Descriptor 2: “Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems”

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Good Environmental Status (GES) Descriptor: "Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems"

by

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Executive summary[2]

Good Environmental Status (GES) Descriptor:

"Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems"

Definition of key terms

Non-indigenous species (NIS; synonyms: alien, exotic, non-native, allochthonous) are species, subspecies or lower taxa introduced outside of their natural range (past or present) and outside of their natural dispersal potential. This includes any part, gamete or propagule of such species that might survive and subsequently reproduce. Their presence in the given region is due to intentional or unintentional introduction resulting from human activities. Natural shifts in distribution ranges (e.g. due to climate change or dispersal by ocean currents) do not qualify a species as a NIS. However, secondary introductions of NIS from the area(s) of their first arrival could occur without human involvement due to spread by natural means.

Invasive alien species (IAS) are a subset of established NIS which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions. Species of unknown origin which can not be ascribed as being native or alien are termed cryptogenic species. They also may demonstrate invasive characteristics and should be included in IAS assessments.

The key term "…levels that do not adversely alter the ecosystems" is described as the absence or minimal level of "biological pollution". The later is defined as the impact of IAS at a level that disturbs environmental quality by effects on: an individual (internal biological pollution by parasites or pathogens), a population (by genetic change, i.e. hybridization), a community (by structural shift), a habitat (by modification of physical-chemical conditions) or an ecosystem (by alteration of energy flow and organic material cycling). The biological and ecological effects of biopollution may also cause adverse economic consequences.

GES in relation to the descriptor "*Non-indigenous species…*"

IAS cause adverse effects on environmental quality resulting from changes in biological, chemical and physical properties of aquatic ecosystems. These changes include, but are not limited to: elimination or extinction of sensitive and/or rare populations; alteration of native communities; algal blooms; modification of substrate conditions and the shore zones; alteration of oxygen and nutrient content, pH and transparency of water; accumulation of synthetic pollutants, etc. The magnitude of impacts may vary from low to massive and they can be sporadic, short-term or permanent.

The degradation gradient in relation to NIS is a function of their relative abundances and distribution ranges, which may vary from low abundances in one locality with no

[2] The executive summary is based on the Task Group "Non-indigenous species…" report prepared by TG Members: Sergej Olenin (Chair), Francisco Alemany, Stephan Gollasch, Philippe Goulletquer, Maiju Lehtiniemi, Tracy McCollin, Dan Minchin, Anna Occhipinti Ambrogi, Henn Ojaveer, Kathe Rose Jensen, Inger Wallentinus, Borys Aleksandrov and Ana Cristina Cardoso (EC Joint Research Center, representative), Laurence Miossec (OSPAR, observer) and Monika Stankiewicz (HELCOM, observer).

measurable adverse effects up to occurrence in high numbers in many localities, causing massive impact on native communities, habitats and ecosystem functioning.

There is a fundamental difference between various forms of pollution. IAS do not respond in the same way as a chemical pollution or eutrophication which may be diminished provided that appropriate measures are taken. The risk of new biological invasions can be most effectively reduced by precautionary measures (e.g. ballast water management); while control or eradication of existing IAS is more challenging. NIS may expand their distribution and increase their abundance from a local source through processes which may not be controllable. The spatial extent, rate of spread and impacts on the environment will depend on biological traits of a NIS and environmental conditions within an invaded ecosystem.

The assessment of IAS at different temporal and spatial scales

The assessment of IAS impacts generally should begin at the local scale, such as "hot-spots" and "stepping stone areas" for alien species introductions (marinas, port areas, aquaculture installations, offshore structures, etc) or in areas of special interest (marine reserves, NATURA 2000 sites, lagoons, etc). Depending on the taxonomic/functional group an IAS belongs to, the assessment can involve areas from confined benthic habitats to the entire water column. Local scale assessments can be further integrated into the next spatial level evaluations at a sub-regional (e.g. Gulf of Finland in the Baltic or Adriatic Sea in the Mediterranean) or a regional sea level.

The attributes of biological invasions are changing at different temporal scales (e.g. days/weeks for phytoplankton and years/decades for benthic communities and fish). The temporal scales addressed should vary depending on the taxonomic/functional group of an IAS. The temporal scales will also be influenced by the purpose of the assessment. Initial baseline assessments are the prerequisite for further evaluation of any adverse effects of IAS in an area under consideration.

Key Attributes of the Descriptor

Number of NIS recorded in an area

This basic indicator addresses anthropogenic pressures regarding NIS introductions. There is a general acceptance that those areas with elevated numbers of NIS are at greater risk of exposure to future invasions. Further, the ratio between NIS and native species should be calculated, at least in well studied taxonomic groups, as a measure of change in species composition.

Abundance and distribution range of NIS

This attribute is a prerequisite for assessment of the magnitude of the NIS impacts. The abundance and distribution range of a NIS should be assessed in relation to the organism group the NIS belongs to. The same measurement units of abundance (numbers per area, biomass or percentage of coverage) should be used for the NIS and native species. The abundance and distribution range may vary from "low numbers in one locality" to "high numbers in all localities".

NIS impact on native communities

NIS may cause changes in community structure due to displacement of native species, shifts in community dominant species, loss of type-specific communities and keystone species. The magnitude of the impact in an assessment area may vary from no changes (NIS are present but do not cause any measurable shifts in community) to extinction of native keystone species in the worst case.

NIS impact on habitats

NIS may cause alteration, fragmentation and/or loss of native habitats. The magnitude may be ranked from no noticeable alterations in benthic or pelagic habitats to massive impacts with irreversible changes.

NIS impact on ecosystem functioning

NIS may cause shifts in trophic nets and alteration of energy flow and organic material cycling. This may involve cascading effects causing large scale changes. This may be quantified through the energy channelled through the food web by an IAS. However, such studies are rare; therefore the changes in functional groups may be used as a proxy for this attribute. The magnitude of the impact may be ranked from no measurable effect to massive ecosystem-wide shifts in the food web structure and/or loss of the key functional groups within different trophic levels.

How are the indicators aggregated to assess GES for the descriptor?

Efforts should be made to record all NIS known in the assessment area; however attention should be paid primarily to assessments of IAS impacts. Methods for aggregating indicators for GES assessments need to take into account the known IAS effects in other world regions or in neighbouring areas. One of the approaches may be estimation of the magnitude of bioinvasion impacts or "Biopollution level" (BPL) index which takes into account the abundance and distribution range of NIS in relation to native biota in the invaded area and aggregates data on the magnitude of the impacts these species have on: native communities, habitats and ecosystem functioning (free access to BPL assessment system is provided at: www.corpi.ku.lt/~biopollution). BPL aggregates the results of the assessment into five categories: "No bioinvasion impact", "Weak", "Moderate", "Strong" and "Massive". First two categories may indicate acceptable levels of biopollution for GES. The assessment has to be done for defined assessment units (a particular water body or its part) and certain periods of time.

Monitoring and research needs

Standard marine biological survey methods are recommended for monitoring of NIS; which may have to be adapted to obtain the level of taxonomic identification required. Habitats exposed to a high risk of receiving IAS also should be taken into account, even if they usually are not being monitored on a regular basis. There are many monitoring and recording systems in place and efforts should be made to collate and co-ordinate this information so that it can be used effectively for the GES assessment.

Further resource and research needs are varied and include a requirement for focused taxonomic training (or access to taxonomic expertise), increased effort to monitor poorly studied ecosystems, risk assessment methodologies and the further development of IAS environmental impacts assessment methodology. There is a need to quantify uncertainty in relation to propagule pressure (number of individuals of NIS multiplied by the number of introduction attempts), vector analysis, traits of introduced species, impacts and how the presence of these species relates to the evaluation of GES in all assessments regarding IAS.

The EU Marine Strategy Framework Directive Task Group 2 on Non-indigenous Species

Contents

1 List of acronyms and abbreviations used in text

Abbreviation	Meaning
BPL	Biopollution Level, a measure of the magnitude of the biological invasion impact
BSAP	Baltic Sea Action Plan
BSC	Commission on the Protection of the Black Sea Against Pollution
BWMC	International Convention on the Control and Management of Ships' Ballast Water and Sediments (of IMO)
CBD	Convention on Biological Diversity
DAISIE	Delivering Alien Invasive Species Inventories for Europe, an EU Framework Programme 7 project
EEA	European Environmental Agency
FP6	EC Sixth Framework Programme
FP7	EC Seventh Framework Programme
GES	Good Environmental Status
GISP	Global Invasive Species Programme
HELCOM	Helsinki Commission
IAS	Invasive Alien Species
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
ISSG	Invasive Species Specialist Group
IUCN	International Union for Conservation of Nature
MSFD	EU Marine Strategy Framework Directive
NIS	Non-indigenous Species
OSPAR	Oslo – Paris Commission
SEBI	Streamlining European 2010 Biodiversity Indicators
TDA	Transboundary Diagnostic Analysis
UNCLOS	United Nations Convention on the Law of the Sea
WFD	EU Water Framework Directive

2 Initial interpretation of the descriptor "*Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems*"

2.1 Definition of the key terms used in the descriptor

"Non-indigenous species…"

The key term within this GES descriptor is "***Non-indigenous species***" (Text Box 1). A variety of definitions of this term exists both in scientific literature (e.g. Leppäkoski *et al.,* 2002; Occhipinti Ambrogi and Galil, 2004; Carlton, 2009) and legislative/administrative (EC 2008) documents. Definitions used in this document are mainly based on the outcome of the EU funded project DAISIE which has collated the most recent knowledge on the subject (Pysek *et al.,* 2009).

Text Box 1. Non-indigenous species (NIS)

(synonyms: alien, exotic, non-native, allochthonous)
these are species, subspecies or lower taxa introduced outside of their natural range (past or present) and outside of their natural dispersal potential. This includes any part, gamete or propagule of such species that might survive and subsequently reproduce. Their presence in the given region is due to intentional or unintentional introduction resulting from human activities, or they have arrived there without the help of people from an area in which they are alien.

The term "non-indigenous species" is better known in scientific and administrative documents, therefore hereafter, the terms "species" and "lower taxa" are used as synonyms in this report. In some cases the true origin of a species remains obscure because of insufficient taxonomic knowledge, lack of early introduction records or other reasons (see Chapter 2.2 for details). However, such ***cryptogenic species*** (*sensu* Carlton, 1996. Text Box 2) should be taken into account, especially, then precautionary measures or risk assessment tools are being developed, and therefore, this category of species fall into the scope of the present GES descriptor:

Text box 2. Cryptogenic species

are those of unknown origin which can not be ascribed as being native or alien.

"…human activities…"

There is a broad range of human activities which may lead to introduction of NIS: deliberate introductions for aquaculture and stocking purposes, life food and aquarium trade, unintentional transfer of propagules (i.e. individuals of NIS) carried by shipping or with fishing gears, etc (see chapter 2.3 for details). It is important that the transfer of these species over the environmental barriers, e.g. land masses or vast open ocean spaces, separating the source and recipient regions took place as the result of human activities. Natural shifts in distribution ranges (e.g. due to climate change or dispersal by ocean currents) do not qualify a species as a NIS. However, secondary introductions of NIS from the area(s) of their first arrival could occur without human involvement due to spread by natural means.

"…levels that do not adversely alter the ecosystems"

NIS introduced outside their native range do not necessarily cause harm to the environment. However, our concern is based on many documented examples showing that some of these species are posing serious threat to native biodiversity, habitats and ecosystem functioning; and may cause damage to economy and/or impacts on human health. These species are termed as "***Invasive alien species***" (Text Box 3); this term is synonymous with "invasive non-indigenous species" but is more generally known worldwide; therefore it is proposed to use it hereafter.

> **Text Box 3. Invasive alien species (IAS)**
>
> **are a subset of established NIS and/or cryptogenic species which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions.**

Invasive species causing harm are not necessarily alien. Native organisms may also reach high level of abundance, interfering with human activities and impacting quality of life or local biodiversity. Such species are termed "***Pests***" (Text Box 2). However, it should be noted that MSFD GES Descriptor 2 "*Non-indigenous species…*" does not include native pest species.

