., 1998). Settling larvae have been detected at the island of Bornholm (DEPA, 2003). They had selected the harbor of Rønne (Bornholm) as a control site because no shipworms were supposed to be present, but test-blocks were bored. Present distribution is probably cosmopolitan (NOBANIS, 2007).

Teredo navalis has planktonic larvae that only swim for a short period (less than a week). It reaches sexual maturity very fast (about 6 weeks). There is conflicting information on the minimum salinity required for reproduction, ranging from 12 ppt in most publications to 8 ppt (NOBANIS, 2007).

Shipworms comprise a serious threat to all wooden structures and the costs of replacing wood pilings in marinas and ports are huge (US$205 million annually; Pimentel et al. 2005). Until recently it was assumed that historical ship-wrecks in the Baltic were "safe" from shipworm attacks, but the recent spread and possible adaptation to reproducing at lower salinity has been a major concern of underwater archaeologists (Skaarup 2001; Förster 2003; Jöns 2004).

Besides the population in the Danish Wadden Sea there is also a population in the western Limfjord, and new recruits were found in the early spring of 2007 on sluice gates of Ringkøbing Fjord and Nissum Fjord on the North Sea coast of Denmark (see Danish National Report 2008).

Crassostrea gigas (Ostreidae: Ostreoida)

In 1970, *Crassostrea gigas* was introduced as aquaculture to replace overfished populations of the native oyster. As recent as 1975, natural spat from Arachon Bay and Bay of Marennes-Oleron was sufficient to sustain the French oyster production. This spat production was initially limited to the southern of France Atlantic coast. But since the 1990s, natural recruitment was observed along the Brittany coasts northward to the Normandy coast. The same observations were made elsewhere in Europe where the species was introduced for aquaculture purposes and initially thought not to reproduce. In recent decades settlements of small numbers of oysters have been found on the south and west Irish coasts (Boelens et al., 2005). This oyster species reproduces in the wild and is exhibiting an extended reproductive period as observed along the Belgium and British coasts, in Dutch and German waters after a series of mild winters in the 1990s and early 2000s (Spencer et al., 1994; Reise et al., 2005; Gollasch et al., 2007; Kerckhof et al., 2007). Specimens less than a year old appeared along the Swedish west coast after the mid winter 2006/2007 (see Swedish National Report, 2008) and in 2008 reproduction and newly settled larvae were seen (WGITMO 2009). Figure 1 shows the location and years of first settlement in the Wadden Sea. *Crassostrea gigas* was massively introduced in the beginning of the 1970s in France for aquaculture purpose. Environmental conditions were appropriate to obtain yearly regular spat recruitment. In 2009, an Alien Species Alert report is being prepared.

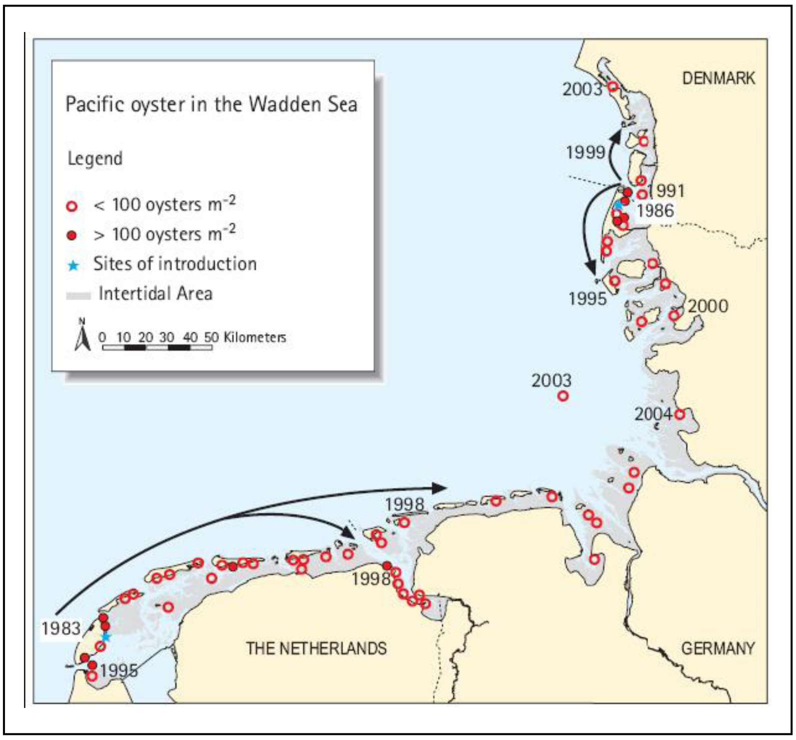

Figure 3: *Crassostrea gigas* in the Wadden Sea. Asterisks indicate introduction sites (Texel, The Netherlands and Sylt, Germany). Years indicate first records of settlement. Circles refer to mean Pacific oyster abundance in 2003 (from Reise et al., 2005).

The oyster appears to be competing with the native mussel on hard substrates. It can modify mud habitats that interfere with other shell fishing activities. Other reports suggest that the reefs formed by *C. gigas* provide habitat for benthic organisms, thus resulting in an increase in biodiversity in the short-term. The long-term impacts are unknown.

Japanese or Manila Clam *Venerupis philippinarum* (Veneridae: Veneroida)

The Japanese or Manila clam, *Venerupis* (= *Ruditapes*) *philippinarum* originates in the Pacific but was introduced into France in 1973 from Puget Sound area (Canada) for aquaculture purposes (Flassch and Leborgne, 1992), Portugal and Spain in the early 1980s, and the UK and Ireland in 1982. In France it was introduced in intertidal areas and in oyster ponds where favorable environmental conditions resulted in natural reproduction in the field. First aquaculture experiments were developed in Arachon Bay in 1980 and by 1988, first natural beds were observed (Robert et Deltreil, 1990). Initially, research indicated that the Manila clam was unlikely to breed in the wild. It however spread and became established in the late 1980s. The key natural reproduction sites in Europe include Italy, France, Spain and Ireland. More latterly it has spread from the one site (Poole Harbour) where it became established in southern England.

The introduced species competed with the native species *Venerupis decussata,* which was outcompeted rapidly. Bertignac et al. (2001) demonstrated that *V. philippinarum* represented 94% of clam species and 97% of clam biomass in the natural bed of Arachon Bay in 2000. The same situation was observed along the Atlantic coast, especially in the Golf of Morbihan. Moreover the alien species is now present along the French coasts of the English Channel. Limited aquaculture of Japanese clams was performed in Mediterranean lagoons; consequently the native clam species is still dominant.

Venerupis philippinarum reproducing populations are also found in Poole Harbour, South Coast of Britain (Naylor, 1965; Jensen et al., 2005). Naturally recruited Manila clams have also recently been found about 35 miles to the east of this, site in Southampton Water. As this site is only semi-enclosed further dispersal is possible under prevailing conditions of higher seawater temperatures. This species is one that may be a candidate for global climate change expansion. Along the French Brittany coast, populations of this species are thriving in the wild and they have gradually replaced the indigenous *Venerupis decussata.*

Important fisheries have developed where this has happened. In England there is hearsay evidence that Manila clams have been seeded (illegally) into the new areas by those with a commercial interest in expanding the range of the species. Climate change makes further natural recruitment increasingly likely. There is a view that native *Palourdes* are 'swamped' and disappear in the presence of Manila clams, although this is not certain. Environmental effects of standard cultivation methods are local, and short-lived when the clams are removed. Fishing usually involves suction dredging and can be carried out with little environmental impact.

Razor Clam *Ensis directus* (Pharidae, Veneroida)

The American jackknife clam *Ensis directus* was first discovered in 1979, in the German Bight, were the species was most probably introduced with ballast water. *Ensis directus* disperses through planktonic larvae and since its accidental introduction, it has rapidly spread and colonized the shallow coastal waters all along the coasts of the southern North Sea, eastern coasts of the UK, Kattegat and Skagerrak seas and it extends in the eastern English Channel along the French Normandy coast. *Ensis directus* often forms massive populations, occurring in extremely high numbers, outcompeting native *Ensis* species and other bivalves. When it occurs in high densities, it appears to alter habitat and impact native species, including native shellfish species.

***Crabs* (Malacostraca: Arthropoda)**

Asian shore crabs *Hemigrapsus takanoi* (Varunidae, Decapoda) (was misidentified as ***H. penicillatus***)

Hemigrapsus sanguineus (Varunidae, Decapoda)

Hemigrapsus takanoi was first found in Europe in 1993 in hull fouling samples. In 1994 it was found in the Bay of Biscay (France) and thereafter in Spain, Le Havre (France) and The Netherlands. In 2003 *H. takanoi* was found for the first time in Belgium waters and in 2007 in German waters. It appears under stones, dead oyster shells, oyster reefs in tidal areas with mud sediments, estuaries, brackish waters and sheltered beaches. In some cases individuals have been found down to 20m depth.

Hemigrapsus takanoi is native from warm and subtropical regions from the NW Pacific Ocean (Japan). It competes actively with native decapods and can cause their displacement, but its impact on native species is not well-documented. It may compete with native crabs of commercial interest, such as *Carcinus maenas*. Until 2005 this species was cited in European coasts as *Hemigrapsus penicillatus*.

Hemigrapsus sanguineus was first identified in France in 1999, and has been found in France and Germany and the Netherlands (see map in German report WGITMO 2008). It is similar to *H. takanoi*, but does not have the tuft of fur on its claw. It is found in similar habitats to *H. takanoi* and had similar impacts on the ecosystem and economics of the region. *Hemigrapsus sanguineus* was first reported in the US northwest Atlantic in 1988 and probably was the origin of the crab in Europe.

Chinese mitten crab *Eriocheir sinensis* (Varunidae, Decapoda)

The Chinese mitten crab *Eriocheir sinensis* was first recorded in the Aller River in Germany in 1912 and it was most likely introduced by shipping (ballast water and hull fouling of vessels). As there are no migrating native decapods in estuarine waters and rivers of the North Sea there has been little competition for the invader (Marquardt 1926). Because of favourable conditions, little competition, and an abundant food supply the crabs became abundant in German waters over several decades during the last century, but their abundance is oscillating (Panning 1938, Fladung 2000). The last mass development was observed in the mid-1990s in the Elbe River (Germany) and similar patterns although in lower numbers have taken place in the Thames River (Clarke pers. comm.) and in Dutch waters (Wolff, pers. comm.). *Eriocheir sinensis*' European distribution is shown in Fig.3 It is known from OSPAR regions II, III and IV (Schnakenbeck 1924, Jensen 1936, Petit 1960, Petit and Mizoule 1974, Haahtela 1963, Hoestland 1948, 1959, Christiansen 1977, Zibrowius 1991, Clark et al. 1998, Cabral and Costa 1999, Valovirta and Eronen 2000, Tendal 2001, Pienimäki and Leppäkoski 2004, Herborg et al. 2005; Gollasch and Rosenthal 2006, Minchin 2006b, Lundin *et al*., 2007).

The area of origin is waters in temperate and tropical regions between Vladivostock (Russia) and South-China (Peters 1933, Panning 1938), including Japan and Taiwan, with a centre of occurrence in the Yellow Sea (temperate regions off North-China) (Panning 1952). *Eriocheir sinensis* is an omnivorous predator, feeding on a wide range of plants, invertebrates, fishes and detritus. Gastropods and bivalves are the dominant food component. Juveniles actively migrate upstream up to 1,500 km inland in China and in Europe they are found until Prague and St. Petersburg (Ojaveer at al. 2007) and as far north as the northern Bothnian Bay (Fig. 4).

These crabs have both a human health and economic impact that is directly related to humans and also alter habitats for native species. The crabs are the second intermediate host for the human lung fluke parasite in Asia (not yet recorded in crabs in Europe). *Eriocheir sinensis* damage nets and prey upon fishes caught in traps and nets. In freshwater ponds they feed on cultured fish as well as their food. The burrowing activities of crabs result in increased erosion of dikes, river, and lake embankments that both alter native habitats increase sedimentation and threaten structures. During massive migrations, they can clog up industrial water intake filters. In some European countries crabs are caught as by-catch in inland fisheries and sold to Asian restaurants, but they may also be used as fishing bait, for fish meal production, and for cosmetic products (Peters 1933, Panning 1938, 1952, Gollasch 2009). Use of live crabs for fishing bait may be a secondary dispersion mechanism.

Figure 4. Distribution of the Chinese mitten crab *Eriocheir sinensis* in the OSPAR region (Gollasch 2009).

Red King Crab, *Paralithodes camtschaticus* (Lithodidae, Decapoda)

The red king crab *Paralithodes camtschaticus* was introduced into Russian waters and had migrated to Norway waters by 1976. It is found throughout northern Norway. It competes with local predators, modifies habitat and may impact shellfisheries.

A fairly comprehensive account of the Red king crab in Russian and Norwegian waters is given in (ICES 2005b). Most of the following texts and figures are excerpts from that report.

The native living range for the Red king crab *Paralithodes camtschaticus* is the Okhotsk and Japan Sea, Bering Sea and Northern Pacific Ocean (along the Aleutian islands).