> **Text Box 4. Pests**
>
> **are harmful organisms (not necessarily alien) living in places where they are unwanted and have a detectable environmental and/or economic impact or impact on human health. Pests may be native, cryptogenic or alien species.**

Often the impact of harmful IAS may be interpreted as decline in ecological quality resulting from changes in biological, chemical and physical properties of aquatic ecosystems. These changes include (but are not confined to): elimination or extinction of sensitive and/or rare species; alteration of native communities; algal blooms; modification of substrate conditions and the shore zones; alteration of oxygen and nutrient content, pH and transparency of water; accumulation of synthetic pollutants, etc (Olenin *et al.,* 2007). Thus, the key term "…levels that do not adversely alter the ecosystems" may be defined as the absence or minimal level of "***biological pollution***" (*sensu* Elliott, 2003; Olenin *et al.,* 2007) (Text Box 5).

> **Text Box 5. Biological pollution**
>
> **(synonyms: biopollution, biological invasion impact, bioinvasion impact) is the impacts of invasive alien species at the level that disturb ecological quality by effects on: an individual (internal biological pollution by parasites or pathogens), a population (by genetic change, i.e. hybridization), a community (by structural shift), a habitat (by modification of physical-chemical conditions), an ecosystem (by alteration of energy and organic material flow). The biological and ecological effects of biopollution may also cause adverse economic consequences.**

2.2 Links with other GES descriptors in MSFD

The Descriptor "Non-indigenous species…" is closely related to several other GES descriptors in MSFD because of the great variety of impacts which IAS may have on native biodiversity, ecosystem functioning, seabed habitats as well as commercial marine resources (Table 1).

Table 1. Links of the Descriptor "Non-indigenous species…" with other GES in MSFD

GES Descriptor (MSFD, Annex I)	Examples of relevant IAS impacts
(1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	Genetic change due to hybridization, decline in populations of native species, shifts in community structure, changes in biotope diversity. Introduction of NIS may result also in local increase of species richness and habitat heterogeneity.
(3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	IAS may impact on stocks by: interference with exploitation/culture activities, competition with exploited/cultured resources, alter recruitment and population abundance, provide for new exploitable/cultured resources.
(4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.	Reduction and alteration of food web by IAS diseases, parasites, predators, competitors for space, food, light and nutrients causing displacement or exclusion, alteration of communities and habitats resulting in changes in energy flow. IAS are often better competitors for food, light and space than native species, and may thus become dominant members of the community. This leads to shifts in the food web, which can hamper the functioning of the food web or even cause loss of some key ecosystem functions.
(5) Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.	Eutrophic conditions can cause changes in the phytoplankton population for both native and alien species. It is not known whether NIS will be more susceptible to forming harmful algae blooms than native phytoplankton while affected by eutrophic conditions. Invasive alien phytoplankton species are known to cause harmful algae blooms, including those resulting in production of Paralytic and Diarrheic Shellfish Poisoning toxins or causing fish kills. Also benthic IAS may contribute to storage and/or release of nutrients.
(6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	IAS may essentially change physical-chemical structure of bottom sediments by biodeposition, particle trapping or converting soft sediments into shell deposits or biogenic reefs; due to bioturbation and nutrients release; by causing coastal erosion (e.g. digging animals such as crabs). They may change habitat architecture (e.g. sea-weeds and seagrasses, reef-building polychaetes) and light climate (large canopy species, shading understorey algae or filter-feeding animals making water more clear); they also may increase concentration of toxic materials in sediments due to bioaccumulation.

(8) Concentrations of contaminants are at levels not giving rise to pollution effects.	Bioaccumulation of contaminants in living organisms due to introduction of, e.g. alien seston feeding organisms may take place in areas where they did not occur before. Also, improvements to water quality, e.g. declines in organotins of antifouling paints, may promote invasion success of IAS if appropriate measures to stop new introductions are not taken.

2.3 Identification of relevant policies and conventions related to the descriptor

2.3.1 Global conventions

The United Nations Convention on the Law of the Sea (UNCLOS, 1982), explicitly places a general requirement for Parties to take measures "to prevent, reduce and control pollution of the marine environment resulting from…the intentional or accidental introduction of species alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto" (Article 196). The rights and responsibilities agreed in UNCLOS have created the legal basis for subsequent marine legal regimes, including those concerning European marine environment (as EC has ratified the Convention in 1998).

Until recently, the policy background regarding alien species lies within Europe's commitment as a party to the Convention on Biological Diversity (CBD). In May 2006 the European Commission adopted a Communication on biodiversity aimed at halting biodiversity loss by 2010. One of its objectives is to substantially reduce the impacts of IAS and alien genotypes. To achieve the objective, four Actions are set out, the most important encouraging Member States to develop national strategies on invasive alien species and to fully implement them by 2010.

Additional international conventions such as the Convention on the Conservation of European Wildlife and Native Habitats (Bern Convention, 1979) recommend a European strategy on invasive alien species. Moreover, the Convention on Wetlands (Ramsar Convention, 1971), the Bonn Convention on Migratory Species (1979) have both resolutions regarding exotic alien species.

The main goal of the IMO International Convention on the Control and Management of Ships' Ballast Water and Sediments (BWMC) is to prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens through the control and management of ships' ballast water and sediments. The entry into force of the Ballast Water Management Convention would be one of the most important steps towards the reduction of un-intentional spreading of IAS regionally and worldwide.

2.3.2 EU legislative and administrative documents

So far (December 2009) no comprehensive instrument exists on EU level to tackle IAS. In particular there are no mechanisms to support harmonisation or consistency of approaches between neighbouring countries or countries in the same sub-region, and therefore no formal requirements exist for risk analysis for intentional introduction of non-native species that may affect biodiversity. For example, there is no common EU ballast water policy and no legal mandatory requirement in place. By now it could be concluded that the EU approach is leaning on the ratification and implementation of the BWM Convention by the EU member states (David and Gollasch, 2008). However, the BWM issue may also be addressed under the framework of the new EU Maritime Policy and the MSFD.

In contrast, the Phytosanitary Directive (EC, 2000), Regulation on wild species trade (EC, 1997), and various environmental directives including the WFD, as well as the regulation on the use of exotic species in aquaculture partly cover the issue (EC, 2007). Especially, the EC "Regulation for use of alien and locally absent species in aquaculture" (EC, 2007) establishes a system for assessment and management of the risks associated with the introduction of new organisms for aquaculture.

Recommendations on policy options to minimise the negative impacts of invasive alien species on biodiversity in Europe and the EU have been developed recently (Shine et al., 2008). This study also estimated the cost impact of aliens in Europe.

A recent communication "Towards an EU Strategy on Invasive Alien Species" (EC, 2008) has indicated the magnitude of the invasive species problems for various economic sectors and made it clear that the problem will exponentially increase unless appropriate action is taken urgently. It was stated that a coordinated approach at EU level is indispensable, as the impacts are transboundary. Therefore the development of an EU Strategy on tackling invasive species is the most appropriate way to address the problem and meet the policy objectives set. Such document should take into account the biogeographical provinces of European marine environment to reduce species exchange within EU waters (e.g. Ponto-Caspian spread to other European Seas, and vice versa).

2.3.3 Relation to EU Water Framework Directive (WFD)

Regarding assessment of environmental status WFD stipulates detailed procedures for the classification and monitoring of ecological status of water bodies including transitional and coastal waters. Biological indicators of good ecological status proposed for the WFD are generally multivariate expression of the presence of species differentially sensitive to pollution (e.g. Borja *et al.*, 2006). The presence of NIS is in itself the expression of an elevated exposedness to human mediated stressors and hence indicates some degree of deviation from the pristine ecological status. Moreover, IAS may influence not only biological but also physical-chemical parameters (e.g. transparency of water or nutrient concentrations) used for establishment of ecological quality in the framework of WFD (Olenin *et al.*, in prep.).

In WFD there is no explicit mention of alien species and their potential impact on ecological quality, although in the instructive WFD Guidance Document the introduction of alien species is given as an example of both biological pressure and impact. Therefore it is of general awareness that IAS may constitute an environmental pressure. In this context a plan was initiated in 2007 to foster discussion regarding the inclusion of IAS in the Member States' ecological assessment methods.

A workshop on 'Alien species and the EC WFD' has been held at Ispra, 17-18 June 2009. A final report from this workshop came in September 2009 and was presented for discussion and agreement at the WFD Ecological Status Working Group in October, and was available to TG2 to guarantee harmonisation of approaches between the WFD and MSFD regarding alien species. However, the approaches in the ecological quality judgement in WFD and MSFD are different (e.g. there are five classes in WFD whereas MSFD defines only one level, i.e. GES), therefore the harmonisation may be difficult to some extent.

2.3.4 Regional conventions and activities in European Seas

At the level of intergovernmental regional conventions and organisations the problem of IAS is getting increasing attention.

HELCOM

HELCOM has established a Working Group to develop a road map towards harmonised implementation of the IMO International Convention on the Control and Management of Ships' Ballast Water and Sediments (BWMC) within the HELCOM area. Additionally, this WG should have a look at other specific regional actions to address the problem of introduction of invasive species, such as a mandatory reporting system on ballast water, promotion and use of technical equipment for treatment of ballast water onboard ships and also consider a proposal for registration of ballast water passing Denmark. The working group also should evaluate steps to be taken before the entry into force of the convention to avoid the spreading of NIS such as risk assessment, mandatory reporting system, ballast water exchange, designation of ballast water exchange zones and a ballast water management decision support system. As a part of the HELCOM Baltic Sea Action Plan (BSAP), the road map towards ratification and harmonized implementation of the BMW Convention was adopted in 2007. According to BSAP, HELCOM countries agreed to ratify the BWM Convention as soon as possible, but by 2013 at the latest. The WG will continue its work in order to guide and monitor the implementation of the road map and acts also following a mandate given in the Road Map "to establish a correspondence group that regularly updates the current status in implementing the road map and that offers a forum to discuss relevant developments".

HELCOM was the first regional convention to use the bioinvasion impact assessment (BPL) method (Olenin *et al.,* 2007) for estimating the magnitude of the alien phytoplankton species (particularly, invasive dinoflagellate *Prorocentrum minimum*) effects on local phytoplankton community, pelagic habitat and ecosystem functioning on the scale of the entire Baltic Sea (Olenina *et al*., 2009). HELCOM has also assessed the distribution of alien species in 60 areas in the Baltic Sea and is currently applying the BPL method to assess all the IAS in the convention area.

OSPAR

The final version of the OSPAR Quality Status Report 2010 (OSPAR, 2009) is to be published soon. It provides an up-to-date evaluation of the quality status of the marine environment of the North-East Atlantic, summarising 10 years of assessment work under the OSPAR Joint Assessment and Monitoring Programme. NIS introductions are identified as a relevant pressure of human activities in the OSPAR Maritime Area (OSPAR, 2009).

The ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) made an overview assessment of NIS in the OSPAR maritime area, as a contribution to the OSPAR Quality Status Report 2010 (www.ospar.org). A document provides information on the distribution and abundance of NIS introduced into the OSPAR maritime area as a result of human activities, including information related to adverse impacts on marine ecosystems if available. WGITMO analyzed data on the presence and distribution of marine NIS collated from the Delivering Alien Invasive Species Inventories for Europe database (DAISIE) and from ICES member countries. Over 160 marine alien species have been identified in OSPAR regions. It was not possible to provide the information requested by OSPAR in relation to species abundance as the available data for the OSPAR maritime region are limited. Of the 160 NIS indicated, ca. 20% were identified as problematic invaders that can have human health, economic, and ecological impacts. The overview includes information on how the NIS were introduced. Aquaculture, via deliberate transfers and as attachments on imported cultured shellfish, has been a major vector of initial introductions. Ballast water from ships, hull fouling, and fishing activities are then secondary anthropogenic vectors that have moved species to other locations. Many of these species have economic impacts, e.g., as fouling organisms on aquaculture facilities, hulls, docks, piers, and other man-made structures or affecting harvests.