In the period from 1961-1969 1.5 million zoea larvae (stage I), 10 000 1-3 year old juveniles and 2,609 5-15 year old adults (sex ratio approximately 1:1 for juveniles and adults) were intentionally introduced to the areas east of Motovsky Bay at the Russian coast of the Barents Sea. (Orlov and Karpevich, 1965; Orlov and Ivanov, 1978). (Brick red, Figure 5)

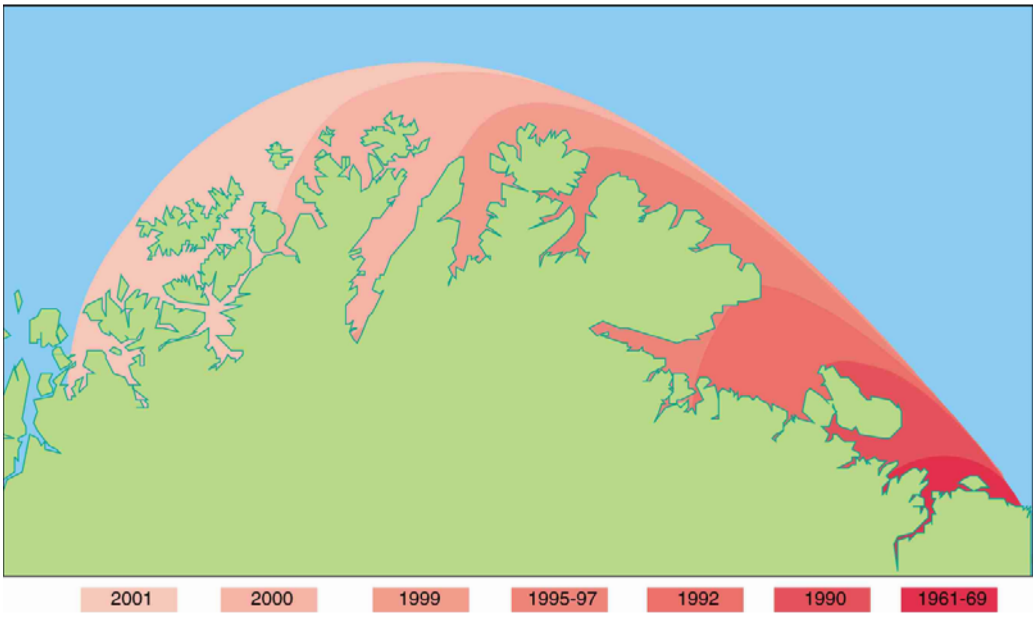

Figure 5. Coarse estimate of spread and distribution of the red king crab from its release region in the Barents Sea. Illustration by Jan Sundet, Institute of Marine Research, Norway.

Red king crabs may live 20 years (Kurata, 1961) and can reach a carapace length of ~220 mm and a weight of ~10 kg (Wallace *et al.*, 1949). Young larvae settle in the sublittoral zone shallower than 20 m (Marukawa 1933). Juvenile crabs are dependent of cover the first 2 years, but later become less dependent. (ICES 2005b) and references therein. The king crab has two migrations, a molting/mating migration to shallower (<60m) water in spring/summer and a feeding migration to deeper water (300-400m) in autumn/winter. Adult crabs can potentially migrate far and effectively. In an experiment, Jørgensen et al (2007) found a walking speed on 270m/h. Additionally, the pelagic larvae will follow the water currents as long as they remain in the water column, and may be transported significant distances.

Food consumption and composition of species consumed were described for the red king crab(From ICES 2005b). The red king crab in the Barents Sea region feeds on bivalves and echinoderms in the spring and summer and polychaetes in the winter, in a similar way as native populations, and the availability of food for the crab would appear to be the most important factor in limiting its distribution in its new environment (Gerasimova, 1997). The total index of stomach fullness (organic stomach content (g)/crab weight (g)) of the red king crab in the Barents Sea (Manushin, unpublished data) is similar to the red king crab population from the North Pacific Ocean (Tarverdieva, 1976; 1978) and indicates that the food availability in the Barents Sea is presently sufficient to support the existing population. However, there appear to be some changes in the diet from echinoderms to fish over the period 1997–2000, which is probably a result of crabs feeding on fish discarded from fishing vessels.

Consumption of benthos species in the Murmansk region at depths >100 m (calculated as daily stomach content and energy balance of the crab) ranged from 15 000 to 20 000 tonnes per year (Manushin, unpublished data). These data are based on daily consumption for all crab size groups scaled up to a year and includes an estimate of 20% of the food handled not being consumed.

Norwegian by-laws has allowed for by-catch and free fishery of king crab W of "Nordkapp" at 26 ºE since 2004/2005. The density in the western part of its extension range has not increased clearly the latter years, thereby indicating a possible success for the open (culling fishery). East of 26 ºE a TAC is proposed by The Joint Russian-Norwegian Fishery Commission. For 2009/20010 the quota is 1075 ton male crabs. Additionally, a quote of 110 ton crabs with injuries (males) and 106 ton females. This is calculated to correspond to approximately 474 000 males and 50 000 females.

FOULING ORGANISMS

This section identifies several introduced fouling organisms that are often prevalent on human-made structures such as docks, piers, pilings, ship hulls and many offshore structures such as aquaculture farms, buoys, oil rigs, wind farms, and offshore terminals (e.g. for liquid natural gas tankers). Although there are many native fouling organisms, non-native species may become the dominant species in numbers and/or biomass. Examples of species that dominate the biomass are tunicates such as *Styela clava* and *Didemnum vexillum.* In other cases, the organisms clog water pipes and require maintenance that has high annual costs.

Segmented Worms (Polychaeta: Annelida)

Ficopomatus enigmaticus (Serpulidae, Palpata)

Ficopomatus enigmaticus was first reported in northern France in 1921 (Fauvel 1923). It was first recorded from London docks in 1922 (Monro 1924). This origin of this species is not clear, it occurs in waters of variable salinity in temperate or warm temperate areas of both northern and southern hemispheres, and it was possibly introduced from Australia and regions of the Indian Ocean (Zibrowius & Thorp 1989). However, recent Australian literature lists *Ficopomatus enigmaticus* as introduced, and the best conclusion is that it is clearly southern hemisphere in origin (L. McCann & J. Carlton pers. comm.).

Probably introduced as hull fouling or as larvae in ballast water, *F. enigmaticus* can form extensive reefs of up to 7 m in diameter, but are usually 3-20 cm in temperate areas and 1.5 m under mixohaline and hyperhaline conditions in warm climates or around thermal effluents (Minchin 2009). Individual worms can grow at 1.5-2 cm per month and collectively produce up to 13 kg of calcareous tubes in 3 months. Established reefs may provide refuge for invertebrates including snails and crabs that, in turn, may have an impact on native species communities. Their dense tube colonies attach to intake pipes, reducing water flow and causing blockages and foul surfaces in aquaculture ponds, ports and docks, all of which require cleaning and maintenance. *Ficopomatus enigmaticus* fouls the hulls of leisure craft and floating structures in lagoons and docks.

Table 2. Records of *Ficopomatus enigmaticus* in OSPAR

Netherlands	1968	Ten Hove, 1974, Wolff 2005	Veerse Meer and the Kanaal door Walcheren
Belgium	<1952	Leloup and Lefevere 1952, WGITMO 2001-2006	Oostend Harbour
France (mainland)	1921	Goulletquer et al 2002	near Caen (Normandy)
Germany, North Sea	1975	Kühl 1977b	Port of Emden
Ireland	2004-2006	Pederson, pers. obs.; Minchin 2007b	Shannon, Ireland
Denmark	1953	Jensen and Knudsen 2005	Copenhagen
Spain	1924	Fischer-Piette 1937, 1951, 1955	Alicante

Barnacles (Maxillopoda: Arthropoda)

Balanus improvisus (Balanidae, Sessilia)

Balanus improvisus, a barnacle, is probably native to the northwest Atlantic coast. Early reliable records of this species for northwest Europe are scarce, in the first place because Darwin only properly recognised and described the species in 1845. Moreover, it was difficult for former scientists to distinguish *B. improvisus* from other common white barnacle species occurring along the northwest European coasts. Kerckhof & Cattrijsse mention *B. improvisus* from a 16th century archaeological context. If *B. improvisus* is non native to northwestern Europe, it must have been an early introduction, with an invasive history probably comparable to *Mya arenaria*.

Table 3. Record of *Balanus improvisus* in OSPAR regions

Norway (mainland)	1800s	Sneli 1972, Brattegard and Holthe 1997, Hopkins 2001	
Spain (mainland)	<1900	Walford and Wicklund 1973	Galicia
Denmark North Sea, Kattegat		Jensen and Knudsen 2005, Knudsen 1989	
Sweden Skagerrak; Kattegat, Baltic Sea			
The Netherlands	1827	Hoek 1876 *in* Kerckhof & Cattrijsse 2001	
Belgium	17th century	Kerckhof & Cattrijsse 2001	Antwerpen, Archeological context
Germany, North Sea	1858	Kirchenpauer 1862	buoys in the Elbe estuary
Ireland	1990	Furman 1990; Minchin 2007b	

Figure 6. Distribution of *Balanus improvisus* throughout Europe and the Baltic and Caspian Seas (Olenin and Olenina 2009 DAISIE)

Some additional fouling organisms that are present in the OSPAR region and cause problems. The organisms foul docks, piers, hulls of ships, aquaculture facilities, and compete with native species.

Austrominius (= Elminius) modestus (Balanidae, Sessilia)

This species which is native to Australia and especially New Zealand has been observed in Europe since 1946.

Table 4. Record of *Austrominius modestus* in OSPAR regions.

Netherlands	1946	Boschma 1948, Den Hartog 1953, Wolff 2005	Wassenaarse slag and on breakwaters at Loosduinen-Kijkduin
Belgium	1950	Kerckhof and Cattrijsse 2001, Kerckhof 2002	
Spain (mainland)	<2006	WGITMO 2006	Asturias, Rio Eo, Villaviciosa and Ribadesella (Bay of Biscay)
Denmark North Sea, Rømø, Wadden Sea	1978	Jensen and Knudsen 2005, Knudsen 1989	
France (mainland)	<1953	Goulletquer et al 2002	N and S Brittany
Germany, North Sea	1953	Kühl 1954	Elbe estuary, near Cuxhaven
Ireland	2005-6	Minchin 2007b	

Skeleton Shrimp (Malacostraca: Arthropoda)

Caprella mutica (Caprellidae, Amphipoda)

Although not living attached to surfaces, this species is considered to be a fouling organism. It may occur in massive densities. The species is indigenous to northeast Asia.

The first record of *Caprella mutica* was 1998 in Belgium, for the UK was in July 2000, from a fish farm in Scotland (Willis *et al*., 2004), and Ireland (Minchin 2006, 2007b; Cook et al. 2007). The species' natural distribution is the coastal waters of the sub-boreal areas of north-east Asia (Willis *et al*., 2004). It is now found from Norway to Belgium, but so far not yet seen in ~Sweden. Its abundance may vary throughout the year, but it may be the dominant and most abundant amphipod when it is present.

Insect (Insecta: Arthropoda)

Telmatogeton japonicus (Chironomidae, Diptera)

This chironomid species is native to the western Pacific. The species was first found in the Kiel Kanal (Baltic) in 1963 (as *Telmatogeton remanei*). It is found throughout the OSPAR region e.g. in the UK (Murray 2000), North Sea in 2002, the Netherlands, Belgium (buoys off the Belgian coast) WGITMO 2005, (Kerckhof, pers. Comm) and the species forms monocultures in the splash zone on the newly constructed offshore windmill foundations of Denmark, (Dong Energy 2006), Belgium, (Kerckhof, pers. comm), and Sweden (Brodin & Andersson 2008).

Bryozoan (Gymnolaemata: Ectoprocta)

Bugula stolonifera (Bugulidae, Cheilostomata)

This species of bryozoan is found in Regions II to V (North Sea and includes the Azores).

Table 5. This species of bryozoan, *Bugula stolonifera* has been found in OSPAR regions.

Belgium	1999	Kerckhof 2000
Portugal (Azores)	2000	Morton and Briton 2000
Spain (Canary islands)	2003	Aristegui and Fernandez-Gil 2003
Netherlands	1993	D'Hondt and Cadée 1994, Wolff 2005

Sea Squirts (Chordata: Tunicata: Ascidiacea)

Styela clava (Pleurogona: Styelidae)

Probably introduced to Europe as fouling on warships, the sea potato sea squirt *Styela clava* arrived in Europe during the Korean War. It is native to the Pacific coast of Asia and once introduced to Europe, it was reported on ship and leisure craft hulls. The first introduction of *S. clava* in the Mediterranean was in the Bassin de Thau (Davis and Davis 2008). It may be spread with oyster stock movements and movement of floating port structures where *S. clava* is a fouling organism. Although the larval stage lasts for a short period of time (24-48 h), introduction by ships' ballast is possible during local short voyages. The sea squirt can attain densities > 1000/m^2 in sheltered areas, creating a high biomass that results in competition with other filter-feeders. Young individuals often attach to larger specimens (up to 200 mm) to form clusters and the long-lived *S. clava* may serve as substrate for other non-native species

(Pederson, pers. comm.). Some humans are susceptible to respiratory problems from sprays produced from damaged tissues when removing them from oysters. Fouling of artificial structures in port regions, ranched oysters, shellfish held in hanging culture, and attachment to fish cages result in economic costs associated with maintenance. In the St Lawrence Estuary, Canada, *S. clava* abundance has caused declines in cultured mussel production (Minchin 2009).

Table 6. Record of *Styela clava* in OSPAR regions.

Portugal (mainland)	2005	Davis and Davis 2005	northern coast and near Lisbon
Spain (mainland)	???	Davis and Davis in print	Bay of Biscay
Netherlands	1974	Lützen 1999, Wolff 2005	Port of Den Helder
Belgium	<1986	d'Udekem d'Acoz 1986	Knokke Heist
Denmark North Sea	<1978	Jensen and Knudsen 2005, Knudsen 1989, Christiansen and Thomsen 1981	W Limfjord
France (mainland)	1968	Goulletquer et al 2002	Dieppe (Normandy)
Germany, North Sea	1997	Nehring 2005, WGITMO 2006, Reise 1998aandb	List, Sylt
Ireland	1986	Minchin and Duggan 1986; Minchin et al. 2006; Minchin 2007b	Cook Harbor, SW Ireland

Figure 7. Distribution of *Styela clava* in Europe and the Mediterranean (Minchin 2009, DAISIE)

Didemnum cf. *vexillum*

This species is native to western Pacific and until recently has been described as *Didemnum* sp. A, *D. lahillei,* and *Didemnum* sp. It was identified in the Netherlands in 1991 in Oosterschelde estuary, WGITMO 2006 (Haydar, pers. comm.) and more recently in Ireland (Pederson pers. obs. 2004; Minchin et al. 2006; Minchin 2007b)

SUMMARY

The summary identified a variety of algal and invertebrate species that have been introduced intentional or unintentionally by a variety of vectors. Aquaculture (as deliberate transfers and hitchhikers on shellfish) were major vectors of initial introductions. Hull fouling, fishing activities, and drift were secondary vectors that move species from one location to another. Most of these species have economic impacts usually as fouling organisms on aquaculture facilities or during harvest. In addition, fouling of hulls, docks, piers and other man-made structures are a nuisance and have economic costs associated

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ANNEX 5 REPORT Species Alert Report : Crassostrea gigas

Alien Species Alert: ***Crassostrea gigas*** **(Pacific oyster)**

Prepared by the working Group on Introductions and Transfers of Marine Organisms

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1 Introduction

The Pacific oyster *Crassostrea gigas* (Thunberg, 1793) is one of the 20 species from the genus *Crassostrea*. Although endemic to Japan, *C. gigas* is a hardy species that has been introduced to a number of countries worldwide, including the United States, Canada, United Kingdom, France, Korea, China, New Zealand, Australia, South Africa and South America mainly for aquaculture purposes (Mann *et al.*, 1991; Orensanz *et al.*, 2002). As a result, *C.gigas* has become the leading species in shellfish culture world production estimated to be 4.8 million metric tons in 2006 (FAO, 2006). Because *C. gigas* does not need additional food to sustain growth, this species is relatively inexpensive and easy to produce. Its capacity to adapt to various environmental conditions and environmental stress (°T), and its rapid growth, and resistance to high turbid areas contribute to its success.

2 Identification

The taxonomic status of *C. gigas* is now well established (Table1).

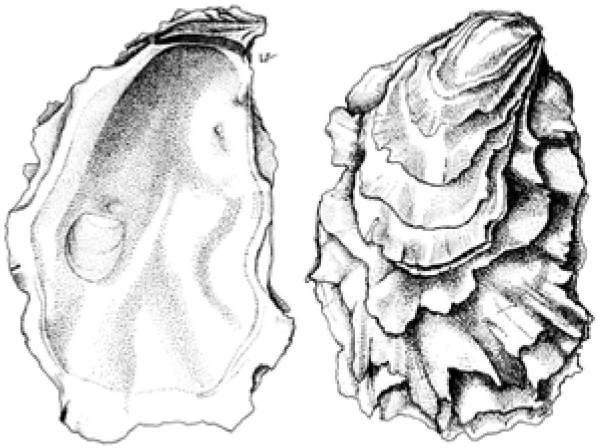
Table 1: The taxonomic status of *Crassostrea gigas* according to the ITIS (Integrated Taxonomic Information System - http://www.itis.gov/index.html).

Phylum	Mollusca
Class	Bivalvia
Subclass	Pteriomorphia
Order	Ostreoida
Family	Ostreidae
Genus	*Crassostrea*
Species	*gigas*

Identification of oyster species is still largely based on phenotypic characters, and the primary distinguishing feature is shell morphology (Figure 1).

The Pacific oyster *C. gigas* is described as having an elongated rough shell, which can reach a 20-30 cm size. Although highly variable, the two valves are solid but unequal in size and shape (CIESM, 2000; Hughes, 2002). The left valve is slightly convex and the right valve is quite deep and cup shaped. One valve is usually cemented to hard substrata. Shells are sculpted with large irregular, rounded radial folds. Radial ribs are on both shells starting from the umbo. Usually whitish, they show purple streaks and spots. Its inner side is white and partially whitish milky colour. The adductor muscle scar is kidney shaped.

Although several studies based on morphology and geographic range information have attempted to identify characters and traits that can be used for identification and to resolve relationships among species (Stenzel, 1971; Bernard, 1983; Harry, 1985; Brock, 1990), this process has proven problematic. The high plasticity of morphological characters, greatly affected by habitat, added to the influence of anthropogenic activities to the geographical distribution of this species has raised a need for more accurate method of identification. During the past decade, molecular biology has contributed some clues to initiate resolving the taxonomic riddle represented by the taxonomic classification of *Crassostrea* oysters.



Crassostrea gigas

Crassostrea gigas

Figure 1: Shell morphology of the Pacific oyster or Japanese oyster, *Crassostrea gigas* (Thunberg, 1793) – Picture Ifremer.

A major remaining taxonomy question relates to the relative status of the Portuguese oyster, *Crassostrea angulata*, and the Pacific oyster, *Crassostrea gigas* (Figure 2). *Crassostrea gigas* and *C. angulata* were classified as two different species by Thunberg in 1793 and Lamarck in 1819, respectively. This classification was influenced foremost by the apparent different geographical distribution of the two species, *C. gigas* and *C. angulata* being found respectively in Asia and Europe, respectively. However, recent studies using mitochondrial markers have reported the presence of pure populations of *C. angulata* in Taiwan, suggesting an Asian origin of European *C. angulata* populations (Boudry *et al*., 1998; Huvet *et al*., 2000). This hypothesis is supported by the observation of mixed populations of *C. angulata* and *C. gigas* in Northern China (Yu et al., 2003; Lapègue *et al.,* 2004).

No morphological characteristic allows differentiating the two taxa, as larval and adult shells of both taxa have similar features (Menzel, 1974; Biocca and Matta, 1982).

However, differences in growth performance, ecophysiological criteria and disease susceptibility are reported. *Crassostrea gigas* grows faster than *C. angulata* and the latter species is subject to higher mortality rates (Bougrier *et al*., 1986; Soletchnik *et al*., 2002). These observations could be explained by differences in clearance rate, oxygen consumption and feeding activities (Goulletquer *et al*., 1999; Haure *et al*., 2003). High mortality of *C. angulata* was observed between 1967 and 1973 in France. Irido-like viruses were suspected to be the causal agent of these events (Comps, 1988). These viruses were also observed in *C. gigas* but no associated mortality was observed (Comps and Bonami, 1977; Comps and Duthoit, 1976). These observations suggested that the *C. gigas* and *C. angulata* have different resistance patterns to virus infection.

When comparing *C. gigas* and *C. angulata*, the genetic differentiations represent the most controversial aspect. Experimental hybridization followed by viability and fertility of hybrids as well as electrophoretic studies of enzyme polymorphism led to the conclusion that *C. gigas* and *C. angulata* belong to a single species (Mathers *et al*., 1974; Buroker *et al*., 1979; Biocca and Matta, 1982; Mattiucci and Villani, 1983; Gaffner and Allen, 1993, Huvet *et al*, 2001; Huvet *et al.* 2002). Recent studies based on nuclear and mitochondrial DNA also highlighted the close genetic relationship between *C. angu-*

lata and *C. gigas* (Lopez-Flores *et al*., 2004; Reece *et al*., 2008). On the other hand, additional studies on mitochondrial DNA (Boudry *et al*., 1998; Huvet *et al*, 2000b) and karyotype analyses (Leitao *et al*, 2004) demonstrated genetic differences between *C. angulata* and *C. gigas* populations.

As a conclusion and according to the current knowledge, *C. gigas* and *C. angulata* are considered as being two different taxa that are indeed very similar but can be distinguished.

Figure 2: The Portuguese oyster *Crassostrea angulata* and the Pacific oyster *Crassostrea gigas* (pictures Ifremer)

3 Biology (general data)

3.1 Anatomy

Oyster flesh is covered by a tegument, the mantle involved in the process of shell calcification. The free space between the two lobes of the mantle is the pallial cavity, divided by the gills into an inhalant and exhalant part where seawater circulation occurs (without siphons). Gills act as a filter to retain particles and also oxygen for the respiration process (Gerdes, 1983; Bougrier *et al*., 1995, 1998; Goulletquer *et al*., 1999, 2004). The mouth, surrounded by the labial palps is near the hinge, whereas the anus is just above the adductor muscle. During reproduction, the gonadal mass is largely diffuse within the body flesh, and reach up to 70% of the total dry meat weigh for adults (Figure 3).

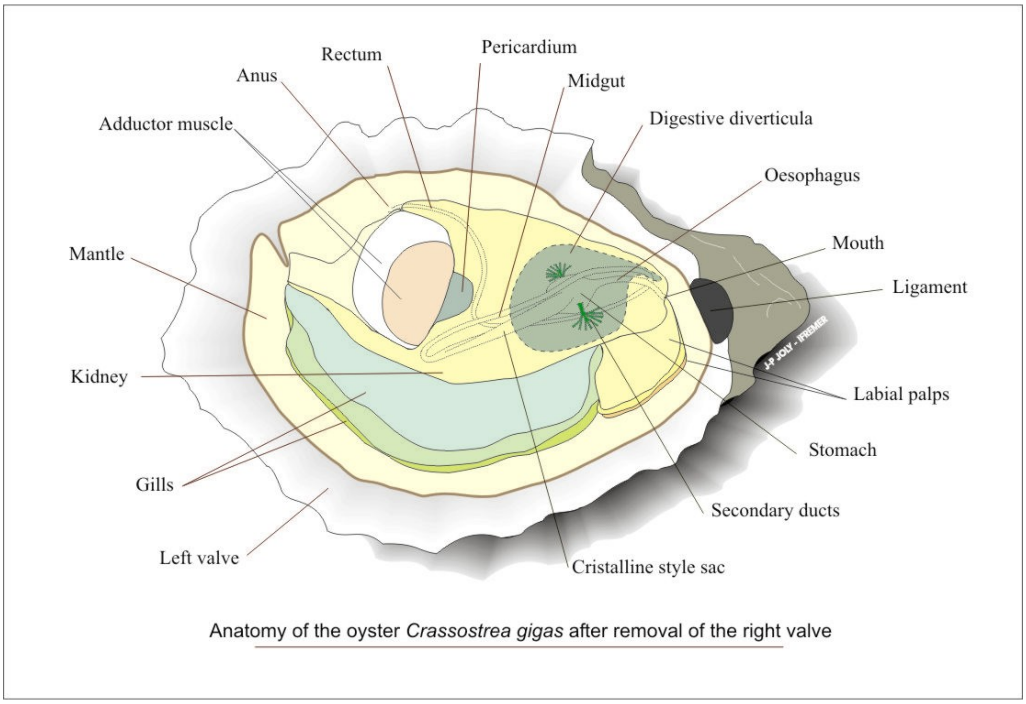


Figure 3: Anatomy of the oyster *Crassostrea gigas* (courtesy of J.-P. Joly, Ifremer).

3.2 Behaviour

Crassostrea gigas is a plankton feeder, filtering phytoplanktonic species for food (filter-feeder) and also ingesting detritic particulate organic matter. Whereas mucous secretion is used to transport particles towards the mouth, *C. gigas* has a capacity to select particle size at the gill and labial palps levels (Barillé *et al.*, 1997, 2000; Bougrier *et al.*, 1997). Therefore, they can reject faeces resulting from the digestive activity, as well as pseudofaeces that consists of non ingested agglomerated particles. Temperature is the factor driving all the physiological processes, including filtering activity, metabolism, respiration and excretion rates (Bougrier *et al.*, 1995). *Crassostrea gigas* is an oviparous oyster with a high level of fecundity (Deslous Paoli and Héral, 1988). They change their sex during life, usually spawning first as a male, and subsequently as a female (Héral & Deslous- Paoli, 1990). Spawning is temperature dependent and occurs in summer months (15-20°C) synchronously (Goulletquer, 1997). Reproductive effort is high, a female producing 20-100 million eggs per spawning (diameter 50- 60μm). Fertilisation is external taking place in the seawater column. Larvae (Figure 4) are firstly free-swimming and planktonic; developing for two to three weeks before metamorphosis and finding a suitable clean hard substrate to settle on. Usually attached to rocks, they can settle in muddy or sandy areas (attached to debris, small rocks, shells) or on the top of other oysters, leading to reef building (Orensanz *et al.*, 2002). Highly sensitive to environmental conditions, a very small percentage of larvae survive to become spat (Figure 4). Natural habitat is intertidal and the species can be found down to 15 m deep on either hard or soft substrate. The species resist temporarily to very low salinity (5 ppt). The swimming stage and capacity to survive in various environmental conditions facilitate the species dispersion along coastal areas and its capacity to colonize new areas (CIESM, 2000; NIMPIS, 2002).