Barcelona Convention

The Barcelona Convention addresses the subject NIS and associated impacts in respect of protected areas. The protocol concerning the Mediterranean Sea as a specially protected area obliges Parties to take measures in order to protect these areas. The measures may include the prohibition of the introduction of exotic species and the regulation of the introduction of zoological and botanical species in protected areas.

UNEP RAC/SPA

The Regional Activity Center/ Specially Protected Areas for the Mediterranean has coordinated a number of initiatives for the Mediterranean, including also the countries of the east and south coast, addressed the harmonization of methods for controlling IAS and a field course in Sharm el Sheik (2009) was held for the dissemination to many state officials of the appropriate monitoring and assessment techniques

Commission on the Protection of the Black Sea

The Commission on the Protection of the Black Sea Against Pollution (BSC) developed Transboundary Diagnostic Analysis, which, inter alia, describes recent situation in relation to introduction of exotic species. It is indicated that there that enclosed or semi enclosed ecosystems, such as the Black Sea, are particularly sensitive to biological invasions. With the increased shipping traffic, aquaculture and trade the Black Sea has become a major recipient of alien species. The shared marine environment contributes to the spread of alien species from one national sector of the Sea to the others. Alien species can cause irreversible environmental impact at the genetic, species and ecosystem levels in ways that cause significant damage to the goods and services provided by ecosystems and thus to human interests. For this reason, they are now recognized as one of the great biological threats to the environment and economic welfare globally.

An inventory of the aquatic and semi-aquatic alien species recorded in the Black Sea marine and coastal habitats was given in Annex 6 of TDA. The number of registered alien species at the regional level amounts to 217 (parasites and mycelium excluded). Nearly half of them (102) are permanently established, a quarter - highly or moderately invasive (20 and 35 species respectively). This high ratio of invasive aliens suggests serious impact on the Black Sea native biological diversity and negative consequences for human activities and economic interests. The Advisory Group on Conservation of Biological Diversity (an integral part of the BSC institutional structure) at its recent meeting (28-29 September, 2009) has specified that the total number of exotic aquatic and semi-aquatic species is 244. In present time the Advisory Group discusses possible measures of prevention of NIS introductions in to the Black Sea.

The International Council for the Exploration of the Sea (ICES)

ICES noted the risks associated with uncontrolled species introductions and transfers almost 40 years ago. Today ICES has two working groups to address the issue, i.e. the ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) to deal with the movement of NIS for e.g. aquaculture purposes and the ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors which focuses on species movements with ships.

ICES, through its WGITMO and in cooperation with other ICES Working Groups and with the European Inland Fisheries Advisory Commission (EIFAC) of the Food and Agriculture Organization of the United Nations (FAO), has addressed the concerns of introducing nonnative species which resulted in the preparation of a Code of Practice. The first version of this code was adopted by ICES in 1973 as Code of Practice on the Movement and Translocation of Non-native Species for Fisheries Enhancement and Mariculture Purposes. The Code was set forth to reduce the risks of adverse effects arising from introductions of non-indigenous marine species. This code was frequently updated and the most recent version was published in 2005, i.e. ICES Code of Practice on the Introduction and Transfers of Marine Organisms. It includes all concerns expressed in the 1994 Code and follows the precautionary approach adopted from the FAO principles, with the goal to reduce the spread of exotic species. It accommodates the risks associated with current commercial practices including trade of ornamental species and bait organisms, research, and the import of live species for immediate human consumption. It also includes species that are intentionally imported to eradicate previously introduced invasive species (biocontrol), as well as genetically modified organisms (GMOs) and polyploids (specifically triploids and tetraploids). The latter sections were prepared together with WGITMO and the ICES Working Group on the Application of Genetics in Fisheries and Mariculture. The code outlines a consistent, transparent process for the evaluation of a proposed new introduction, including detailed biological background information and an evaluation of risks.

ICES Member Countries planning new species introductions are requested to present to the ICES Council a detailed prospectus on the rationale and plans for the introduction. The prospectus content is described in Section II of the Code of Practice and in the detailed code appendices.

ICES may request WGITMO and/or other Working Groups to evaluate the prospectus and, if needed, more information may be requested from the proposer. In case a species introduction is approved, ICES requests to update the Council on the progress of this initiative. ICES views the voluntary Code of Practice as a guide to recommendations and procedures.

2.4 *Recent EU coordinated and national research efforts addressing marine IAS*

A number of recently completed (FP6) or ongoing (FP7) EU projects addressed the problem of biological invasions, including issues relevant to marine IAS. These are:

DAISIE: Dealing with an inventory of all known alien species in Europe and identification of the top 100 'worst' invaders, their distribution and spread. This project summarised the ecological, economic and health risks and impacts of the most impacting species (http://www.europe-aliens.org/).

ALARM: Dealing with management of alien species with the development of toolkits and recommendations in terms of environmental policy, the interaction of IAS and sociology, climate change and chemicals. One of the project's products was the development of the biopollution assessment system which makes possible translation of existing data on miscellaneous invasive species impacts into uniform biopollution measurement units and enables comparison of different ecosystems according to the magnitude of impacts from alien invasive species (http://corpi.ku.lt/~biopollution/). The project will also have involved the production of an on-line journal *Aquatic Invasions*, a peer-review journal which produces a raid dissemination of all aquatic alien species issues (http://www.alarmproject.net/alarm/).

IMPASSE: Involves the development of guidelines and policies for environmentally sound practices for introductions and translocations in aquaculture that also covers quarantine procedures as well risk assessments and assess the impacts of invasive alien biota in aquaculture, protocols and procedures for assessing the potential impacts of invasive alien species in aquaculture and their economic impact (http://www.hull.ac.uk/hifi/IMPASSE).

MARBEF: Is a network of excellence funded by the European Union and consisting of 94 European marine institutes, is a platform to integrate and disseminate knowledge and expertise on marine biodiversity, with links to researchers, industry, stakeholders and the general public (www.marbef.org). This project resulted in publication of two specialized journal volumes dealing with functional role of marine IAS in European coastal waters (Reise *et al.,* 2006, 2009).

ALIENS: this project which has involved 5 European Partners developing a multidisciplinary approach to the problem of seaweed introductions to European shores. The aim was to improve knowledge on macroalgal introductions by studying their distribution, ecophysiology, genetic variation and vectors in order to assess the relative importance of local versus global impacts and the differences in susceptibility to invasion throughout European seas.

MEECE: Uses predictive models that consider the full range of drivers, both climate drivers (acidification, light, circulation and temperature) and anthropogenic drivers (fishing, pollution, invasive species and eutrophication) to explore the responses of the marine ecosystem in a holistic manner. It also reviews the impacts of drivers (including marine IAS) on the marine ecosystem.

Also, there have been several large national research projects dealing with NIS during the past years. Some examples of national studies are listed below.

BITIS (*Is the Biological Integrity Threatened by Invasive Non-native Species*?) 2003-2005 was a Finnish project studying the introduction of alien species, inter alia phytoplankton and their potential for harmful algal blooms, and the impact of established alien species on biodiversity and ecosystem functioning. The project also conducted biological risk assessment of port areas.

AquAliens A research program on how introduced species in Swedish waters could be a threat to and have an impact on ecosystem functions and economy, and how such risks could be assessed, was financed by the Swedish EPA 2002-2008 (www.aqualiens.tmbl.gu.se)

BINLIT (*Biological invasions in Lithuanian ecosystems under the climate change: causes, impacts and projections*). This project aims to collect, summarize and disseminate objective scientific information on the nature of the biological invasions and problems caused by them in Lithuania for a broad auditory consisting of decision makers, environmental institutions, scientists and the concerned public. An essential part of this project is devoted to the studies of marine and estuarine alien species (ik.ku.lt/~binlit/).

INVABIO This French program, started in 2000, aimed to increase conceptual and theoretical knowledge relating to biological invasions, and improve our knowledge on terrestrial and aquatic plant and animal invasions, which the French territory is facing in order to build support tools for management decision. An inventory of marine invasive species has identified 102 species introduced in the wild on the Atlantic coast-French Channel. The rate of invasion has increased considerably during the past 40 years. Thirteen species were introduced deliberately for aquaculture. The probable mechanisms of unintentional introductions are activities related to navigation and imports through shipments of oysters (www.ecologie.gouv.fr/Invasions-biologiques).

PROGIG Another French research program aimed at the study the proliferation of the Pacific oyster *Crassostrea gi*gas on the Atlantic coast-French Channel, to assess its trends, examine its ecological and socio-economic and propose management tools. (http://progig.fr/index.html)

Estonian national study on 'Alien invasive species in the north-eastern Baltic Sea: population dynamics and assessment of ecological impacts' was targeting the following three major items: (1) Distribution and population dynamics of the selected alien species in relation to variability of key environmental parameters; (2) Composition of biota in most important port areas as the high-risk areas in terms of biological invasions, and (3) Assessment of the ecological impact of selected invasive species on natural communities through a set of lab and field experiments (Ojaveer and Kotta, 2006).

3 Review of scientific literature and existing methods

3.1 Numbers of marine NIS in Europe

Almost 30,000 taxa have been listed in the register of European marine species (Costello *et al.* 2001), of which the share of marine alien species is ~3%: according to the European Alien Species Database (DAISIE Database) in total 1016 marine species have been registered in by February 2008; 747 of them are known to be established (DASIE database, unpubl.; Olenin and Didžiulis, 2009). The numbers reported are tending to be based on obvious or otherwise notable species. Some taxonomic groups have not been completely assessed, e.g. small micro- and meiobenthic organisms, gelatinous zooplankton or phytoplankton (e.g. Gomez, 2008), as well bacteria and viruses. There are also problems with new species being described and the imperfect knowledge in relation to what may be native or alien. For many taxonomic groups we still do not know how many species there are, what geographical ranges they have, and whether we can extrapolate from the better known larger organisms to the smaller ones the expected numbers of alien biota. A further source of bias is the uneven availability of taxonomic expertise, so that geographic areas can be differently explored and diagnosed in terms of alien species presence.

Further, transoceanic seafaring started much earlier than biological science, and a reconstruction of introductions during the distant past still needs to be done and for some species may be possible using genetic techniques. Very often alien biota does not become recognised until some years after they will have become established. Only few aliens are known offshore due to the lack of survey. The great majority are revealed in sheltered inlets and estuaries, harbours and canals (e.g. Reise *et al.,* 1999; Gruszka, 1999; Leppäkoski *et al.,* 2002; Zaiko *et al.,* 2007). Rough approximations of ratios for non-native to native species may be 1:40 in majority of the European marine waters, 1:20 at open coasts and 1:5 in estuaries or lagoons (see Reise *et al.,* 1999; Wolff, 2005; Nehring, 2006).

Marine alien species represent a broad taxonomic spectrum of aquatic free living and parasitic organisms, including:

plants - Green (Chlorophyta), Red (Rhodophyta) and other algae (diatoms, dinoflagellates, etc...), Mosses, liverworts and hornworts (Bryophyta), Flowering plants - angiosperms (Magnoliophyta), etc.;

animals - Annelids, segmented worms (Annelida), Arrow worms (Chaetognatha), Bony (Osteichthyes) and Cartilaginous (Chondrichthyes) fishes, Bryozoans (Ectoprocta), Cnidarians (Cnidaria), Comb jellies (Ctenophora), Crustaceans (Crustacea), Echinoderms (Echinodermata), Flat worms (Platyhelminthes), Insects (Insecta), Kamptozoans, goblet worms (Entoprocta), Molluscs (Mollusca), Round worms (Nematoda), Sea squirts (Tunicata), Sponges (Porifera), fungi and other organisms (DAISIE Database).

More than half of all alien species in European Seas are benthic invertebrates and macroalgae rank second in numbers (Streftaris *et al.,* 2005; Gollasch, 2006); and of benthic alien macrofauna species are seston feeders (Olenin and Daunys, 2005).