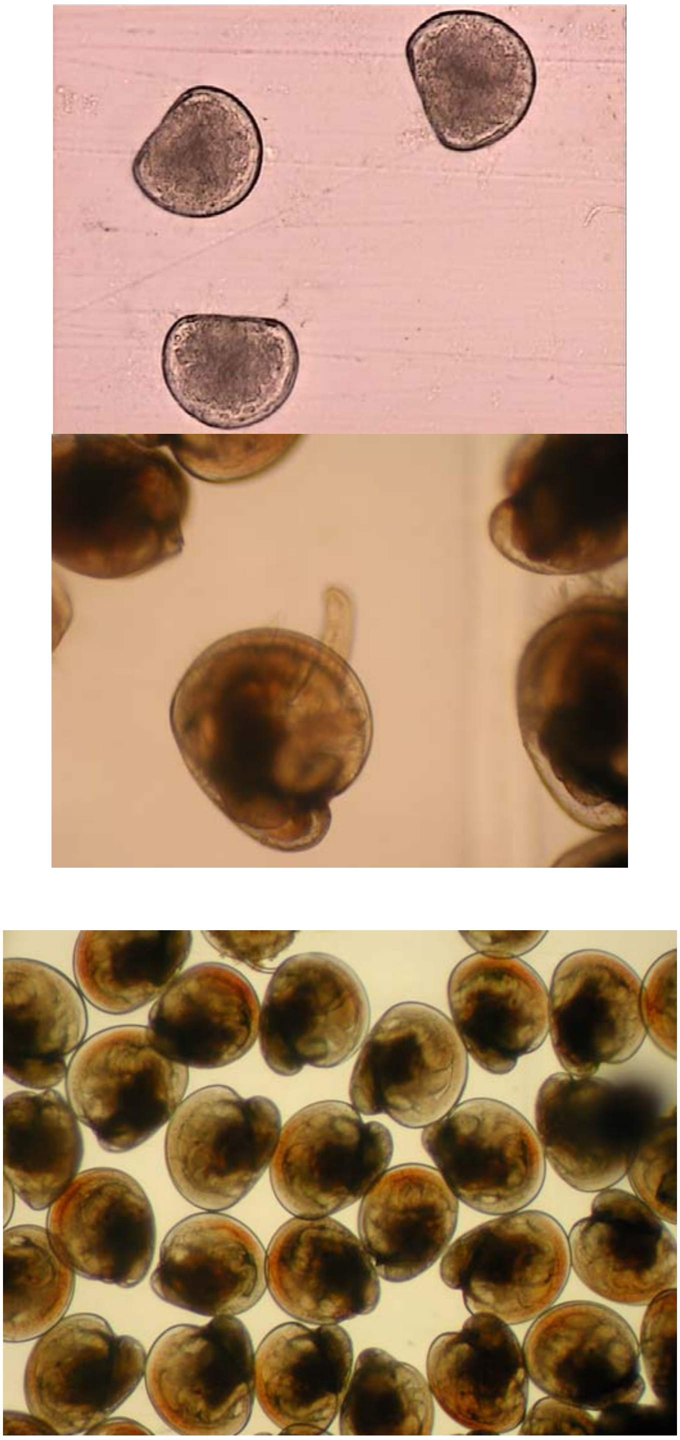


Figure 4: Larval and young spat stages of *Crassostrea gigas* (pictures by L. Degremont, Ifremer).

3.3 Performance

Salinity and temperature tolerances vary greatly amongst on *C. gigas* varieties and amongst geographical locations. *Crassostrea gigas* is a very euryhaline and eurythermic species. Moreover, a combination of factors such as Temperature-Salinity is more representative of species tolerance than straight values (Goulletquer, 1997). Interactions among factors are also critical. Similarly, physiological status is a critical factor for environmental conditions tolerances as well as the life stage (Powell *et al.*, 2000; 2002). The oyster protective shell facilitates protection against temporarily stresses, including pollutants and abnormal temperature-salinity conditions. Obviously, egg and larvae are more sensitive to environmental changes (His *et al.*, 1999). Optimum salinity range for egg development depends directly on the salinity where the parents were grown. Once activated (#12°C), gametogenesis is directly dependent on the duration of this temperature (degree-days) and a temperature of at least 18°-20°C is necessary for spawning. Overall growth performance is highly dependent on local carrying capacity, therefore leading to highly heterogeneous growth.

3.4 Nutrition and feeding

Crassostrea gigas as a filter feeder is using mainly the available particulate organic and inorganic matter, including phytoplankton as a natural diet (FAO, 2004). This diet, and specifically the ratio among components, is highly dependent on environmental conditions and locations (estuarine areas, oceanic waters) (Muniz *et al.*, 1986; Deslous-Paoli and Héral, 1988; Milyutin and Frolov, 1997). Adsorption of dissolved organic matter (e.g., amino acids) as well as bacteria also contributes to the regular diet. Filtered particles are below 50 µm in size and mainly around 10 µm. Nanoplankton can contribute to the diet. For larval culture, a 2 $mg.l^{-1}$ food concentration is considered as suitable to reach metamorphosis. In contrast, survivorship reaches zero at food concentration of about 0.5 $mg.l^{-1}$, while growth and survivorship are affected for <1 $mg.l^{-1}$ food quantity. Although *C. gigas* does not require added food to grow in open environment, in semi-closed ponds and in controlled environment, fertilizers can be used to maximize primary productivity and carrying capacity (Hussenot *et al.*, 1998; Turpin *et al.*, 2001). Depending on initial nutrient concentrations in seawater and also local irradiance, NPSI medium can be used to balance nutrient ratios and therefore maximize algal blooms. It can be carried out either for a specific species or a mass production. For example, the diatom *Skeletonema costatum* production can be maximized with a 10:1:4 N:P:Si ratio. A simple three component medium completed by metals (iron and manganese) with or without metal chelator (EDTA) can be used efficiently at a low cost (2 $US for a 10^6 $cells.ml^{-1}$ bloom in 100 m^3 volume). In this case, a limited inoculum (10000 $cells.ml^{-1}$) can facilitate the bloom. The enrichment of seawater should be carried out in a way that no environmental impact occurs and NPSi medium should be efficient to be entirely consumed by phytoplankton.

3.5 – Health and Predation

3.5.1 – Health

Although *C. gigas* has shown a large tolerance to disease agents, explaining its worldwide production success, several diseases and syndromes have been described (Bower, 2002; OIE, 2003). Owing to its life in open waters and a limited immune system, no curative measure is available for *C. gigas* diseases. Prevention and adapting best management practices remain the option to limit impacts. In the mid-term, genetic research programmes aim at domesticate and develop selected disease resistant (tolerant) strains.

The 'summer mortality' syndrome has been described worldwide and seems correlated with high seawater temperatures and the reproductive activity (Goulletquer *et al.*, 1998). Although not totally understood, this syndrome is likely related to combined factors and highly complex interactions between environmental conditions – health status and opportunistic pathogens. Recent studies have demonstrated the respective roles of environment, pathogens and physiology combined with the genetic of oysters in the "summer mortality" syndrome. The risk of occurrence of a mortality event becomes important when relevant conditions are met simultaneously. These conditions are: a mild and rainy winter, a sea water temperature threshold of 18°C, added to a high level of food availability during the preceding spring, an intensive reproductive effort, and the genetic susceptibility of oyster populations. An additional stress (chemical, thermal or associated with cultural practices) is necessary to trigger a mortality event which in turn will be associated with pathogens such as Vibrios or herpes-like virus (Samain and Mc Combie, 2008).

Box 1. Special focus at the oyster mortality events during summer 2008 in France

Some abnormal mortality events occurred in the major oyster *C. gigas* producing areas in France this summer. The phenomena started during the spring period; during this epidemic a peak of mortality was recorded towards the end of June and finished approximately two weeks thereafter. This mass mortality essentially affected juveniles of less than 24 months and only *C. gigas* species was affected.

Mass mortality of *C. gigas* has been reported over wide geographical areas and with high intensity where the species is cultivated and was present since the mid-1970s in France. In this report, mortality arose for most part in the Mediterranean part of France, followed by Brittany, along the Atlantic coast and later in Normandy in the English Channel. Losses of *C. gigas* in France fluctuate from year to year. They were particularly high in the 1990s. But in 2008, the summer mortality events set off very suddenly, were significantly more severe (up to 100%) and, although they started a little earlier in some areas, they have affected quite simultaneously all the French rearing areas.

Samples were collected from all affected locations and tested for diagnostic purposes. Results show that no listed pathogens were involved but pathogens, Herpes virus OsHV-1 and two vibrio species *Vibrio splendidus* and *Vibrio aestuarianus,* were detected in most of samples especially in moribund oysters.

First investigations on oyster physiology and environmental conditions demonstrated that the model previously developed (Samain and Mc Combie, 2008) was partly met here. An epidemiological study coordinated by L. Miossec is currently undertaken at Ifremer (La Tremblade), in order to determine the respective roles of pathogens and oyster transfers with regards to the exceptional intensity of this event in 2008. This study involves a partnership between Ifremer, the shellfish industry and various French governmental bodies. Additional work is required to characterise the virulence of pathogens identified in association with these mortalities.

Pathogens involved in *C. gigas* infections are now presented below.

Herpes virus infections are caused by viruses presenting similar features, cellular locations and size characteristic of virions from the Herpesviridae family (ICES, 2004; Renault *et al.*, 1994). Herpesviruses have been reported in nine different bivalves worldwide, and shown an increasing pattern for host number (Renault and Novoa, 2004). OsHV-1 can infect several bivalve species and appears to show both a vertical and horizontal transmission patterns. Herpes viruses were associated to significant larval mortality in hatcheries in France and New Zealand (Nicolas *et al*., 1992; Hine *et al*., 1992) and seems widespread worldwide (Renault and Novoa, 2004). Irregular high mortalities of juveniles have been associated to the Herpes viruses since 1991 and OsHV-1 may be associated to the 'Summer Mortality' syndrome.

An oyster velar virus (OVVD, Iridoviridae) was reported in hatcheries in Washington State (USA) during the 1980s' affecting *C. gigas* larvae greater than 150µm (Elston and Wilkinson, 1985). An iridovirus is also considered as the epizootic causative agent leading to the disappearance of *C. angulata* in French waters in 1970s (Comps *et al*., 1976; Héral and Deslous-Paoli, 1990).

Nocardiosis, also called fatal inflammatory bacteraemia (FIB) or focal necrosis is an actinomycete bacteria inducing infection and usually associated with mortalities during the late summer and fall. The agent *Nocardia crassostreae* is distributed in the West coast of North America from the Strait of Georgia, British Columbia to California and also Japan (OIE, 2003). Diagnosis shows round yellow to green pustules up to 1cm in diameter on the mantle, gill, adductor muscle and heart surface. Associated mortalities have reached up to 35% in some localities. DNA probes are available for diagnosis. Although of unknown distribution, the agent appears widespread given the historical *C. gigas* movements. No control method is available, and the appropriate management option is to limit contaminated oyster batch transfer. Off bottom culture as well as rearing oysters outside shallow warm embayment may reduce prevalence.

Vibrios are ubiquitous marine bacteria which have been detected in various marine species including different oyster species such as *C. gigas* and *C virginica*. Vibriosis is the most commonly encountered disease associated with intensive bivalve culture in hatcheries and nurseries. *Vibrio splendidus* have been analysed in different coastal areas in France (Gay *et al*., 2004; Le Roux *et al*., 2002; Lacoste *et al*., 2001), Spain (Pujalte *et al*., 1999), Norway (Jensen *et al*., 2003), the USA (Thompson *et al*., 2004; 2005) and the Pacific ocean (Urakawa *et al*., 1999). Moreover, vibrios isolates (*V. splendidus*) have shown a virulence pattern inducing abnormal mortality rates. Recent data investigating the virulence factors in a specific strain of the oyster pathogen *V. splendidus* demonstrate that the toxicity is correlated to the presence of a metalloprotease corresponding to the *vsm* gene. This gene is the major toxicity factor in the extracellular products (Le Roux *et al*., 2002; Gay *et al*., 2004; Le Roux *et al*., 2007; Binesse *et al*., 2008).

The 'foot disease' resulting from the fungi *Ostracobable implexa* infection has been observed in *C. gigas* and the European flat oyster in Canada and European waters. Fungus grows in shells causing 'wart-like' protuberances on inner shell. This may weaken oyster and diminish marketability. No treatment or prevention measures are available.

Mikrocytosis (Denman Island Disease) is related to a small (2-3µm) intracellular protistan parasite of unknown taxonomic affiliation (OIE, 2003). First reported in 1960, *Mikrocytos mackini* is observed from the west coast of Canada, and likely ubiquitous throughout the Strait of Georgia and other specific localities around Vancouver Island. Focal green yellow pustules or abscess-like lesions up to 5 mm occur within the body wall, on the surface of labial palps or mantle, or in the adductor muscle. Brown scar on the shell is quit often observed. Severe infections appear to be restricted to older oysters (>2 y), although small juveniles oysters were susceptible to infection during experimental challenges. Lesions and mortalities occur in April May following a three to four month period when seawater temperature is below 10 °C. Over a period of 30 years, prevalence in older oysters has varied between 10-40%. In spite the fact that only 10% of infected oysters are usually recovering, loses at the production level remain insignificant. Although marketable values are affected by the disease as well as the seed market, economic impact is rather limited at the production level due to management practices which circumvent the disease effect. They include harvesting and moving oysters in locations high in the intertidal area prior to March and not planting oysters at low tide levels before June. Oysters from infected areas should not be moved to disease free rearing areas (Bower, 1988).

Haplosporidium nelsoni (phylum *Haplosporidia*) cause MSX disease and massive mortalities in the Eastern oyster *C. virginica* (OIE, 2002; NAS, 2004). For this reason, the agent is an OIE notifiable disease when detected. Moreover, the parasite is present in Korea, Japan, the west coast of the USA, France and likely in European waters due to the oyster transfers (Friedman, 1996). However, in contrast to the massive mortalities on *C. virginica* populations, the parasite appears to be hosted by the Pacific oyster at very low prevalence (<2 %) and not associated to measurable mortality in traditional rearing areas (Renault *et al.*, 2000). Introduction trials of *C. gigas* within *C. virginica* natural geographic distribution range have shown resulting mortality rates. Similarly, *C. gigas* become infected by the *Perkinsus marinus* agent, another OIE notifiable disease occurring in *C. virginica* populations, without development of lethal infections (Burreson *et al.*, 1994).

Marteilioides chungmuensis ('Egg disease') is a protozoan paramyxean parasite in the reproductive system of *C. gigas* that can infest ripe eggs, and causes spawning failures by delaying spawning and destroying ripe ovocytes (Park *et al.*, 2001; Ngo *et al.*, 2003).

Other parasites such as *Mytilicola* sp. are considered as affecting oyster physiology, including castration and starvation effects.

3.5.2 – Predation

C. gigas is consumed by a variety of organisms including seastars, boring gastropods and bivalves, spionid polychaetes, crabs, benthic feeding fish such as stingrays and sea breams, ducks and wading birds.

The Japanese oyster drill *Ocinebrellus inornatus* is causing major problems in oyster culture in several countries including Washington State (USA) and France (Carlton, 1999; Martel *et al.*, 2004). The turbellarian flatworm *Pseudostylochus oestrophagus* is also a major predator of *C. gigas*, attacking primarily young spat. Both species have become well adapted in various oyster growing bays where they have been introduced. Red rock crab *Cancer productus* and the green crab *Carcinus maenas* are well known predators, as *Rapana venosa*. Moreover, parasites such as *Mytilicola* sp., boring sponge *Cliona* sp., and sea worms *Polydora* sp. affect the oyster physiology and can impact significantly the oyster culture.

4 Worldwide introduction for aquaculture purpose and current distribution of *C. gigas*

4.1 Historical data and actual non-native distribution

4.1.1 Origins of *C. gigas*

Originating from the north eastern Asia, *C. gigas* is endemic to Japan, where it is also an important and historical aquaculture species. There are various accounts of the origins of oyster cultivation in Japan, but the first written record can already be found as early as in the 16th century in the famous Hiroshima Bay, which is also the first historical record of cultivation of *C. gigas* worldwide. Over the past 400 years the Japanese productions of *C. gigas* have increased to reach its maximum in 1968. For the past 10 years, the Japanese production of oysters has attained a stable level. The development of productions was accompanied by both technological innovations and a move of production areas further off-shore, in relation with the industrial development of Japan and poorer environmental quality. In 2002 there were 3370 oyster farms in Japan, with major cultured species *C. gigas* and *Crassostrea nippona* (http://web-japan.org/atlas/nature/nat30.html).

Other Asiatic countries with well documented records of oyster aquaculture, including the native *C. gigas*, are Korea (Park *et al*., 1988) and China (Park *et al*., 1988; FAO, 2006). Methods of culture in these last places combine both traditional and highly technological modern techniques. China is reported as being the country with the largest *C. gigas* production worldwide (FAO, 2006).

4.1.2 Introductions and translocations

Crassostrea gigas has been introduced and translocated from its native continent into a number of countries, mainly for aquaculture purpose (CIESM, 2000; CSIRO, 2002; NIMPIS, 2002; Wolff and Reise, 2002; Leppäkoski *et al*., 2002; Ruesink *et al*., 2005), but in some countries its introduction occurred accidentally, such as in Denmark (Wang *et al*., 2007), Norway (Mortensen, 2007), Sweden (Wrange, 2008) or New-Zealand (Dinamani, 1991).

We will summarise below the major intentional introductions of *C. gigas* worldwide. Special focus is made at introductions targeted at reviving aquaculture in various places.

Our first examples represented here by the British Isles and Belgium, share in common that *C. gigas* was not expected to be able to establish self sustaining wild populations.

First introduced from North America to a quarantine facility at Conwy in 1965, *C. gigas* aimed at reviving oyster farming in the British Isles, after populations of the native oyster *O. edulis* declined due to overfishing. It was not expected at the time that *C. gigas* would be able to form wild populations from escaped individuals because of the cooler climate experienced in UK waters compared to that of Japan. However, sporadic natural spat falls of *C. gigas* were reported in 1994 (Spencer, et al., 1994) and a survey by Couzens in 2006 revealed the presence of small reefs at some sites in Devon. A further study by Syvret (2008) assigned regions around the British coastline as high, medium and low risk from natural recruitment. Highest risk regions, where recruitment is likely in most years, are south and southeast England. There are already extensive beds of naturally recruited Pacific oysters in some of the estuaries of southeast England. A study by Child et al. (1995) of the genetic make up of stocks of naturally recruited oysters in Britain suggested that those in the River Teign, Devon, may have been of French origin. One possible explanation for this finding was the natural dispersion of larvae from France by water currents.

Another interesting example of active introduction of *C. gigas*, rapidly followed by its unexpected naturalisation is found in Belgium. The Sluice Dock at Oostende, an artificial pond of 86 ha diverted from its original purpose, is used for shellfish mariculture since 1930. Imports of various species oysters have included *O. edulis* and *C. angulata* from other parts of Europe, *C. virginica* from the East coast of the USA and *C. gigas*. This last was imported in 1969 and the early 70s from the Netherlands and revealed the only oyster species apparently able to establish self-sustaining populations and specimens survived even after the cessation of oyster cultivation and imports in 1974 (Kerchkof *et al.,* 2007). However, these authors also report that *C. gigas* became established outside areas of cultivation only in the early 1990s, most likely due to an increase of water temperatures. Since then, *C. gigas* has colonised most part of the Belgian coasts, forming massive reefs and it is also found significantly on far offshore buoys. This last observation also indicates that such man-made floating structures may act as stepping stones in the establishment and dissemination of non native species, such as *C. gigas* (Kerckhof *et al.,* 2007).

The presence of *C gigas was* first recorded in Ireland in 1877 (Minchin 1996). At much the same time *C. virginica* was imported as deck cargo from Long Island Sound (Minchin & Rosenthal, 2002). This followed the exhaustion of wild oyster, *O. edulis,* populations in Ireland following the their higher exploitation and more rapid distribution by rail. These imported oysters were ongrown from the half-grown stage, and following a summer's growth, were sold. Some attempts, following successful settlements of the native oyster in ponds in the early 1900s, were also made with the Portugese oyster on the west coast of Ireland; but these attempts failed as summer temperatures failed to be sustained at a high enough temperature in order to reach settlement (Wilkins, 1989). However, in the 1980s occasional settlements of Pacific oysters took place in lined ponds and in the nearby shallows in Cork Harbour.

However, in many circumstances where *C. gigas* has been introduced in a purpose of reviving aquaculture, it was expected that the species would naturalise and rapidly form self sustaining populations. Successful illustrations of such goal can be made with the importation of *C. gigas* in Australia, North America or France.

Indeed, the introduction of *C. gigas* in Australia illustrates how this species has been used successfully as a "replacement species" to compensate for the exhaustion of stocks of native oyster species. Collecting of oysters has indeed a long history in Australia (Nell, 1993). Indigenous Australians fished for both Sydney rock oyster (*Saccostrea glomerata*), and flat oyster (*Ostrea angasi*). "Middens" (accumulation of old shells after removal of meats) for these species occur widely along the Australian coastline, as a testimony of this ancient fishing activity (Maguire and Nell, 2007). Farming of local species of oysters, although much more recent activity started approximately 120 years ago and is considered as one of the oldest aquaculture activities in Australia. Following European settlement in Australia, the extensive beds of native oyster were exploited industrially for human consumption but also, mostly, for lime (calcium carbonate) production. As a result, these beds were all overfished and exhausted in the 1800s and early 1900s and have never fully recovered since then. First attempts to revive oyster culture in South Australia with the native flat oyster, *O. angasi*, in 1910-1912, have resulted in poor catch results and new trials conducted in the

1960s didn't prove more successful. Other attempts to revive oyster aquaculture in Australia have also involved the introduction of an exotic, hardier species *C. gigas*, and a first shipment of this last came from Japan to Tasmania in 1947-1948. This was followed by new introductions in 1951-1952, and in 1969 transfers of *C. gigas* from Tasmania to South Australia were made. The development of *C. gigas* aquaculture in Tasmania and South Australia was initially based on natural but poor catch (Aquaculture SA, 2003). The real kick off of the aquaculture of *C. gigas* in Tasmania and thereafter in South Australia is linked to the development of hatchery produced spat oysters in the 1980s. In 1985, the aquaculture of *C. gigas* relied mostly on the supply of spat from three Tasmanian hatcheries, later on other hatcheries producing *C. gigas* spat were also established in South Australia.

Although aquaculture of *C. gigas* only kicked off after spat became available from local hatcheries, this species rapidly revealed highly invasive. The need to protect beds of native oysters from the invasion by this exotic species has rapidly prompted State Managers to implement transfer restrictions and eradication programs in South Australia (Ayres, 1991).

In terms of sustaining aquaculture industry, another successful importation of *C. gigas* was made in North America. There also, oysters have been part of human diet for time immemorial. Major native oyster species found in North America are the Olympia oyster, *Ostreola conchaphila* on the Western coasts and the Eastern oyster, *C. virginica* on the Eastern coasts. With regards to the importation of *C. gigas* special focus will be made here to the oyster industry on the Western coasts of North America. There, middens of the native Olympia oyster, *Ostreola conchaphila*, have accumulated wherever the Native Americans fished and ate these oysters. With the arrival of pioneers, oyster fishing activity increased. In some bays such as Californian and Oregon bays, overfishing, together with the development of coastal industries and the associated pollution, resulted in the exhaustion of stocks of *C. conchaphila* as early as the 1850's. Willapa bay continued to supply with *O. conchapila*, but the industry also depleted by the beginning of the 20th century. After the collapse of *O. conchapila*, attempts to cultivate the species were made, but rapidly a first replacement species was used, *C. virginica*, which was massively imported from the Eastern coast. *C. virginica* revived the oyster industry on the Western coasts for a time, but after unexplained mass mortalities of this species were experienced in the 1920s, a second replacement species had to be used. The first shipment of spat *C. gigas* from Japan arrived in 1922 on the western coast of the USA (Washington State). The species adapted well to this new location and allowed a resurrection of the local oyster industry. Initially relying entirely on imported seed, the *C. gigas* aquaculture was later aided by supply of natural spatfall from various Western American bays (Willapa bay and bays of Hood Canal). The imports of *C. gigas* spat continued until the 1970s, but spat supply for aquaculture is now mostly represented by local hatcheries produced seed. Nowadays, *C. gigas* is present and cultured on the West coast of North America from California to the Southeast of Alaska (Washington Sea Grant anonymous publication, 1989; Shaw, 1997; Lindsay and Simons, 1997; Foster, 1997).

In the west coast of Canada, the native oyster is *Ostrea lurida*. Its production based on fishery rather than culture stopped in 1940. Oyster aquaculture started with the introduction of the Eastern oyster *Crassostrea virginica* in the beginning of the 20th century with limited successes. *C. gigas* was first introduced into British Columbia (Canada) about 1912 or 1913. By 1925, breeding had occurred. However, significant quantities of spat and adult oysters were imported between 1926 and 1932 respectively from Japan and Washington State (USA). During this period of time, natural spawning was observed with various successes. In 1948 breeding was prolific and widespread. Consequently, the Canadian oyster industry started to develop significantly using wild spat. Since then, no more oyster importation was necessary to supply the shellfish industry. *C. gigas* are also produced in hatcheries where brood stock are spawned and the larvae raised under controlled growing conditions (Quayle, 1988).

Similarly in France, the history of oyster culture consists of a succession of development phases with different species followed by collapses caused by overfishing and diseases. It is though that the indigenous species, *O. edulis*, has been fished for times immemorial and its exploitation in France developed notably during the Antiquity, under the Roman influence. The native oyster beds were overexploited from the 18th century, especially along the Atlantic coasts (Goulletquer and Héral, 1997), and the culture of flat oysters hit several crises in the various French production areas. Some were unexplained (1920, 1950) others were associated with parasites (*Marteilia refringens* in 1968, *Bonamia ostreae* in 1979). This all favoured the development of the culture of a new species, *C. angulata* in France. The first imports of *C. angulata* were made in 1860, and aimed at compensating from the exhaustion of *O. edulis*. The species then spread along the Atlantic coast where both species *O. edulis* and *C. angulata* were cocultured. Productions of *C. angulata* reached their maximum after 1950, and then started to decrease. Mortalities were observed and explained by overstocking of production units (Héral and Deslous-Paoli, 1990). Productions gradually decreased until the outbreak of the gill disease in 1966. This disease caused by an iridovirus spread rapidly throughout all culture zones causing massive mortalities between 1970 and 1973 and leading to the total extinction of *C. angulata* in France. The oyster industry reacted promptly with the "Resur" plan which consisted of the introduction of a new species, *C. gigas*. Small scale trials were conducted between 1966 and 1970, followed by the import of several hundred tons of broodstocks from Canada (Grizel and Héral, 1991). This very successful operation resulted in abundant spat capture from the first year in the Marennes-Oléron area, where the imported broodstocks had been placed. At the same time, 10,000 tons of *C. gigas* spat were imported from Japan and distributed to all other production areas in France, including in the Mediterranean Sea. *Crassostrea gigas* revealing a fast growing and healthy species, productions were able to increase rapidly. Spat capture, very successful in Marennes-Oléron and Arcachon bays, was sufficient to supply all the French production sites and further imports became unnecessary (Buestel, 2006) The reproductive population of *C. gigas* in France, initially confined to the South Atlantic coast has now established to more Northern latitudes and it is though that global warming has greatly influenced this move (Cognie *et al.*, 2006) as well a *C. gigas* physiological capacity and adaptability to various environments (Cardoso *et al.*, 2007).

As a result of these imports to various European countries, wild populations of *C. gigas* have now colonised not only all coastal areas in France, but can now also be found in more northern European countries. These wild populations can indeed be observed significantly throughout Europe from Portugal to the north of Germany and Denmark (Cardoso *et al.*, 2007; Buck *et al.*, 2006). A few specimens have also been found along the southern coast of Norway, successful spawning has also been reported in the early 2000, in a former shellfish farm located at the South of Bergen. Although the number of naturally settled *C. gigas* found in this part of Norway is low (less than 100 individuals) the species has shown its capacity to adapt to this environment and is suspected to be spread out into the fjord system further North, where a couple of individuals have also been found (Mortensen et al., 2007). Recent data show that the south coast of Sweden is now colonized with a wild population of *C. gigas* which probably arrived from secondary introductions by drifting of larvae (Wrange 2008).