Marine alien species accounts have been compiled for Sweden (Jansson, 1994, continuously updated at www.frammandearter.se), Belgium (Kerckhof *et al.,* 2007), Denmark (Jensen and Knudsen, 2005), Germany (Gollasch and Nehring, 2006), Britain (Eno *et al.,* 1997; Minchin and Eno, 2002), The Netherlands (Wolff, 2005), three Baltic States (Estonia, Latvia, Lithuania) (Olenin, 2005), Ukraine (Alexandrov *et al.,* 2007), Norway (Hopkins, 2002), France (Goulletquer *et al.,* 2002), Italy (Occhipinti Ambrogi, 2002), Greece (Pancucci-Papadopoulou *et al.,* 2005), Ireland (Minchin, 2007a) and also for different regions: semi-enclosed seas (Leppäkoski *et al.,* 2009), Baltic (Leppäkoski *et al.,* 2002), Sea of Azov (Zaitsev and Ozturk, 2002), Mediterranean Sea (Galil and Zenetos, 2002; Rilov and Galil, 2009; CIESM Atlas, 2009), North Sea (Gollasch *et al.,* 2009), The Wadden Sea (Reise *et al.*, 2005), The White Sea (Berger and Naumov, 2002), The Marmara Sea (Ozturk, 2002), The Black Sea (Gomoiu *et al.,* 2002), The Caspian Sea (Aladin *et al.,* 2002) as well as general accounts for Europe (e.g. Galil *et al.,* 2009).

Several national, regional and taxa specific alien species databases have been developed in recent years. The first Internet based regional database on alien species was the Baltic Sea Alien Species Database (online since 1997, http://www.corpi.ku.lt/nemo/). This initiative was followed by NOBANIS in the early 2000s establishing a common portal access to IAS-related data, information and knowledge in northern Europe. For the Mediterranean Sea comprehensive and group specific inventories of alien species were developed by CIESM. National information websites on IAS exist in many European countries; most of them contain sections on marine alien species. One overarching approach is the Global Invasive Species Programme (GISP) for which IUCN's Invasive Species Specialist Group (ISSG) developed an alien species database. GISP provides details on the top 100 invasive terrestrial and aquatic species worldwide. The detailed species reports aim to illustrate the range of impacts caused by alien species. During the EU funded DAISIE project a similar approach was chosen with a focus on European alien species.

3.2 Origins of marine NIS in Europe

Non-indigenous marine biota in different European seas originates from diverse source areas. Some species have been introduced from distant overseas regions (e.g. south-eastern Asia, Australia, New Zealand, Americas), while others from one region of Europe to another, i.e. from the Ponto-Caspian region to the Baltic, or from the North Sea to the Black Sea. Generally, the biogeographical composition of alien biota is region-specific: for example, in the Mediterranean Sea most of the alien species (65–95%, depending on the western or eastern sub-basin) originate from tropical areas, mainly from the Red Sea, Indian Ocean or Indo-Pacific due to direct transport of species through the Suez Canal (Rylov and Galil, 2009); while in the Baltic Sea ~25% come from the North America, ~25% from the Ponto-Caspian region (in the eastern and southern coastal lagoons up to 60%) and ~20% are of south-eastern Asia origin (Leppäkoski and Olenin, 2001;

Leppäkoski *et al.*, 2009). Such differences depend on the matching of environmental conditions between source and recipient areas as well on prevailing introduction pathways.

Not all introduced species will be true marine species: some will have arrived to, or from, brackish water areas such as the Caspian Sea (Bij de Vaate *et al.,* 2002) or will involve areas with varying salinity such as the Baltic or Black Seas (Leppäkoski *et al.,* 2009). Many of these species can withstand a wide range of salinities on account of their physiological plasticity and so may become transported *via* inland corridors and establish themselves in estuarine or coastal low salinity areas (Olenin, 2002, Paavola *et al.,* 2005).

The true origin for many species is muddled after becoming widely dispersed over a long time. Precise localities will be known for some, such as the New Zealand mudsnail *Potamopyrgus antipodarum*; but for others only a general region may be known. True aliens need to be separated from species with seemingly isolated distributions but are naturally spread to regions beyond where they normally occur and so may become recorded as aliens. These are vagrant species and are normally unable to maintain populations on arrival, as in the case of the trigger fish *Balistes carolinensis* arriving in summer to the Atlantic coasts of northern Europe, and should be filtered out of alien species lists.

Broad changes to climate over time lead to northward expansions of southern species and contractions of some native biota (Stachowitz *et al.,* 2002; Boelens, 2005; Occhipinti Ambrogi, 2007). Unless the northward expansions of species have known distant origins and progressed using secondary dispersal mechanisms, that may include natural spread, the identity of the human induced movements may not be possible or otherwise easily identified.

3.3 Pathways and vectors of introductions

A NIS arriving in a new location directly from its native region is called **a primary introduction**, while its subsequent spread from the founding site is considered to be a **secondary introduction**. This spread may occur through a combination of natural dispersal and human-associated transport mechanisms, i.e. pathways and vectors (Text Box 6).

Text Box 6. Pathways and Vectors

A pathway is the route an alien species takes to enter or spread through a non-native ecosystem, e.g. shipping. Each pathway may have a number of vectors that are involved in a species transmission.

A vector is a transfer mechanism and is the physical means by which species are transported from one geographic region to another, e.g. ballast water or ship's hull.

Several vectors within a pathway may be involved in a transmission; also the role of vectors may change over time and may differ regionally (Galil *et al.*, 2009; Minchin *et al.*, 2009). Main pathways and vectors are listed below in priority order (Table 2).

Table 2. Main pathways and vectors of introduction in marine environment:

Pathway	Vectors
1. Ships, floating structures (all vessels, buoys etc...)	Water, sediments, solid and sedimentary ballast; the hull and hull projections; intakes and crevices; bored wood; bilges and ships water, wells, tanks and cargo; anchor, anchor chains, lockers fenders, portable moorings, deck recesses, overland transport, snagged materials; dredge spoil and sediment displacements.
2. Canals (channels, drainage cuts to lagoons, marina basins, etc)	The Suez Canal is recognized as the main source of NIS in the Mediterranean Sea. Also, water flow; tidal exchanges, and other alteration to water levels from lock flushing; transport of floating timber, pontoons, other equipment contribute to NIS introductions.
3. Wild fisheries	Stock movements; population re-establishment; discharges of by-catch, disease agents from processing live, fresh and frozen foods; live bait releases and discharges of live packaging material; movement of retrieved fishing equipment; releases of organisms intended as living food supplements; releases of transported water.
4. Culture activities	Intentional releases and movement of stock associated water; unintended or unauthorized releases; movement of nets, cages, lines, pumping equipment, etc.; discarded or lost nets, floats, traps, contaminated containers, live packaging materials and/or associated transport media; broadcasting of live, fresh, frozen feed; release of genetically modified species.
5. Aquarium and live food trade	Intentional and accidental releases from aquaria and empoundments; organisms associated with rock, gravels and sediments ('living rock'); untreated waste discharges; unauthorised releases of imported living foods, discharged live packing materials; releases of transported water.
6. Leisure activities	Live bait movements and discharge of packaging materials; accidental/ intentional transport and release of angling catch; water sport equipment (diving, angling gear); live souvenirs; stocking for angling.
7. Research and education (including pilot projects)	Intentional releases, field experiments, including translocations; accidental release; waste water and biological waste discharges; discarded samples and demonstration materials; living food releases from cultures or inspired movements; field and experimental gear movement (including diving gear); releases/ escapes of caged organisms used for monitoring.
8. Biological control	Releases to reduce diseases and parasites; to control invasive species or pests.
9. Alteration to natural water flow	Movements of abstracted water; moved drained water; (see also canals); desalination waste disposal; piped and pumped supplies.

Pathway	Vectors
10. Habitat management	Soil stabilization/reclamation using rock barriers, sediments and plantings; use of filter-feeding invertebrates for managing water quality

As an introduced species expands its new range, further opportunities to spread by additional vectors may present themselves. On occasion, the arrival of a NIS may result from a series of different vectors acting in a relay to convey that species. Identifying how a species arrived, however, is not always possible: very often the actual certainty of an operating vector is incompletely understood. For this reason different levels of certainty should be ascribed to the vector involved according to the species transmitted (Minchin, 2007b). Direct evidence comes from purposeful movements of a species and likely transmissions arise where an operating vector takes place in the region of a new arrival and where it is known that such a species has been associated with the same vector in other regions. Possible transmissions arise where a species is found, often some years after becoming established, in areas where several vector processes may be in operation. In many cases the operating vector remains unknown.

The strength of a vector is not easily ascribed because this largely depends on the volume, extent and timing of local or regional trading activities as well as political and socio-economic circumstances. Vectors are in a state of change, some no longer operate, some new ones evolve and others vary in their power of transmission according to changes in trading patterns, routes and season. Any single vector may transmit fundamentally different suites of organisms. In the case of molluscs these may attach to hulls as fouling, be associated with other fouling species, may be encrusting or burrowing and may carry pathogens or microalgae residing within the tissues or mantle cavities of other organisms (Minchin and Gollasch, 2003).

The arrival from a distant source area is a primary inoculation and following establishment an IAS may subsequently become distributed by the same vector, or by several other vectors, to new regions, termed secondary spread. Such vector overlap can result in a radiation from the primary inoculation hub to many varied localities which may even involve overland transmissions.

The secondary spread may be greatly facilitated by natural vector processes, such as: water dispersal (downstream and tidal movements, alongshore drift, internal waves, flooding events, tidal waves; turbidity currents), transfer by wind or (storm events, waterspouts), spreading by animals (attachment, in tissues, in gut, etc). This secondary spread may disperse alien biota more efficiently and so could compromise the ability to manage their spread. Many of the mechanisms of natural dispersal are not fully understood and require more serious study.

The role of different pathways and vectors also may alter due to climate change; alteration in environmental quality, political and social events, management policy and emergence of new trading routes.

3.4 *Impacts of IAS on marine environment and socio-economy*

Unlike terrestrial systems where bioinvasions have caused significant damage to economic interests (e.g., agriculture, forestry, animal husbandry), the majority of demonstrable marine bioinvasion impacts appear to be primarily on native biodiversity and ecosystem health (e.g. Leppäkoski *et al.,* 2002; Hewitt *et al.,* 2009) with few demonstrable direct impacts on economic values (e.g. Shine *et al.*, 2008). Similarly, the kinds of devastating impacts that are so readily observed on land are seen by only a few members of the public when they occur in the marine environment – many marine invasions remain unnoticed for years if not decades (Hewitt *et al.,* 2009). However, virtually all established NIS have at least some impact on the environment in the area where they dwell, feed and occupy a certain territory. The lack of impact in most cases is assumed by the absence of evidence - but if such evidence has never been sought, clearly no such conclusions can be made (Carlton, 2002). It cannot be overemphasized that for most invasions experimental work is required to determine whether or not there is a statistically significant alteration in one or more parameters of the populations or communities of those species that existed at a given site prior to the introduction. In contrast, however, most conclusions about impact, or the lack thereof, are based upon anecdotes and correlations, or, even less, on conjecture, suppositions, and presumptions (Carlton, 2002).

The nature of the impact varies greatly from the obvious effects on industries (e.g. additional repair and maintenance work of submerged structures) to the loss of species in a particular area or alteration of communities, habitat changes and, in some cases, ecosystem functioning and loss of yield in native fisheries. In the context of GES descriptors to MSFD, this report illustrates mostly the environmental impacts of marine bioinvasions. In general, these effects may be traced at all levels of biological organization from genes to communities and biotopes (Table 3).

Table 3. Marine bioinvasion impacts at different levels of biological organization, examples from European Seas*

Level	Effect	Examples
Genetic	hybridization and addition of genetically modified organisms	• Marsh grass *Spartina anglica*, North Sea • Brown alga *Fucus evanescens*, NW European seas
Species	addition of alien species, elimination of native species	• Green alga *Caulerpa taxifolia,* Mediterranean Sea • Fishhook water flea *Cercopagis pengoi,* Baltic Sea
Functional / community	changes in community structure, emergence of novel or unusual functions, alterations of food webs and ecosystem functioning	• Red gilled mud worm *Marenzelleria* spp Baltic Sea • N American comb jelly, *Mnemiopsis leidyi,* Black Sea
Biotope	habitat engineering, encrusting of solid objects, changes in bottom microtopography, alteration of biotope	• Common slipper shell *Crepidula fornicate*, NE Atlantic coast of Europe • Red algae *Acrothamnion preissii,* Mediterranean Sea

*based on Leppäkoski *et al.*, 2002, Reise *et al.,* 2006, Wallentinus and Nyberg, 2007 and references therein.