The presence of *C. gigas* in African countries is not as well documented as in other parts of the world. However, the species has been cultivated for a long time in this continent and notably along South African coasts where it has represented the main cultivated oyster species for the past 30 years (Robinson *et al.*, 2005). Although *C. gigas* has been present for long time along these coasts, these authors indicate that naturalised populations of *C. gigas* can only be observed in estuaries but not in the open coasts of South Africa. Cultivated for a similar time length in Tunisia, *C. gigas* has not proven to be able to produce sufficient natural spatfall to sustain local aquaculture. The culture of *C. gigas* in Tunisia still relies on spat imported since 1972 from Japan, and now mostly from France (Dridi *et al.*, 2007).

C. gigas arrived in South America about 20 years ago, and relatively lately compared to most other countries where the species is present as a result of an active introduction. It was introduced on the Pacific Ocean in Chile and Peru (Winter *et al.* 1984) and in the Altantic Ocean in Brazil and Argentina (Pascual and Oresanz, 1996; Oresanz *et al.*, 2002; in Escapa *et al.*, 2004). Introduction of *C. gigas* in these last countries was experimental and for aquaculture purposes. These trials were rapidly abandoned, but the species survived. Orensanz *et al.* (2002) report that this settlement has increased explosively between 1998 and 2000 in Argentina. There, the reefs of wild *C. gigas* are extending rapidly, thus generating dramatic changes in the environment that these authors predict as being potentially disastrous.

All these reports indicate that *C. gigas* was truly considered as being the hardy species required to sustain aquaculture purposes in many countries worldwide. *C. gigas* has demonstrated its ability to adapt to various latitudes after being introduced by man (Figure 5). Subsequent to these active introductions, *C. gigas* settled and formed wild populations. Initially found in the neighbourhood of cultivation areas the species revealed capable to colonise areas located far away. Indeed, its biological characteristics make it suitable for a wide range of environmental conditions, although it is usually found in coastal and estuarine areas within its natural range.

With regard to suitable rearing areas, the main constraint to determine is carrying capacity. Usually coastal and estuarine areas are highly productive, due to the freshwater inputs and the resulting primary productivity. Therefore, large food availability facilitates more intensive rearing densities. Since *C. gigas* is highly tolerant to seawater temperature and salinity range, it has the capacity to grow in highly variable environment from estuarine areas (brackish waters) to off-shore areas in oceanic waters. The fact that seed is largely available, and can be easily transferred, facilitates the use of those various environments, including in areas where no natural recruitment occurs. In contrast, natural recruitment areas are usually located in coastal estuarine waters, impacted by freshwater inputs. Actually, larval survival rate is driven by a temperature-salinity combination, which is optimum in slightly desalinated areas. From a geographic point of view, the worldwide distribution of *C. gigas* demonstrates that only the Equatorial and Polar regions are less favourable to such culture or to colonisation.

Although highly variable, the invasiveness pattern of *C. gigas* has been demonstrated in several countries and therefore considered as a pest or a noxious species in those areas (Ashton, 2001; Blake, 2001; Orensanz *et al.*, 2002; Ayres, 1991). In other regions, the species poses no problem being considered of economic interest (McKenzie *et al.*, 1997; Escapa *et al.*, 2004; Leppäkoski *et al.*, 2002). The consequences of the current distribution of *C. gigas* will be discussed in part 5 of this report.

Figure 5: Worldwide distribution of *Crassostrea gigas*.

4.2 Growout production systems

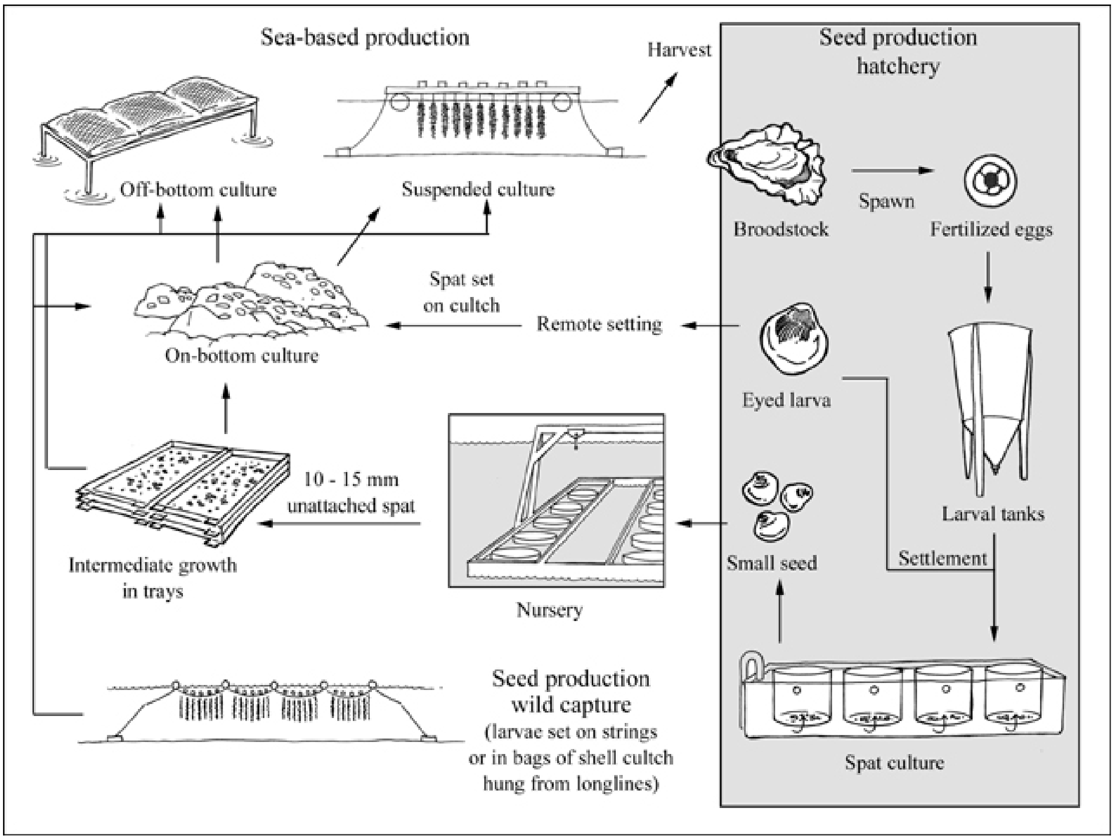


Figure 6: Traditional and modern rearing techniques (FAO fact sheet, 2008)

Most of the traditional oyster culture is based upon collecting natural seed in open areas using spat collecting techniques (Figure 6). Spat collectors are deployed at the right location and timing considering the spawning season to facilitate and maximize settlement and recruitment (NAS, 2004). After several months of rearing in open waters, oyster spat issued from natural falls is either removed from the spat collectors to be deployed onto culture grounds (on bottom) on sticks, or into oyster bags on trestles, baskets, suspensions or stay for pre-growing on the collectors, therefore requiring a thinning out or density decrease. This is done in coastal bays as well as inland using semi closed oyster ponds where seawater fills in by gravity and tide effect. Usually, oyster density-stocking biomass is adapted to local carrying capacity and by adapting mesh size to oyster size to maximize current pattern and food availability, ultimately to reduce the rearing cycle time span.

In areas, where no natural recruitment occurs, farmers rely on hatchery production which is based on mimicking in a controlled environment a natural reproductive season by adjusting temperature and algal food for broodstock conditioning (FAO, 1990; 2004). Once the broodstock is mature, gametes are collected either by inducing a thermal shock or by stripping the gonads. Fertilisation is done in a controlled environment, including gametes density, to obtain larval culture. Larvae can be cultured in large tanks (up to 100 m^3 in China) where vitamins and antibiotics are provided to maximize survival rate and yield (Guo *et al.*, 1999). Food is provided up to the metamorphosis (two weeks) and metamorphosis is facilitated by deploying either spat collectors similarly to those in open environments (shell strings, PVC dish, and tubes) or calibrated shell pieces to obtain single cultured oyster. The later technique, producing single cultured oysters, is preferred as it will facilitate the steps of sorting and calibrating oysters at the micronursery and nursery stages of the rearing. In addition, removing the spat oyster from collector being unnecessary with this technique, it reveals less stressful for the spat oyster as well as time saving.

The hatchery productions have allowed the development of oyster culture in area where poor natural catch occurred and permitted the domestication of the species (Ernande *et al.*, 2003; Degremont, 2003; Huvet *et al.*, 2004). Shellfish farmers have found many interests in utilising seed supply from hatcheries. Indeed, these last allow working with a constant all year round seed supply issued from selected strains as well as polyploid sterile individuals (triploids) (Allen *et al.*, 1989; Guo and Allen, 1994; Gérard *et al.*, 1994).

Several techniques are used for the pre-growing and growing stages, depending on peculiarities of each rearing area. Oysters are produced using on-bottom and off-bottom techniques either inter-tidally or sub-tidally. On- bottom culture (intertidally or in deep water) is carried out by first hardening the bottom and sowing seed directly with or without their spat collectors. Several techniques are used such as stone, sticks culture or directly on bottom. Although considered as more cost effective due to labour cost reduction, subtidal culture using dredging boat for sowing and harvesting requires higher investment. By using the third dimension, the overall yield per acre is greatly increased over the off-bottom method. Off bottom culture is either developed inter-tidally using rack culture on iron tables, whereas oysters are deployed into oyster bags or cages, or sub-tidally on long lines, floating rafts (plastic, wood, bamboo), anchored rafts, where oysters are deployed into pearl nets, lanterns, tubular nets, cages or bags on racks or cemented onto lines for hanging. Structures should be regularly adapted to the oyster size along the rearing cycle. For those reasons, oyster culture is often considered as labour intensive. In some productive coastal areas, it is possible to achieve high density yields which are usually more characteristic of artificial, intensive culture system than extensive culture. In this case, intertidal coastal areas, embayment can be occupied by a large acreage of rearing structures such as trestles.

Once marketable size is reached, oysters can be harvested by hand, fork on on-bottom culture, by dredge in sub-tidal on bottom culture, or bags, lanterns are brought ashore to the packing houses. Usually, oysters are sorted, graded and stored in clean waters before marketing to remove mud and grit and operate a slight depuration. In polluted areas, depuration is compulsory to avoid any public health problem. Like other bivalves, *C. gigas* has requirements for survival, including taking oxygen, discarding CO_2 and waste products. During transportation, *C. gigas* does not need to be kept in submerged seawater as they can survive relatively long periods out of the water as long as they are kept in moist, cool, out of the sun, and not disturbed. Transport is likely the best in portable coolers, in tight parcels to avoid lost of internal waters and refrigerated environments. Careful handling and transportation are essential to avoid stressing oysters.

Productions of *C. gigas* are mostly based on culture. Indeed, oyster fisheries have shown poor sustainability with reduced quality product. *C. gigas* capture fisheries were never relevant, with a production of only a few tonnes / year (Table 2)

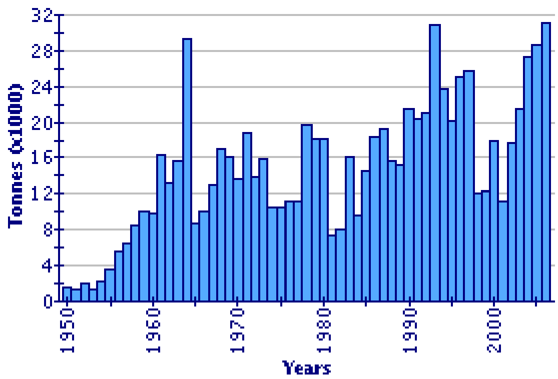


Figure 7: Global capture production for *Crassostrea gigas* (FAO Fisheries statistic, 2006)

By 2003, *C. gigas* aquaculture has reached a 4.8 million tons record high, representing approximately 98 % of the total oyster culture production in the world (FAO, 2006). The main world producer, China, had a recorded production of 3.9 million tons in 2006, followed by Korea (283,000 $tons.yr^{-1}$), Japan (208,000 $tons.yr^{-1}$). Next comes European production, that ranges around 126,000 $tons.yr^{-1}$ with France as a major producer (116,000 $tons.yr^{-1}$), followed by Ireland (6,500 $tons.yr^{-1}$), the United Kingdom (1,400 $tons.yr^{-1}$) and Spain (1,200 $tons.yr^{-1}$).

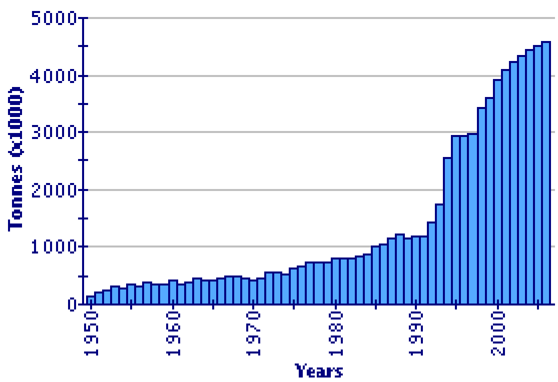


Figure 8: Global aquaculture production for *Crassostrea gigas* (FAO Fisheries statistic, 2006)

5 Consequences of *C. gigas* introduction

5.1 - Environmental impact

Native species from Asia, *C. gigas* is now present in a number of countries worldwide (Figure 5).

In those areas where *C. gigas* has established wild populations, it appears that a number of factors have influenced its dissemination. During the 1960s and 1970s, a major period of active importations of *C. gigas*, notably to European countries, it was thought that temperature would be the main limiting factor. Indeed the natural distribution of *C. gigas* being in relatively warm waters, it was not expected at the time that the species would be able to reproduce and establish self-sustainable populations in northern parts of European countries (Drinkwaard, 1999).

The importance of temperature with regards to the reproductive and dissemination patterns of *C. gigas,* is mostly sustained by the biological data on reproductive features. Not only spawning seems to be induced at around 18-22 °C (Mann, 1979; Kobayashi *et al*., 1997), but larval and juvenile survivals are also affected by low winter temperatures. Child and Laing (1998) have reported that the minimum temperature tolerance of juvenile *C. gigas* is about three weeks at 3 °C.

While climate change is becoming a major concern worldwide, it also has a proven impact on the geographical distribution of many species. It has recently been noted that the invasion and expansion of *C. gigas* in the German Wadden Sea, were accelerated by high late summer water temperatures (Diederich *et al*., 2005), similar findings are made on the Belgian coasts (Kerckhof *et al*., 2007), in France (Cognie *et al*., 2006) and the expansion of *C. gigas* in more northern European countries seems also a result of climate change. Climate change is frequently considered as global warming. However, climate change will also have an influence on oceans currents, and modify them. For example, it is expected that the Gulf Stream may slow down within few decennials (Minobe *et al*., 2008), thus resulting in a dramatic decrease of temperatures in European countries under its influence. Therefore, the long term effects of climate change could result in a variation of the distribution of species and the current trend of colonisation of more northern European latitudes by *C. gigas* may change.

Current findings, suggesting that water temperature is an important factor for reproduction of *C. gigas* and the establishment of wild populations, also indicate that other environmental factors must also be considered (Cardoso *et al*., 2007).

In a view of assessing further expansion of *C. gigas* in Europe, Cardoso *et al*. (2007) have carried out a study on relative physiological performances of wild populations of *C. gigas* along a latitudinal gradient from south-western France (La Rochelle) to the northern part of the Netherlands (Texel, western Dutch Wadden sea). Their findings showed large differences in the various length-at-age and mass-at-age data in the locations studied. Overall, a general trend of increase in terms of growth and reproduction was found from La Rochelle to Texel suggesting that temperature is not the main limiting factor for reproduction, but also global optimal physiological conditions, such as food availability or less stressful environmental conditions are also required. An important finding related by Cardoso *et al*. (2007) is that oysters located in the more northern locations, produce a larger number of eggs. These last being of smaller size, the resulting larval development and the pelagic stage take longer, thus increasing larval dispersal capacity and expansion of the population far away from spawning sites.

Syvret (2008) assigned regions around the British coastline as high, medium and low risk from natural recruitment, according to temperature profiles. He then applied climate change predictions into this assessment and concluded that the medium risk regions, including Northern Ireland, Wales and Southwest England, would become high risk, with recruitment in most years, by 2040.

Occasional wild settlements of Pacific oysters have been found on all Irish coasts including Donegal Bay in north-west Ireland and Strangford Lough on the Irish Sea coast (Boelens et al., 2005). However, these settlements are not as intense as those found in sheltered bays and inlets on the south coast of Britain. Sparse settlements are known from the north coast of Britain near Conwy.

Crassostrea gigas was introduced in the North Adriatic lagoons and in Greece for aquaculture purpose in the 1980s and are now naturalized species (Marino et *al.*, 2006; Zenetos et *al.*, 2004). Information regarding the natural settlement of *C. gigas* are available at the following address http://www.tutelamare.it/cocoon/sa/app/it/index.html.

Box 2. Special focus at the climate aspects relevant to Europe.

In a meeting report of the ICES WGITMO (2008), the following climate aspects relevant to *C. gigas* were reported by country.

Ireland: A combination of factors promotes *C. gigas* spread; one of those is climate change. Settlements have taken place on all coasts where there are shallow bays that are sufficiently warmed (Minchin, pers. Com.).

Belgium: Oysters spawn earlier after warm winters, indicating that their spread is likely climate related.

Germany: The observed trend of oyster spread appears to be climate related. Because there is no salinity change in the Wadden Sea and no food limitation, the correlation of change and temperature appear to be climate related.

Norway: There are only one or two locations in southern Norway where *C. gigas* is known in the wild.

Sweden: In summer 2007, less than a year old specimens of *C. gigas* appeared in Sweden along almost 300 km of the west coast, which may be considered as an indication for a climate change related spread in the oyster distribution from Denmark or German, since the previous winter and spring were mild.

United Kingdom: *C. gigas* is spreading.

France: There is a natural spread of *C. gigas* outside farms, and great concern about ecological impacts (e.g. food limitations, maintain integrity of mudflats). Cleaning and reduction efforts are underway for escaped populations.

Netherlands: *C. gigas* is spreading. There are plans to destroy oyster reefs to keep mudflats.

Italy: No recent difference in *C. gigas* occurrence.

Spain: *C. gigas* is found in farms and in the wild, but it is unknown if temperature impacts the populations.

5.2 - Acidification of Oceans

Other reported environmental factors that have an influence on the growth and potentially, on the dissemination of shellfish species, is related to the acidification of oceans. Indeed, human emissions of carbon dioxide have already lowered and will further lower the pH of the surface waters of oceans. The sea water pH currently ranges between 7.8 and 8.2 and is already on average 0.1 pH unit lower than it was prior to the industrial revolution (Caldeira and Wickett, 2003). Predictions, based on realistic scenarios for future CO_2 emissions, suggest that ocean pH will further decrease by 0.3 to 0.4 unit by 2100 (Caldeira and Wickett, 2003). This process is expected to have dramatic consequences on calcification and metabolic processes of many marine species. Resulting effects are variable depending on species. As an example, the ophiuroid brittlestar, *Amphiura filiformis,* will increase the rate of many of its biological processes; however this is accompanied with other negative effects, notably on its muscle (Wood *et al*., 2008). In other calcified species, the acidification of oceans will result in reduced rates of calcification (Gattuso *et al*., 1999; Feely *et al*., 2004) as well as in reduced growth (Michaelidis *et al*., 2005). Gazeau *et al*. (2007) predict that this phenomenon will have a dramatic impact on both cultured and wild populations of mussels, *Mytilus edulis*, and *C. gigas*, who may see their calcification rates decrease respectively by 25 % and 10 % by 2100. The effects on the larval stages are unknown, but acidification is expected to alter considerably survival rates at the larval stages. Oceans acidification also has an effect on non-calcifying species. Some studies have shown that increasing the carbone:phosphate ratio can reduce the growth rate of certain phytoplankton and reduces fecundity in zooplankton (Barry *et al*., 2008). More experimental and field data is still required to fully assess the consequences of this phenomenon, but a dramatic impact on coastal biodiversity and ecosystem functioning can be expected by the end of this century. Field studies, incorporating an ecosystem based approach, are necessary to demonstrate these hypotheses.

5.3 Ecological competition and Impact on biodiversity

In a review related to the impact of bivalve introductions in marine ecosystems, Barber (1997) explains that the intentional introduction of an exotic species may result in direct biological competition with native species and out-compete these last for food and space.

As a result of the colonisation of *C. gigas*, an ecological competition between this exotic species and native species is reported in many places. The increase of *C. gigas* populations represents not only a food competition but also a competition for space availability with other filter feeding species such as cockle (*Cerastoderma edule*) or mussel (*M. edulis*), as reported in Dutch and German waters of the Wadden Sea (Bouwe van den Berg *et al*., 2005; Diederich, 2005). However, some authors also stress that the decline of *M. edulis* beds observed in the Wadden Sea is a result of the combined effects of invading species, namely *C. gigas* and the slipper limpet, *Crepidula fornicata*, and climate change. Indeed, there is evidence that the decline of *M. edulis* beds is mainly caused by a decline of spatfall, in possible relation with mild winters. Mild winters and warm summers in turn facilitating spatfalls of *C. gigas* and *C. fornicata*, the presence of these two exotic species in the Wadden Sea only enhances a phenomenon that is primarily provoked by climate change (Nehls *et al*., 2006) that also favours a higher predation rate of bivalve spat by shrimps and crabs, sensitive to cold winters and favoured by warm winters (Nehls, 2007).

By out-growing cockles, *C. edule,* in the Wadden Sea, one of Europe's most important wetlands for migratory birds populations, *C. gigas* is also taken as responsible for the reduction of food availability for birds feeding on them (Bouwe van den Berg *et al*., 2005; Smaal *et al*., 2005).

In the USA, it is thought that *C. gigas*, primarily introduced to revive the declining shellfish industry based until then on *O. conchaphila*, also contributed to the decline of this last, native, species, essentially by out-competing *O. conchaphila* for food and space (Chew, 1991).

In France, *C. gigas* could also have contributed to the depletion of *C. angulata*, the species cultivated locally until it was imported. Indeed, it is thought that it may have been a carrier for the iridovirus responsible for the virtual disappearance of *C. angulata* from French coasts (Grizel and Héral, 1991).

C. gigas arrived in the New South Wales (South Australia) accidentally, as a result of natural breeding and larval transport from other areas, aided by boat carriage and via shipments of contaminated native spat oysters. When the settlement of *C. gigas* in several estuaries became obvious in 1973, it was declared as a "noxious species" and eradication programmes started to reduce the competition with the native species *S. commercialis* (Ayres, 1991; Bourne, 1979).

Similarly New South Wales, *C. gigas* was introduced accidentally to New Zealand via the hulls of ships, as larvae in ballast water, or larval transport from Tasmania (Bourne, 1979; Dinamani, 1991). *C. gigas* again proved capable to out-compete the native species, *S. glomerata*, for food and space. In addition, *C. gigas* has a greater fecundity and growing to market size that is twice faster than *S. glomerata*, thus, it became the dominant species in New Zealand as early as 1977.

Besides the competition for food and space between the introduced *C. gigas* and native species, especially bivalve molluscs, *C. gigas* introductions have also had a significant global impact on local ecosystems in many places. Although such impacts are in majority considered as being negative, there are also reports of potentially beneficial effects.

In the Wadden Sea (Bouwe van den Berg *et al*., 2005; Smaal *et al*., 2005; Nehls, 2007), along Belgian coasts (Kerckhof *et al*., 2007), in France (Cognie *et al*., 2006) and in many other places, *C. gigas* has formed dense reefs and dramatically changed landscape. By changing the original habitat and competing with local species, a significant alteration of the overall biodiversity and biomass can be expected (Kerckhof *et al.* (2007). However, several other studies reviewed by Nehls (2007) have shown that the three dimensional structure of *C. gigas* reefs offer a rich habitat for epibenthic as well as for endobenthic species, and play an important role in marine food webs, for instance for birds and other predators. Similarly, Nehring (2003) suggests that *C. gigas* has a beneficial effect on the richness of the environment in the Wadden sea. Indeed, the decline of native oyster beds *O. edulis*, resulting from overfishing in the 18^{th} century has been accompanied by a concomitant decline or disappearance of associated invertebrate populations. The establishment of new *C. gigas* reefs allows the re-establishment of these communities, at least in intertidal zones. A comparative study conducted by Görlitz (2005) shows that the species richness did not differ between *M. edulis* and *C. gigas* beds, although some species were found in different abundances. *Cirripedia* had similar densities on oysters and mussels, *Semibalanus balanoides* and juvenile crab (*Carcinus maenas*) were lower on oysters, whereas higher densities of *Littorina littorea*, *Ralfsia verrucosa* and *Polydora ciliata* were recorded upon oyster beds, but no loss of species has been documented (Görlitz, 2005).

As in the Wadden Sea, the effects of the introduction of *C. gigas*, in Willapa Bay (USA) have been investigated. Amongst alien species reported there, *C. gigas* and the cordgrass, *Spartina alterniflora, m*ay play a particularly important role in structuring previously unstructured tideflats. Thus, *C. gigas* reefs and cultured sites provide new extensive hard substrates for fish, invertebrates, and macroalgal species such as *Ulva* spp and *Enteromorpha* spp. Although the oyster expansion has occurred at the expense of burrowing shrimp and other infauna, by changing their native habitat, it is also taken as partly responsible for the increased richness and biodiversity recorded locally (Ruesink *et al*., 2006). However, this apparent beneficial effect of the introduction of *C. gigas* requires further studies to better evaluate the long term consequences on the native ecosystems.

The accuracy of such evaluation obviously requires the availability of descriptive and quantitative data related to the native ecosystems. This is stressed in a review made by the Argentinean and Uruguayan scientific community (Orensanz *et al*., 2002) aimed at evaluating the status of the so called Patagonian Shelf Large Marine Ecosystem, a marine protected area classified by the UNESCO as part of the World's Heritage. Their findings show that most coastal ecosystems between La Plata River estuary and central Patagonia have already been modified following the introduction of species. Although the number of recorded introduced species (31) (Orensanz *et al*., 2002) is relatively low compared to other well-studied areas such as San Francisco Bay (150) (Cohen and Carlton, 1998) or the Chesapeake Bay (180) (Ruiz *et al*., 1999) a significant ecological impact has already incurred in estuarine ecosystems, nearshore and shallow bays, and is mostly due to the effects of 5 introduced marine species, a barnacle, *Balanus glandula*, a macrofouler, *Limnoperna fortunei*, a reef builder, *Ficopomatus enigmatus*, kelp, *Undaria pinnatifida* and the Pacific oyster, *C. gigas*. The reefs formed by *C. gigas* settlement in shallow bays have expanded explosively since 1998. Dramatic changes are underway as oyster reefs develop and provide a new spatial architecture representing an increased refuge place for the intertidal communities. Short term, the new habitats provided by these oyster reefs might benefit to the richness of the environment. For instance, increased prey abundance is available for birds feeding on them (Escapa *et al.,* 2004). However, the long terms effects are unknown but it is likely that introduced species, including *C. gigas* will continue to change dramatically the local benthic communities (Orensanz *et al*., 2002). Marine reserves in the San Juan Archipelago (Washington State, USA) were found to contain higher densities of two invaders, *Sargassum minutum* and *C. gigas*, than comparable unprotected areas outside reserves. Mechanisms involved were still unclear, but these findings underlined the potential vulnerability of reserves to biological invasion (Klinger *et al*., 2006).