Depending on the context the same impact may be regarded as negative or positive. For example, the impact of the introduced seaweeds occurs on many levels of the ecosystem through e.g. competition with native plants for space, light and nutrients; competition for space with sessile animals; reduced water movements - especially when growing on previously barren shores; accumulation of sedimenting particles - which can reduce food abundance for benthic filter-feeders - and in some cases by producing deterrents or toxic compounds affecting grazers (Wallentinus, 2002). They may also have a positive impact, by providing places for shelter in previously barren areas or increasing habitat diversity and spatial heterogeneity (Wallentinus and Nyberg, 2007).

The assessment of genetic impacts of introduced species on native taxa is a relatively new field of research as it has only been possible to detect genetic changes at the level of single genes by enzyme electrophoresis since the 1960s. Consequently, the most understudied impact of alien species may be the genetic impacts they have on native species. Today, the knowledge on changes in the genetic integrity of indigenous populations resulting from alien species introductions and genetically-modified organisms is mainly limited to hybridization events.

There is evidence of the deliberate (for aquaculture or stock enhancement) or accidental introduction of new species into water bodies occurring in all Member States. Further the deliberate or unintentional movement of species from one water body to another is well known in Europe. Both activities have had serious ecological and economic consequences and there are few examples which appear to have been beneficial with no obvious environmental cost. Intentional species movement for e.g. aquaculture and in aquarium trade resulted in the rapid spread of disease agents and pathogens thereby exposing potentially highly susceptible species to new negative impacts. Due to the economic growth of the aquaculture business with a continuing expanding trend the issue of unwanted disease and pathogen transfer became of major importance.

Ecological impacts resulting from species introductions range from single prey-predator interactions between non-native and native species (e.g. Lehtiniemi and Gorokhova, 2008) to massive shifts in ecosystem functioning (e.g. change in food-web structure from top-down- to bottom-up-driven system, change from an energy-rich to an energy-poor system; fast to slow cycling of nutrients, etc.) (e.g. Shiganova and Bulgakova, 2000). Species having the greatest impacts are typically ecosystem engineers, which either create habitat complexity or heterogeneity or which destroy/decrease complexity (e.g. Wallentinus and Nyberg, 2007).

One of the key issues associated with the introduction of NIS are the potential alterations to energy flow in the trophic web as well as impacts on the biodiversity in the invaded regions. Very often arrival of NIS increases the number of species in an area, however, one has to consider that the local extinction of native species and the spread of alien species common to numerous regions of the planet, are leading towards a general homogenisation of the fauna and flora worldwide. This is in itself a loss of global biodiversity, because it promotes the deletion of rare and unique assemblages that were once characteristics of specific habitats.

The impacts of IAS may be permanent or temporal. For example, in pelagic environment, an IAS may became dominant for a certain season, like the potentially toxic dinoflagellates *Prorocentrum minimum* which successfully established itself in the Baltic Sea during the last two decades and has become a coastal summer bloom forming species, although occurring irregularly between years (Hajdu *et al.*, 2000; Olenina *et al.*, in prep.)

Knowledge of impacts of IAS is of crucial importance because it is needed for

a) developing of early warning systems, which only can make possible successful eradication of unwanted introduction;

b) compilation of target "black" lists, i.e. IAS that result in harmful effect;

c) cost-benefit analysis of management options, which involve species that can be practically managed in some way;

d) environmental status assessments taking into account the marine bioinvasion effects (that can only be deduced if relevant monitoring is in place).

3.5 Methods for quantifying GES in relation to IAS

In CBD, "Trends in invasive alien species" is one of indicators of threat to biodiversity that form part of the framework for monitoring progress toward its "2010 target", i.e. the commitment to achieve by 2010 a significant reduction in the current rate of biodiversity loss (CBD, 2000a,b, 2006).

The EU also included this indicator in the first set of headline biodiversity indicators to monitor the progress towards the 2010 targets. Also it is part of the European Environmental Agency (EEA) Streamlining European 2010 Biodiversity Indicators (SEBI) 'Trends in IAS in Europe'. EEA has outlined a strategy for the development of the indicator that is centred on more narrowly defined indicator elements that can be developed successively. This package of indicator elements include:

1) Cumulative numbers of alien species in Europe since 1900;

2) Worst invasive species threatening biodiversity in Europe;

3) Impact/ abundance of invasive alien species;

4) Awareness of invasive alien species and,

5) Cost of invasive alien species.

Within the first phase of SEBI (2005-2007) only the first two of above have been developed and proposed for inclusion in the set of EU biodiversity indicators (EEA, 2007).

The SEBI indicator "*Cumulative numbers of alien species…*" demonstrates where a large number of species have become introduced within a study region. This may be important for assessment of introduction rates, especially in relation to availability of pathways and vectors, because it is apparent that such localities with large numbers of alien species are prone to receive more. However this indicator is of limited value for overall bioinvasion impact assessment because species need to be classified according to the magnitude of their effects on environment. The impacting, invasive species form a small component of all NIS. Williamson and Fitter (1996) suggested this approximates to about 10% of established alien species, although there are several exceptions. However, in the marine environment it is difficult to deduce such a percentage because the presence of many alien species remains unknown. For example, it was found that out of 121 alien species recorded in the Baltic Sea area, 79 are known as established, documented data on environmental impact was available for 33, and only 4 species have shown strong impact on native communities and ecosystem functioning (Olenin and Zaiko, in prep.).

The devastating effect on marine environment and economy may be caused by just one successful and powerful invader, regardless of how many alien species are present in the system. Also, the impact on the environment does not correspond to the numbers of introduced species within the groups. For example, quite few introduced species are green algae, but *Codium fragile* and the *Caulerpa* species are known to have caused large problems in the western North Atlantic and Mediterranean, respectively (Wallentinus, 2002 and references therein).

There is growing recognition of the necessity to include, in one way or another, the account of NIS into the overall environmental status assessment (e.g. Cardoso and Free 2008; Orendt *et al.,* 2009). In one of the recently proposed method, the presence of alien species is considered as "biological contamination" regardless of their abilities to cause negative ecological and/or socio-economic impacts (Arbačiauskas *et al.,* 2008). The method includes calculations of "abundance contamination" and "richness contamination" at ordinal taxonomic rank, from which integrated estimations of biocontamination are derived. It was found that the proportion of identified orders comprised of alien species had a stronger negative influence on ecological quality than the relative abundance of alien specimens (Arbačiauskas *et al.,* 2008). Clearly, more research needs to be carried out on how to deal with and integrate the overall effect when there are several IAS present for each biological element as well as for the overall structure and functioning of the water body (Cardoso and Free, 2008).

Some indicators may be developed using examples from terrestrial invasion ecology, e.g. percentage of land surface area covered by alien plant species; area and density of weeds under active management; distribution and abundance of selected alien species; number and extent of exotic species in park ecosystems (McGeoch *et al*., 2006 and references therein); rate of increase in aquaculture-related introduced species in the marine environment in European Seas (EEA, 2003); total number of invasive species as a percentage of particular groups (McGeoch *et al*., 2006 and references therein).

Recently a set of composite indicators that include problem-status and management-status measures have been proposed (McGeoch *et al.,* 2006). The single indicators at national and global scales are number of IAS and numbers of operational management plans for IAS. Global trends in IAS are measured as the progress of nations toward the targets of stabilizing IAS numbers and the implementation of IAS management plans. The proposed global indicator thus represents a minimum information set that most directly addresses the indicator objective and simultaneously aims to maximize national participation. This global indicator now requires testing to assess its accuracy, sensitivity, and tractability.

Managers are mainly interested in those species that result in some overall effect on human health, quality of life, economic impact or have a significant impact on the environment. As a result, methods for quantifying GES in relation to alien species firstly need to take into account the effects of spreading species in other world regions as well as in neighbouring areas that have resulted in some form of impact.

A standardised method to classify the impacts of invasive alien species on native species, communities, habitats and ecosystem functioning (the **biopollution index, BPL**) was developed in the framework of two EU FP6 projects, ALARM and DAISIE (Olenin *et al.*, 2007). According to this method, the BPL calculation is based on abundance and distribution range (ADR) of the NIS under consideration and the magnitude of its bioinvasion impact.

The assessment should be performed in a defined aquatic area (e.g. a coastal lagoon; offshore sand bank, or an entire regional sea) and for a defined period of time. Abundance of a NIS is ranked as ‘‘low” (a species makes up only a small part of the relevant community: e.g. a population of a NIS forms a minor portion (few %) of the total community); “moderate” (an alien species constitutes less than a half of abundance of the native community); and ‘‘high” (it exceeds half, i.e. quantitatively dominates in the invaded community). The distribution scored as “one locality” when a NIS was found only at one locality (e.g. sampling station) within the assessment unit; ‘‘several localities’’ (the species spread beyond one locality but is present in less than half of sampling stations), ‘‘many localities’’ (extends to more than a half of the stations) and ‘‘all localities’’ (found at all localities). Combination of the abundance and distribution scores gives five classes of ADR (A-E), ranking an alien species from low abundance in a few localities (A) to occurrence in high numbers in all localities (E).

After ADR is estimated, it is related to the magnitude of bioinvasion impacts, ranging from no impact (0) through weak (1), moderate (2), strong (3) and massive (4). Three categories of impacts have been considered, namely: 1) impact on native species and communities (ranging from C0 to C4); 2) impact on habitats (H0 to H4); 3) impact on ecosystem functioning (E0 to E4). In accordance with the suggested approach, the overall BPL for the assessment unit is determined according to the greatest impact level for at least on IAS which was noticed during the evaluation period in the assessment unit (for details see Olenin *et al.*, 2007).

The BPL estimation is supported by an online Biopollution Assessment System ((http://corpi.ku.lt/~biopollution/) which translates existing data on invasive species impacts into uniform biopollution measurement units and accumulates data on bioinvasion impacts. This system implies three confidence levels while assessing ADR and the impacts: high (data documented by field studies for the given assessment unit), medium (data documented for a part of the assessment unit and extrapolated to the entire system by expert judgment) and low (expert knowledge of the species impact based on data from studies made elsewhere applied; see BAS, 2009 for details).

The BPL assessment approach needs to be developed further in order to specify the magnitude of impacts in different categories and for different groups (phytoplankton, macrofauna, macroalgae, fishes, etc). It may be used for monitoring of biopollution effects, evaluation of effectiveness of bio-invasion management, and prioritizing impacting species (incl. quarantine measures in aquaculture).

4 Identification of relevant temporal and spatial scales for the descriptor

4.1 Spatial scale

NIS will have impact on the environment at very different spatial scales. Even a rare alien species which is present in just one small locality will have some impact on its surroundings. However, in many cases such impact will remain unnoticed (or not measurable) unless a species achieves certain level of abundance and distribution range.

It is important to distinguish a fundamental difference between various forms of pollution. For example, chemical pollution will disperse from a source (over which there is some control), whereas alien species may expand their distribution and increase their abundance from a local source through processes which may not be controllable. Spatial extent and rate of spread will depend on biological traits of NIS and environmental conditions: e.g., species with planktonic phases will have a greater dispersal potential.

The assessment of IAS impacts generally should start on the local scale, such as "hot-spots" and "stepping stone areas" for alien species introductions (marinas, port areas, aquaculture installations, offshore structures, etc) or areas of special interest (marine reserves, NATURA 2000 sites, lagoons, etc). Depending on the taxonomic/functional group an IAS belongs to, the assessment can involve from confined benthic habitat to entire water column. Local scale assessments can be further integrated into next spatial level evaluations: sub-regional (e.g. Gulf of Finland in the Baltic Sea or Adriatic Sea in the Mediterranean) or a regional sea.