5.4 Genetic evolution

Hybridisation among *Crassostrea* spp has been well studied and demonstrated in specific cases (NAS, 2004). Crosses between *Crassostrea ariakensis* and *C. gigas* are viable, whereas *C. ariakensis* has been cultured throughout southern China and Japan for over three hundred years (NAS, 2004). Moreover, several *C. gigas* races or morphotypes are found in Japan. Therefore, it is likely that some natural hybridisation has already occurred accompanying the many years of transfer and worldwide introductions. In Washington State (USA), hybridization between *C. ariakensis* and *C. gigas* occurred during the 1960-1990, resulting from a deficient broodstock management. It is thought that a reduction of genetic diversity has been incurred in some way. But given the high oyster plasticity and the relatively recent availability of genetic markers, it is likely that this process has been underestimated until now. This observation is supported by the identification in New Zealand Pacific oysters of two rare alleles that had only been previously recorded in *S. glomerata* (Dinamani, 1991). Such interbreeding between introduced and local species may result in a loss of genetic variability with unknown results (Newkirk, 1979). In addition, natural hybridisation between genetically differentiated populations of *C. gigas* and *C. angulata* was demonstrated (Huvet *et al.*, 2004). Therefore, the remaining populations of the *C. angulata* ecotype in Portugal are in threat by current culture development and extensive transfers of *C. gigas* (Huvet *et al.*, 2000).

5.5 *C. gigas* as a vector for disease and parasites and other hitch-hikers

Historically, concern surrounding intentional introductions was for the production of the introduced species, and not for the ecosystem receiving the exotic species. Little care was taken to ensure that only the intended species was introduced (Barber, 1997). As a result, a number of "hitchhikers" species were introduced along with the intended species and the impact of these additional exotic species on local ecosystems was not generally realised until some time after the original introduction has occurred.

Several hitchhiking marine species were introduced along with *C. gigas* to the western coasts of the USA, Europe and other places where *C. gigas* had been imported. Goulletquer *et al*. (2002) report that of the 87 exotic species introduced accidentally to the Atlantic and Channel coasts of France, Spain and Portugal, 28% are presumed to have been brought in association with oyster shipments, mainly *C. gigas* in the 1970s, and four were oyster parasites. These species had various ecological or economical impacts. For example, the establishment of the Manila clam *Ruditapes philippinarum*, has supported a considerable industry in various places, such as in the USA (Barber, 1997). Other species, such as the Japanese oyster drill *Ocinebrellus inornatus*, the flatworm *Pseudostylochus ostreophagus*, or the parasitic copepod *Mytilicola orientalis* have a non-negligible negative impact on oyster or mussel productions.

Algae are also represented amongst the hitch-hiker species imported along with *C. gigas*. In the paper by Goulletquer et al. (2002: Table 1) 21 introduced seaweeds were listed, 13 of which (62%) presumably had come with introductions of oysters. For about the same coastal areas, but including also the Canary Islands and the Azores, Wallentinus in the 10 year Status report for algae and plants (ICES 2007: Table 2.1) listed 30 introduced seaweeds, 13 of which (43%) presumably had been introduced with oysters. For the southern coasts of France and Spain together with the Italian coasts, she listed 80 introduced seaweeds, of which 42 (53%) presumably had been brought with oysters (ICES 2007: Table 2.1). The whole area included in her report (including also Canada and USA, as well as coasts of the Baltic Sea) had 129 introduced seaweeds, 50 of which (39%) presumably had oysters as a vector (ICES 2007: Table 2.1). The very high percentage of seaweeds being brought that way, especially in southern and southwestern Europe, points to the importance of oysters as a vector for especially seaweeds and the need to mitigate that risks by proper treatment of imported adults by using quarantine conditions. Since many of these seaweeds have important impact on the ecosystems, by competition and habitat modification they have in many cases become a nuisance. Some of the most well-known and invasive species having been brought that way are the Japanese brown algae, *Sargassum muticum* and *Colpomenia peregrina,* the Japanese kelp *Undaria pinnatifida;* the red algae

Grateloupia turuturu, Heterosiphonia japonica, and perhaps also the invasive strain of the green alga *Codium fragile* ssp. *fragile.*

In January 1993 large consignments of half-grown oysters were imported to Ireland from France despite the advice that this would compromise the status of the stock in culture that was derived from the quarantined population in Conwy. These were first introduced to Ireland in 1969. In February 1993 *Mytilicola orientalis* and *Myicola ostrea* were found in imports and *M. orientalis* subsequently became established in Dungarvan Bay, on the south coast of Ireland (Holmes & Minchin, 1995). Following these imports summers mortality events were recorded for the first time. Small seed and half-grown oysters were imported into the 21st century and small numbers of male *Crepidula fornicata* and *Styela clava* were found on arrival but were not found to survive in culture in bags on trestles, where they became crushed. It is strongly suspected that the introduction of *Sargassum muticum* to Strangford Lough in Ireland was with imports of oysters from the Channel Islands.

Apart from the parasite *Haplosporidium nelsoni*, and the Japanese oyster drill *O. inornatus*, (Garcia-Meunier et al, 2002) there is little data available on the introduction of exotic diseases or parasites along with *C. gigas* intentional shipments or accidental introductions. *Crassostrea gigas* have been frequently found attached to the hulls of ships. Transmissions by shipping may result in spawning events on entry into warm harbours or possibly result in the release of pathogens. The transmission of pathogens by hull fouling molluscs remains unresearched (Minchin & Gollasch, 2003).

Some pathogens are ubiquitous, their presence worldwide and their recorded impact on many marine species and many areas, suggest that they could have been present in many parts of the world since ancient times. Therefore, it does not seem realistic to try and determine if, for instance, OsHV-1 or *Vibrio* spp., have been present worldwide since ancient times or if their current localisation is a result of human activities and/or transfers of species from one part of the world to another.

However, even in the absence of recorded signs of disease, there is a need for more active research and to conduct surveys aimed at searching for exotic pathogens. Given the number of movements of *C. gigas* around the world, it is likely that some exotic pathogens are present at a sub-clinical level in some areas. And, although they may not have a noticeable impact at the time we speak, the recorded and predicted environmental changes added to the intensification of cultures and to the changes in cultural practices could lead to the emergence of new problems. Such comprehensive surveys would help setup early appropriate sanitary management and prevent future potential pathological issues, notably in cultivated areas.

5.6 – Control or management procedure

There is little published reference data on eradication or reduction programmes targeted at *C. gigas*, apart from Australia (Ayres, 1991) where *C. gigas* is considered as a noxious species in the areas where it will out-compete native oysters. Information tools have been developed by the NIMPIS (http://www.marine.csiro.au/crimp/nimpis/) that are also aim at providing potential control options. However, none of the methods described have proved totally efficient with regards to the eradication of *C. gigas*.

A similar approach was enforced by northern European countries, where the NOBANIS database (www.nobanis.org) was implemented as an echo of the Australian tools. However, as a result of these efforts, the Netherlands is the only European country where real mass reduction trials were conducted.

With regards to *C. gigas*, additional controversial views must be stressed. Indeed, the species might be considered as a pest in the Wadden Sea, or in Australia but at the same time a great fishery in France. Moreover, in some areas, a distinction must be made between wild and cultured stocks of this species and their respective ecological and economical impacts as well as their impact on other human activities. For example in France several studies have been carried out in the Marennes-Oléron basin (Coïc, 2007), in the gulf of Morbihan (Le Gall, 2006) or in the Bourgneuf bay (Cognie *et al.*, 2006) or at a national level (Progig programme, 2008). The collection of such data on a national and regional basis is an essential preliminary step to be carried out as it will allow determine the most appropriate actions to undertake, taking into account the various specificities of each particular site.

The Marennes-Oléron basin in France might be taken as an example of successful reduction measures. Indeed, the restructuration of leases in the Marennes-Oléron basin, enforced over the last decade, allowed a significant reduction of wild stocks in farmed areas. A thorough cleaning of wild *C. gigas*, and at the same time of its trophic competitor, *C. fornicata*, and predator, *O. inornatus* involved the use of powerful engines such as caterpillars and snow tractors, geared specially for sea marine activities. A specialised barge was also equipped in the purpose of collecting abandoned shellfish gear, to quarry unwanted stones, sand and mud, and gather animals to be removed from the cleaned areas (Miossec and Goulletquer, 2007).

5.7 Economical impact

Considering the fact that only about 5.25 % of the worldwide production is originated from its native range, *C. gigas* overall introduction has had a highly significant economic impact, amounting to 3 305 M US $ values on a yearly production basis (FAO, 2004). In several countries, the species introduction has resulted in building a sustainable shellfish industry providing direct revenues for thousand of farmers and concomitant activities (e.g., equipment). Moreover, a highly valuable (and unaccountable) indirect economic impact concerns the lasting establishment of coastal communities in otherwise unfavourable rural areas, therefore playing a significant role in coastal management values. As an example, the European oyster crisis in the 1970s followed the fast disappearance of disease impacted *C. angulata* populations was solved by the introduction of *C. gigas* which saved the collapsing industry (Goulletquer and Héral, 1992; NAS, 2004). In contrast, *C. gigas* introduction has had economic side effects in several countries such as Australia (NSW), whereas the native Sydney Rock oyster was partly outcompeted by the *C. gigas* invasiveness, leading to several business collapses. Indirect economic impact concerns increasing coastal management costs to limit *C. gigas* reef expansion and eradication costs.

5.8 – Social impact

The various aspects of the social impact of *C. gigas* have been well studied in France (Progig programme, 2008). Unpublished observations (C. Hily, personal communication) are reported below. Although the relative importance of these aspects may vary depending on the country or region of concern, they are mostly of global interest.

5.8.1 Farming activity

The socio-economical impacts of wild *C. gigas* can be represented by its consequences on other industries settled in neighbour areas, and in particular shellfish farming or professional fishing activities (C. Hily, personal communication related to work carried out under the PROGIG programme, Ifremer).

Of the potential negative impacts of *C. gigas* on other cultivated shellfish species, the trophic competition is non-negligible and other nuisances are reported, such as an increased difficulty to up-keep the equipment and an acceleration of its deterioration after it is colonised by wild *C. gigas*. In addition, wild oyster beds result in some areas in an accumulation of mud that generates new difficulties to access to mussel culture areas. In other areas, the invasion of mudflats by wild *C. gigas*, having a physical impact on the environment and modifying it, is greatly affecting the professional fishing activities on mudflats, such as the collection of clams.

On the other hand, some positive effects of wild *C. gigas* are also reported. Indeed, wild *C. gigas* can favour the collection of spat mussel that can attach to them. In some places, the reefs of wild *C. gigas* are also considered as an opportunity to diversify professional activities and generate income, as they can be exploited and commercialised.

5.8.2 Recreational activity

Similar to farming activities, the dispersal of *C. gigas* can have impacts on recreational activities. Here too, positive and negative aspects can be discussed. For instance, its impact on recreational fishing activity can be both positive, when *C. gigas* represents a new species to collect, and negative, when there is a reduction on the other concerned species, and particularly those living in mudflats.

The presence of *C. gigas* is considered as a nuisance with regards to many recreational activities when the sharp shells provoke cuts on people swimming or bathing/playing in the sea or on beaches during low or mid-low tides. These cuts are also frequent during nautical activities or recreational fishing.

The *C. gigas* industry is contributing significantly to coastal management as a permanent, year round, coastal user. Therefore, it contributes to coastal communities' economic sustainability, and represents a stakeholder within the Integrated Coastal Zone Management process. Since oyster industry requires suitable seawater quality for public health reasons, it also contributes to environmental long term monitoring. Considered as a traditional activity in several producing countries, *C. gigas* culture has been of interest for 'green' tourism development.

6 Conclusion

Overfishing and poor management of stocks of native shellfish species, added to pollution and pathological events, lead to the exhaustion of these species. Exotic species were translocated to supply the shellfish industry. *C. gigas* is probably the best example of mollusc species introduced in a purpose of reviving aquaculture. In several countries, the species introduction has resulted in building a sustainable shellfish industry providing direct revenues for thousand of farmers and concomitant activities (e.g., equipement). This situation could be explained by its capacities to adapt to various environmental conditions.

Translocations of *C. gigas* in new areas were done with limited management practices. Consequences on native environment was not estimated and more generally not expected. Naturalisation of the Pacific oyster was observed in the different introduced countries, as in neighbouring areas due to larval dispersion or illegal introductions.

Consequences of C. gigas introductions on biodiversity is still in debate. Competition for food and space was generally observed with other filter-feeding species, even those which were overfished, contributing by this way to their decline. However, several studies demonstrated too that *C. gigas* reefs could represent new habitat where a rich community could be observed. Moreover, the Pacific oyster could be a source for food for many marine species. For a better evaluation of positive and negative impacts of the *C. gigas* spreading, an ecosystem based approach is relevant.

Expansion of *C. gigas*, especially in Northern European areas, is often thought to be related to global warming. Additional studies need to be developped taking into account the genetic characteristics of this species in its adaptability to new environments.

Once introduced, eradication is not always possible and in many countries it is not desirable because *C. gigas* now supports an important aquaculture industry. But even in these countries, mitigation actions are necessary to limit the expansion of the Pacific oyster. However, negative and positive impacts of theses programmes need to be assessed at a limited scale before a larger application. Relevant recommendations and comprehensive methodological approaches to best practices for management of introduced species have been provided in numerous programmes worlwide and are now available for implementation.

Goverments and stake-holders are more and more concerned about the protection of the marine environment and the risk associated with introduction of exotic species for aquaculture purposes. New regulations concerning use of alien species in aquaculture have been published, often based on the Code of Practices (ICES, 2004a). They propose a framework for good cultural practices when introducing exotic species for aquaculture development, in order to avoid or minimize the possible impact of these and any "hitchhiker" species on aquatic environment.

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