Determining the size of an assessment area will vary according to whether it is a single species under consideration or whether a general study of a region is to be performed. Within defined localities the impact of a species can be more easily assessed, while at larger scale (e.g. sub-regional) the effect will depend on the number of localities impacted. Given the nature of the effect even such localised impacts have to be highlighted in order to avoid the underestimation of the impact. For example Conrad's false mussel (*Mytilopsis leucophaeata*) occurs on the Finnish coast only in warm water discharge areas outside nuclear power plants, but due to high abundances it causes harm for the plants and is therefore considered as harmful species (Finnish national alien species strategy, in prep.).

Efforts to tackle issues of spatial scale have been undertaken within regional sea conventions. For example, HELCOM have developed an approach to address spatial scale for GES assessment within MSFD for a regional sea which is harmonised with WFD assessments in marine coastal areas (Annex 2).

4.2 Temporal scale

The attributes of biological invasions are changing at different temporal scales, e.g. days/weeks for alien phytoplankton and years/decades for benthic communities. The temporal scales addressed should vary depending on the taxonomic/functional group of an IAS. The temporal scales will also be influenced by the purpose of the assessment. Initial, or baseline, assessments are the prerequisite for further evaluation of any adverse effects of IAS in an area under consideration.

All invasions begin with one or more incidences of arrival, then an establishment of a small group of successfully reproducing individuals, and these may proceed into an expansive phase which eventually will turn into a phase of adjustments. It is important to know in which phase of an invasion process an evaluation of effects is attempted, particularly in comparisons with the same invader in other regions or vice versa. Research should focus on initial phases to identify limiting factors which prevent an introduced species from entering expansion phase. This may help to make predictions and plan management options.

NIS is a biogeographical category, indicating an alien, human-mediated origin of a species in a particular area. Because of that all NIS will always remain alien species in that area. However, those that have existed over a long period may normally have adapted and we may not any longer recognize changes that they have caused in the structure and function of natural communities, whereas those that have recently arrived will have a greater potential to cause environmental perturbations.

Temporal scales for monitoring of marine NIS (see Chapter 6 for details) and for the assessment of GES in relation to bioinvasions are different. The latter involves two temporal scales: integration of all existing data (the initial assessment) and the subsequent ongoing assessments involving different time periods.

The initial assessments should report:

- the inventory of all non-indigenous and preferably also all cryptogenic species known in an area;
- the ratio between non-indigenous and native species, at least in well studied taxonomic groups;
- abundance and distribution range of IAS taking into account the phase of invasion;
- a summary of IAS impacts on native communities, habitats and ecosystem functioning. The impacts should be reported using a standardized bioinvasion impact measures;
- a vector account (see Section 2.3) as measure of anthropogenic pressure.

<u>The ongoing assessments</u> should report:

- the inventory of newly arrived NIS and areas of their origin;
- vectors associated with new introductions;
- changes in power of pathways and their vectors;
- account of newly colonised localities as a result of primary introduction and secondary spread;
- impacts of newly established IAS;
- changes in bioinvasion impacts of previously established IAS.

The spatial and temporal scales of IAS assessments should be harmonized with other TGs developing recommendation on GES methodology for MSFD.

5 General framework for describing environmental status

5.1 Pressure-State-Response approach in relation to marine bioinvasion impact assessment

Pressure-State-Response approach was applied to describe a general framework for marine bioinvasions:

<u>Pressure</u>

Pressures are the pathways that spread alien biota (see Chapter 3.3).

<u>State</u>

State may be expressed as the number of established NIS and cryptogenic species known in an area; as the ratio between NIS and native species; as the abundance and distribution range of IAS; and as the magnitude of impact on native communities, habitats and ecosystem functioning (Chapters 3.4-3.5). It also involves the socio-economic consequences of impacts by IAS.

<u>Response</u>

This is how management responds to a bioinvasion impact. Invasion process involves a series of successive stages (Fig. 1), which should be considered when planning and executing management options. The number of species involved in the pathway is always greater than the number of species which managed to survive transportation and establish a population. However the possible management responses also narrow as an invasion progresses (Lodge *et al.,* 2006; Minchin, 2009). Prevention of introductions is the first and the most cost-effective option. Prevention is possible only early in the process, before a species arrives in a new location or in the point of entry. Once an alien species is established, eradication is costly and sometimes impossible: it depends on the rapid application of appropriate technology, political will, and resources. It is important to raise the public awareness on introduced species, as well as develop systematic mapping programs and maintain a good taxonomic expertise level to be able to recognize marine introductions. Discoveries of invasive species in new localities by public and private monitoring programs should be readily available on the internet.

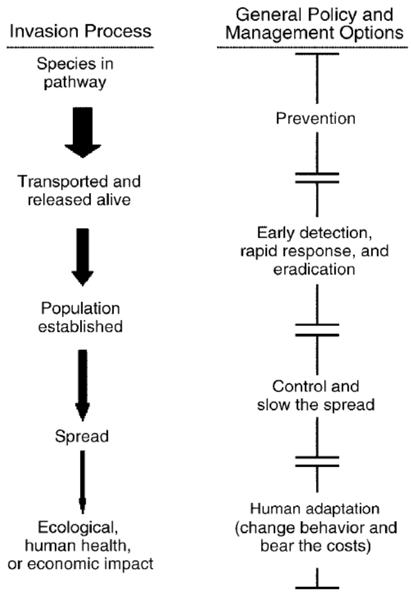

Figure 1. Phases of invasion process and management options (adopted from Lodge *et al.*, 2006)

5.2 Are IAS introductions related to a degradation gradient?

IAS do not respond in the same way as a chemical pollution or eutrophication which may be diminished provided that appropriate measures are taken (e.g. reduce in waste water discharges, proper treatment of chemically polluted outflows, decrease in use of fertilisers, etc). Biological invasions can be minimised only if preliminary precautionary measures are taken (e.g. ballast water management, quarantine measures in aquaculture). In general, an elevated number of alien species indicates a greater exposedness to the effects of anthropogenic activity and hence, diminished naturalness of a marine area. For example, Parties of the World Heritage Convention (UNESCO, 1972), acting to establish World Heritage Sites in the marine environment, assume obligations to protect the values for which the site has been identified (e.g., important and significant habitats for conservation of biological diversity). Parties should respond to IAS, including provisions through national management plans, legislation and regulations. Failure to do so could impair the values of a property, possibly resulting in the removal of the property from World Heritage listing (Hewitt *et al.*, 2009).

Areas disturbed by human activities or by previous invasions may have more alien species (e.g. Occhipinti Ambrogi and Savini, 2003; Zaiko *et al.*, 2007). Moreover, it was shown (for freshwater environments, though) that over 35% of native species of aquatic invertebrates are only able to live in areas with excellent or very good water quality, and are intolerant of organic pollution; while in contrast, all invaders are tolerant of at least moderate amounts of organic pollution (Karatayev *et al.*, 2009). On another side, there are examples to illustrate that this was not always the case, some ports are quite polluted and do not encourage IAS establishment and in other cases nature reserves (i.e. not polluted and not disturbed by human activities) may have large numbers of alien species. It was suggested that there was no clear correlation between the disturbance level and the number of IAS. Further, improved environmental conditions could lead to an increase in numbers of alien species. However, improved environmental conditions are also to the great benefit of native species which may already be absent in some disturbed areas due to a low tolerance towards pollutants.

Introduced marine species do not show a direct correlation with environmental degradation gradient as do most indicators of human impacts. The number of species and the frequency of introduction depend on human activities such as shipping or aquaculture. Whether NIS become established is only in part related to environmental status; it also depends on biological traits of the species and integrity of native ecosystems. The overall objective to reach a better environmental status of the European seas has substantial positive consequences for marine biota and all resource users. However, improved water quality may also result in higher numbers of introduced NIS with the potential to become IAS. Consequently, among other efforts to reach GES, measures should be taken towards NIS vector management, as otherwise the improved water quality may result in increased numbers and impacts of IAS which is the opposite effect to that desired.

6 Monitoring

Unless monitoring is undertaken there is no rational basis for providing adequate advice for management. Monitoring provides a basis for recording an early arrival and can provide some indication of the level of confinement of a species. Such findings often warrant a more intensified local study to verify the most effective management method. No management in the control of a species is an option that needs also to be considered but needs to be based on good scientific advice. Such cases arise where the natural vectors have a greater capability of spreading a species than any given form of management has in control. Whatever the monitoring methodology used it is important that the results are reported directly so that a rapid and planned response is possible.

One method of rapid assessment involved the study of sessile biota and associates attaching to floating pontoons found at fish farm and marinas sites (Minchin, 2007c). These can be readily examined at any tidal state, so saving field excursion time. The approach involves the development of a target list of impacting species to search for at each site for which some familiarity has been developed from photographs, museum specimens and field keys. These should include species occurring in neighbouring regions with known impact as well as species whose range may expand within the area under study. This can involve a single person and a large number of such sites can be visited in a short time making a rapid assessment possible that can be repeated annually. The approach can also be applied to single species of specific concern.

It is important to realize that monitoring can never cover all spatial and time scales and thus need to be supplemented by information from other sources, including, e.g., the general public, without loosing the quality of the records. Different types of alien species monitoring may be applied depending on the purposes and further use of information:

- Surveillance monitoring, usually conducted by regulatory bodies, is aimed at early detection of new introductions and inspection of spread of established alien species;
- Compliance monitoring follows the "polluter pays" principle and is aimed to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment;

- Investigatory monitoring is focused on impacts of alien species (does alien species really pose the problem? What will change if we take measures?).

To our knowledge, the "polluter pays" principle so far has not been applied to biological pollution cases, at least in marine environment, although the compliance monitoring is an important instrument in the IMO Ballast Water Management Convention.

Basically it is recommended use standard monitoring methods traditionally being used for marine biological surveys, including, but not limited to plankton, benthic and fouling studies being well described in relevant guidelines and manuals (e.g. HELCOM, 2006). However, specific approaches may be required to ensure that alien species are likely to be found, e.g. rocky shores, port areas and marinas, offshore areas and aquaculture areas. Further, it is important to consider sampling of different depths for e.g. plankton and use of appropriated methods also allowing the sampling and storage of delicate organisms, such as jellyfish. In addition young fish and trawl survey data should be considered.

Some alien species may provide sporadic and seasonal pulses of abundances typical of many planktonic species – this may require adopting the frequency of sampling events.

A combined monitoring programme may be undertaken to fulfil different needs, i.e. same assessment will be carried out and used for both the WFD and MSFD. To be most cost efficient to undertake monitoring of NIS, existing monitoring programmes should be adapted, as appropriate:

- Make researchers aware of the problems caused by alien species and that aliens should be documented in monitoring efforts no matter for what reasons those were undertaken (e.g. monitoring studies required prior and after off shore installations, such as for wind farms and larger bridge constructions and previously completed port sampling programmes (e.g. CIESM PORTAL, http://www.ciesm.org/marine/programs/portal.htm).
- Identification of high priority sampling sites (hot spots, stepping stones) using different methodologies, including hydrodynamic modeling, GIS and risk analysis of vectors. The selection of the study sites should be based on the analysis of most likely "entry" points of introductions and "hot spots" containing elevated number of alien species, such as ballast water discharge areas, docks, marinas, aquaculture sites with imported stock and heated power plants effluents.
- Consider more frequent sampling events to catch all life stages of NIS which may only occur during certain seasons.
- Not all taxonomic groups are addressed in ongoing monitoring efforts. For example the bathing water quality monitoring in EU is focussed on certain human pathogens. Possibly, these studies can broaden their scope also including non-indigenous disease agents, bacteriae and viruses.
- NATURA 2000 sites and other marine protected areas (MPA). Data on NIS from these sites could be reported and could be adapted for bioinvasion assessments.
- WFD monitoring should also be used to provide additional data where possible

- Use sports clubs, SCUBA divers, naturalists, fishermen, aquaculture farmers to either look for specific species, report unusual findings of species or to carry out specific recording duties where possible.
- Consider the monitoring efforts of all other TGs as appropriate.

Future monitoring programmes should always include the documentation (i.e. voucher specimens, including samples for molecular investigations) of NIS and a standardization of sampling strategies, sample frequencies, reporting of new IAS findings. New sampling sites may need to be considered according to future human and resource user activities in the sea.

It is recommended that EU Member States make an inventory of existing marine biological monitoring programs, surveys, and datasets which may be used (adapted) to report findings of IAS. Examples include:

- National and sub-regional databases to be linked so that the spread of IAS can more easily be monitored,
- Continuous Plankton Recorder surveys,
- Environmental Impact Assessment surveys (off shore oil terminals, ports, etc),
- Areas of special interest, such as nature conservation sites should be included into list of the study sites, e.g. NATURA 2000 sites, MPAs monitoring,
- WFD monitoring should report IAS,
- HELCOM / OSPAR monitoring programmes,
- Consideration of dedicated working group reports, such as ICES and CIESM reports.

As a complimentary measure and in the absence of an overall IAS targeted monitoring programme, rapid assessment studies may be undertaken, e.g. port surveys (e.g. Hewitt *et al.* 2000).

Reporting needs in case of findings

Communication channels need to be established and national focal points have to be identified also considering neighbouring countries to allow for the prompt development of contingency plans and/or joint eradication efforts if so decided. These channels may also be used to alert all stakeholders regarding new arrivals, range expansions and impacts of NIS.

National focal points should also run and maintain national data portals to provide a "one stop shop" where all the information is stored and routinely updated. In addition a centralized data base should be created where all national information is summarized. Existing data bases may be used as a starting point (e.g. DAISIE, CIESM, Baltic Sea Alien Species Database). Management data information systems, such as the WISE-RTD system, may be considered to handle the data flow and create awareness (http://www.wise-rtd.info/). This is of particular importance to summarize the data and knowledge on IAS either available or lacking on a regional sea level. Species alert report (see below) and early warnings may also be included on this platform with the aim to develop a Pan-European "one stop shop" information source. This tool may also contribute to a global network of similar initiatives.

The focal points may individually or jointly also issue species alert reports in cases where NIS are found which are of concern in other areas thereby minimizing the spread of such species.

Knowledge gaps

To overcome knowledge gaps it is recommended that future monitoring address aspects of the descriptor which are not or poorly covered. NIS identification is of crucial importance. The lack of taxonomical expertise has already resulted in several NIS having been overlooked for certain time periods. During this time the species established self-sustaining populations rendering any eradication programme useless. Further, the use of molecular approaches including bar-coding are needed to confirm traditional species identification. Genetical studies have already shown that more NIS occur, e.g. wrongly identified *Mnemiopsis* turned out to be another species (Gorokhova *et al.,* 2009) and another case is *Marenzelleria* where originally one species was identified, which is believed to be three species today (Blank *et al.,* 2008).

Further automatic image analyzing, especially for early detection of new introductions, is developing. An automated system may pick up “irregular” biological items and trigger more detailed study into taxonomy of that “unusual” object. Such system have limitations in cases where newly occurring species have a very similar body shape and size compared to earlier reported species in the region sampled.

7 Research needs

Due to recent research efforts (Chapter 2.4) there is sufficient information regarding the rate of arrivals, spread and vectors but there are still serious gaps in our knowledge, e.g.: the methodology used for monitoring, the capability to correctly identify the species either using traditional ID methods or DNA analysis, the traits of introduced species, risk assessment, the impact that they will have on GES and control and management procedures. The effect of climate change will be difficult to distinguish from human mediated introduction and this will have to be taken into account when using predictive modeling.

The recommendations for this section are divided into two A) Information gaps and B) Research needs. In order to address these gaps in knowledge the following research is suggested:

Improvements in monitoring methodology

Current methods used for monitoring do not always detect new invasions and can be time consuming and expensive, which can mean a lower frequency of sampling and that only a specific set of species are targeted. There is very little information available from deep water areas.

<u>Recommendations for research</u>

A) Information gaps

- Undertake a baseline studies in poorly studied ecosystems that are currently not monitored e.g. deep water areas.
- Establish which "hot spot" areas or potential new areas of introduction are currently not being monitored (e.g. mathematical modelling).

B) Research needs

- Development of automated systems for sampling, identification and counting.
- Develop a statistically robust sampling regime that ensures the most cost efficient coverage of the study sites.

Capability to correctly identify species

For some species there are very few experts in the world that can accurately identify the organisms. Samples have to be collected, preserved and stored correctly to enable correct identification using genetic analysis techniques. For many taxonomic groups there are no detailed identification guides at species level. Intercalibration and quality control of taxonomic expertise is crucial.

<u>Recommendations for research</u>

A) Information gaps

- Development of tools to enable easy access to the most up to date identification guides e.g. searchable digital databases that will find similar images from the web to aid identification.
- Develop a protocol for dealing with species for which there is very little information and cannot be identified using existing knowledge.

B) Research needs

- Develop widely available, accurate and cost efficient methods for genetic analysis to confirm identification of any suspected new introduction.
- Develop capability to correctly identify the origin of introduced and cryptogenic species to identify most likely pathways. This would require studies of population genetics.

Traits of introduced species

For many introduced species there is very little information on their traits and how this relates to their ecology and interactions with native species. This can also be true for well known introduced species. While there is often information on community structure and possibly habitat impacts there is very little information on the impacts on ecosystem function. There are also problems with extrapolating the information from one area to another.

<u>Recommendations for research</u>

A) Information gaps

- Use of a method such as Evidence Based Research to review what is known about specific species traits.

B) Research needs

- To compare the traits of successful and unsuccessful introduced species and also related native species to better understand why some species become invasive in some areas.
- Further study of the natural dispersal mechanisms of introduced species after arrival and establishment in a new area. This could utilise GIS approaches and/or physical oceanographic modelling.

Risk Assessment

Risk assessments in relation to introduced species are carried out with a high degree of uncertainty. This is owing to a lack of information on propagule pressure, vector analysis, impacts and how the presence of these species relates to the evaluation of GES.

Recommendations for research

A) Information gaps

- Identification of vectors is often uncertain so there is a requirement for the development of vector management procedures to reduce the risk of new introductions.

B) Information gaps

- Develop risk assessment methods that take into account the high degree of uncertainty that is typical of data in relation to IAS.
- Develop criteria for assessing the invasiveness of a species taking into account the quality of available data.

Impact on GES

There is an important difference when assessing GES in relation to IAS as they do not act in the same way as pollutants e.g. they do not follow the typical degradation gradient, they become an integral part of the ecosystem and are difficult or impossible to eradicate. There are currently no established methods for assessing impact on GES in these circumstances. There is some information on economic impacts but very limited information on ecosystem impacts.

Recommendations for research

A) Information gaps

- Effect by IAS on ecosystem services (e.g. Wallentinus and Nyberg, 2007)

B) Research needs

- Further develop methods for quantifying the impact of IAS. This development would require the results of many of the research needs outlined above such as targeted monitoring and correct identification.
- Develop a method for assessing changes to the resilience and functioning of marine ecosystems.

Control and management methods

In many cases traditional control methods are ineffective and could make the problem worse e.g. fragmentation of seaweeds. In the marine environment there are limited opportunities for implementing a successful control although in some cases a rapid response could result in an eradication. The emphasis should be on prevention methods.

Recommendations for research

A) Information gaps

- Study of the effects of the ban on TBT anti fouling paints.

B) Research needs

- Predictive habitat and/or niche modelling in order to establish potential areas of new introductions in order to put in place control measures.

8 References

Aladin, N.V., Plotnikov, I.S., and Filippov, A.A. 2002. Invaders in the Caspian Sea: In: Leppäkoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 351-359.

Alexandrov, B., Boltachev, A., Kharchenko, T., Lyashenko, A., Son, M., Tsarenko, P., and Zukinsky, V. 2007. Trends of aquatic alien species invasions in Ukraine. Aquatic Invasions 2 (3): 215-242

Apte, S., Holland, B.S., Godwin, L.S., and Gardner, J.P.A. 2000. Jumping ship: a stepping stone event mediating transfer of non-indigenous species via a potentially unsuitable environment. Biological Invasions 2:75–79.

Arbačiauskas, K., Semenchenko, V., Grabowski, M., Leuven, R.S.E.W., Paunović, M., Son, M.O., Csányi, M., Gumuliauskaitė, S., Konopacka, A., Nehring, S., van der Velde, G., Vezhnovetz, V., and Panov, V.E. 2008. Assessment of biocontamination of benthic macroinvertebrate communities in European inland waterways. Aquatic Invasions 3(2): 211-230.

BAS, 2009. Biopollution assessment system. Available at http://corpi.ku.lt/~biopollution/ (accessed December 2009)

Berger, V.J.A., and Naumov, A.D. 2002. Biological invasions in the White Sea. In: Leppakoski E, Gollasch S, Olenin S (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 235-239.

Bij de Vaate, A., Jazdzewski, K., Ketelaars, H.A.M., Gollasch, S., and Van der Velde, G. 2002. Geographical patterns in range extension of Ponto-Caspian macroinvertebrate species in Europe. Canadian Journal of Fisheries and Aquatic Sciences 59: 1159-1174

Blank, M., Laine, A.O., Jürss, K., and Bastrop, R. 2008. Molecular identification key based on PCR/RFLP for three polychaete sibling species of the genus *Marenzelleria*, and the species' current distribution in the Baltic Sea. Helgoland Marine Research 62:129–141.

Boelens, R., Minchin, D., and O'Sullivan, G. 2005. Climate change implications for Ireland's marine environment and resources. Marine Foresight Series (2), 40 (available at www.marine.ie)

Borja, A., Galparsoro, I., Solaun, O., Muxika, I., Tello, E.T., Uriarte, A., and Valencia, V. 2006. The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status. Estuarine Coastal and Shelf Science 66 (1–2), 84–96.

Cardoso, A.C., and Free, G. 2008. Incorporating invasive alien species into ecological assessment in the context of the Water Framework Directive. Aquatic Invasions, 3 (4): 361-366

Carlton, J.T. 1996. Biological invasions and cryptogenic species. Ecology 77: 1653-1655.

Carlton, J.T. 2002. Bioinvasion Ecology: Assessing Invasion Impact and Scale, pp. 7 – 19, in: Invasive Aquatic Species of Europe. Distribution, Impacts, and Management, E. Leppþkoski, S. Gollasch, and S. Olenin, Editors. Kluwer Academic Publishers, Dordrecht, The Netherlands

Carlton, J.T. 2009. Deep invasion ecology and the assembly of communities in historical time. Pp 13-56. In: G. Rilov and J. Crooks (eds) Biological Invasions in marine ecosystems: Ecological, management and geographic perspectives. Ecological Studies 204. Springer, Heidelberg, Germany.

CBD (Convention on Biological Diversity). 2000a. Third national report and thematic reports on alien invasive species. Secretariat of the CBD, Montreal, Quebec. Available from http://www.biodiv.org/ reports/ (accessed August 2009).

CBD (Convention on Biological Diversity). 2000b. Cartagena protocol on biosafety. Secretariat of the CBD, Montreal, Quebec. Available from http://www.biodiv.org/biosafety/ (accessed August 2009).

CBD (Convention on Biological Diversity). 2006. 2010 Biodiversity target. Secretariat of the CBD, Montreal, Quebec. Available from http://www.biodiv.org/2010-target (accessed September 2009).

CIESM Atlas of exotic species in the Mediterranean, 2009. Assessed at http://www.ciesm.org/online/atlas/index.htm (2009-12-14)

Costello, M.J., Emblow, C. and White, R. (eds). 2001. European register of marine species. A check-list of marine species in Europe and a bibliography of guides to their identification. Patrimoines naturels 50:1–463

DAISIE, 2008. List of alien species to Europa and to Europe, pp 133-263. In: Nentwig W (ed) DAISIE The handbook of alien species in Europe: invading nature: Springer series in invasion ecology 3. Springer 263pp.

David, M. and Gollasch, S (2008): EU shipping in the dawn of managing the ballast water issue. Marine Pollution Bulletin, 56(12), 1966-1972

EC, 1997. Council Regulation (EC) No. 338/97 of 9 December 1996 on the protection of species of wild fauna and flora by regulating trade therein. Official Journal of the European Communities, L 61, Volume 40, 3 March 1997.

EC, 2000. Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. OJ, L 169, 10.7.2000, 112 pp

EC, 2006. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy.

EC, 2007. Council Regulation (EC) No 708/2007 of 11 June 2007 concerning use of alien and locally absent species in aquaculture.18.7.2007 - OJ L 168 of 28.6.2007

EC, 2008. Commission of the European Communities. Brussels, 3.12.2008 SEC(2008) 2887 Commission staff working document. Annex to the Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions towards an EU strategy on invasive species impact assessment.

EEA, 2003. European Environment Agency. European environmental indicators. EEA, Copenhagen. Available from http://themes.eea.europa.eu/indicators/ (accessed July 2009).

EEA, 2007. European Environmental Agency. Technical report No 11/2007. Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe. Available from http://www.eea.europa.eu/publications/technical_report_2007_11 (assessed December 2009)

Elliott, M. 2003. Biological pollutants and biological pollution – an increasing cause for concern. Marine Pollution Bulletin 46, 275–280.

Eno, N.C., Clark, R.A., and Sanderson, W.G. 1997. Non-native species in British waters: a review and dictionary. Joint Nature Conservation Committee, Peterborough. 152 pp.

Galil, B., and Zenetos, A. 2002. A sea of change: exotics in the Eastern Mediterranean Sea. In: Leppakoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 325-336.

Galil, B.S., Gollasch S., Minchin D., and Olenin S. 2009. Alien Marine Biota of Europe. In: DAISIE. Handbook of Alien Species in Europe. Invading Nature - Springer Series In Invasion Ecology. V. 3, Springer: 93-104.

Gollasch S 2006 Overview on introduced aquatic species in European navigational and adjacent waters. Helgol. Mar. Res. 60, 84-89

Gollasch, S., and Nehring, S. 2006. National checklist for aquatic alien species in Germany. Aquatic Invasions 1(4): 245-269

Gollasch, S., Haydar, D., Minchin, D., Wolff, W.J., and Reise, K. 2009. Introduced aquatic species of the North Sea coasts and adjacent brackish waters, pp 507-525. In: G. Rilov and J. Crooks (eds) Biological Invasions in marine ecosystems: Ecological, management and geographic perspectives. Ecological Studies 204. Springer, Heidelberg, Germany.

Gomez, F. 2008. Phytoplankton invasions: comments on the validity of categorising the non-indigenous flagellates and diatoms in European seas. Marine Pollution Bulletin 56: 620-628.

Gomoiu, M-T, Alexandrov, B., Shadrin, N., and Zaitsev, Y. 2002. The Black Sea- a recipient, donor and transit area for alien species. . In: Leppakoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 341-350.

Gorokhova, E., Lehtiniemi, M., Viitasalo-Frösen, S., and Haddock, S.H.D. 2009. Molecular evidence for the occurrence of ctenophore *Mertensia ovum* in the northern Baltic Sea and implications for the status of the *Mnemiopsis leidyi* invasion. Limnol Oceanogr 54: 2025–2033.

Goulletquer, P., Bachelet, G., Sauriau, P-G., and Noel, P. 2002. Open Atlantic coast of Europe – a century of introduced species into French waters. In: Leppakoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, ppm 276-290.

Gruet, Y., Heral, M., and Robert, J.-M. 1976. Premie`res observations sur l'introduction de la faune associe´e au naissain d'huı ˆ tres Japonaises Crassostrea gigas (Thunberg), importe´ sur la coˆ te Atlantique Franc¸-aise. Cahiers de Biologie Marine 17, 173–184.

Gruszka, P. 1999. The River Odra estuary as a gateway for alien species immigration to the Baltic Sea basin. Acta Hydrochim Hydrobiol 27:374–382

Hajdu, S., Edler, L., Olenina, I., and Witek, B. 2000. Spreading and Establishment of the Potentially Toxic Dinoflagellate *Prorocentrum minimum* in the Baltic Sea, J Internat Rev Hydrobiol 85(5-6): 561–575.

Hare, J.A., and Whitfield, P.E. 2003. An integrated assessment of the introduction of lionfish (Pterois volitans/miles complex) to the western Atlantic Ocean. NOAA Technical Memorandum NOS NCCOS 2. 21 pp.

HELCOM. 2006. Manual for Marine Monitoring in the COMBINE Programme of HELCOM. Available from http://www.helcom.fi/groups/monas/CombineManual/en_GB/main/ (accessed July 2009)

Hewitt, C., Gollasch, S., and Minchin, D. 2009. The vessel as a vector – biofouling, ballast water and sediments, pp 117-129. In: G. Rilov and J. Crooks (eds) Biological Invasions in marine ecosystems: Ecological, management and geographic perspectives. Ecological Studies 204. Springer, Heidelberg, Germany.

Hewitt, C., Richard, L., Everett, A., and Parker, N. 2009 Examples of Current International, Regional and National Regulatory Frameworks for Preventing and Managing Marine Bioinvasions. In: G. Rilov, J.A. Crooks (eds.) Biological Invasions in Marine Ecosystems. 335 Ecological Studies 204, Springer-Verlag Berlin Heidelberg: 335-352

Hopkins, C.C.E. 2002. Introduced marine organisms in Norwegian waters, including Svalbard. In: Leppakoski E, Gollasch S, Olenin S (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 116-119.

ICES, 2005. ICES Code of Practice on the introductions and transfers of marine organisms. ICES Copenhagen.

ICES, 2005. Vector pathways and the spread of exotic species in the sea. Minchin D, Gollasch S, Wallentinus I. (eds) Co-operative Research Report No271. ICES Copenhagen 29pp.

ICES, 2007. Status of introductions of non-indigenous marine species to the North Atlantic and adjacent waters 1992-2002.

IMO, 2004. International Maritime Organization. International Convention for the Control and Management of Ships' Ballast Water and Sediments. Available from. http://www.imo.org (accessed July 2009)

Jansson, K. 1994. Alien species in the marine environment. Introductions to the Baltic Sea and the Swedish West coast. – Swedish Environmental Protection Agency, Report 4357: 1–67.

Jensen, K.R., and Knudsen, J. 2005. A summary of alien marine benthic invertebrates in Danish waters. Oceanological and Hydrobiological Studies. 34: Supplement 1, 137-162

Karatayev, A.Y., Burlakova, L.E., Padilla, D.K., Mastitsky, S.E., and Olenin, S. 2009. Invaders are not a random selection of species. Biological Invasions. DOI 10.1007/s10530-009-9498-0.

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

Lehtiniemi, M., Gorokhova E., 2008. Predation of the introduced cladoceran *Cercopagis pengoi* on the calanoid copepod *Eurytemora affinis* in the Gulf of Finland, Baltic Sea. Marine Ecology Progress Series 362: 193–200.

Leppäkoski, E. 2002, Non-native species in the Baltic Sea - an Ignored Problem. In: Baltic Coastal Ecosystem Structure, Function and Coastal Zone Management, Schernewski, G. and U. Schiewer (eds.), Ceedes Series, Springer, Berlin, 253-277

Leppäkoski, E., and Olenin, S. 2001. The meltdown of biogeographical peculiarities of the Baltic Sea: the interaction of natural and manmade processes. Ambio, 30, 4-5, 202-209

Leppäkoski, E., Gollasch, S., Gruszka, P., Ojaveer, H., Olenin, S., and Panov, V. 2002. The Baltic – a sea of invaders. Canadian Journal of Fisheries and Aquatic Sciences. 59: 1175-1188

Leppäkoski, E., Olenin, S., and Gollasch, S., 2002. The Baltic Sea: a field laboratory for invasion biology. In: Leppäkoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe: distribution, impacts and management. Kluwer, Dordrecht. 253–259

Leppäkoski, E., Shiganova, T., and Alexandrov, B. 2009. European enclosed and semi-enclosed seas. Pp 529-547. In: G. Rilov and J. Crooks (eds) Biological Invasions in marine ecosystems: Ecological, management and geographic perspectives. Ecological Studies 204. Springer, Heidelberg, Germany.

Lodge, D., Williams, S., MacIsaac, H., Hayes, K.R., Leung, B., Reichard, S., Mack R.N., Moyle, P.B., Smith, M., Andow, D.A., Carlton, J.T., and McMichael, A. 2006. Biological invasions: recommendations for U.S. policy and management. Ecological Applications, 16(6): 2035–2054.

McGeoch, M.A., Chown, S.L., and Kalwij, J.M. 2006. A Global Indicator for Biological Invasion. Conservation Biology 20, 1635-1646.

Minchin, D. 2007a. A checklist of alien and cryptogenic aquatic species in Ireland. Aquatic Invasions 2(4): 341-366.

Minchin, D. 2007b. Aquaculture and transport in a changing environment: overlap and links in the spread of alien biota. Marine Pollution Bulletin 55: 302-313.

Minchin, D. 2007c. Rapid coastal survey for targeted alien species associated with floating pontoons in Ireland. Aquatic Invasions 2(1): 63-70.

Minchin, D. and Gollasch, S. 2003. Fouling and ships´ hulls: how changing circumstances and spawning events may result in the spread of exotic species. Biofouling 19 (Suppl.), 111-122

Minchin, D., and Eno, C. 2002. Exotics of coastal and inland waters of Ireland and Britain. In: Leppakoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 267-275.

Minchin, D., and Gollasch, S. 2003. Fouling and ships' hulls: how changing circumstances and spawning events may result in the spread of exotic species. Biofouling, 19 Suppl:111-22.

Minchin, D., Gollasch, S., Cohen, A.N., Hewitt, C., and Olenin, S. 2009. Characterizing vectors of marine invasions. In: G. Rilov and J. Crooks (eds) Biological Invasions in marine ecosystems: Ecological, management and geographic perspectives. Ecological Studies 204: 109-115. Springer, Heidelberg, Germany.

Nehring, S. 2006. Four arguments why so many alien species settle into estuaries, with special reference to the German river Elbe. Helgoland Marine Research 60(2): 127-134.

Occhipinti Ambrogi, A. 2002. Current status of aquatic introductions in Italy: . In: Leppakoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 311-324.

Occhipinti Ambrogi, A. 2007. Global change and marine communities: alien species and climate change. Marine Pollution Bulletin 55, 342– 352.

Occhipinti Ambrogi, A., and Galil, B. 2004. A uniform terminology on bioinvasions: a chimera or an operative tool? Marine Pollution Bulletin 49, 688-694.

Occhipinti Ambrogi, A., and Savini, D. 2003. Bioinvasions as a component of global change in stressed marine ecosystem. Marine Pollution Bulletin, 46 (5): 542-551.

Ojaveer, H. and Kotta, J. (eds.) 2006. Alien invasive species in the north-eastern Baltic Sea: population dynamics and assessment of ecological impacts. Estonian Marine Institute Report Series no. 14. Estonian Marine Institute, University of Tartu. Tallinn.

Olenin, S., Minchin, D. *et al*. (in prep.) Invasive alien species and ecological quality parameters of the EU Water Framework Directive

Olenin, S. 2005. Invasive Aquatic Species in the Baltic States. Monograph. E. Leppäkoski and D. Minchin (reviewers). Klaipėda University Press, Klaipeda: 42 p.

Olenin, S. and Daunys, D. 2005. Invaders in suspension-feeder systems: variations along the regional environmental gradient and similarities between large basins. In: Dame, R. and Olenin, S. (ed-s). The Comparative Roles of Suspension-Feeders in Ecosystems. NATO Science Series. Earth and Environmental Series 47: 221-237

Olenin, S., and Didziulis, V. 2009. Introduction to the List of Alien Taxa. In: DAISIE. Handbook of Alien Species in Europe. Invading Nature - Springer Series In Invasion Ecology. V. 3, Springer: 129-132.

Olenin, S., Minchin, D., and Daunys, D. 2007. Assessment of biopollution in aquatic ecosystems. Marine Pollution

Olenin, S., and Zaiko, A. (in prep.). What is the level of biological pollution in the Baltic Sea?

Olenina, I., Hajdu, S., Wasmundm N., Jurgensone, I., Gromisz, S., Kownacka, J., Toming, K., and Olenin, S. 2009. Impacts of invasive phytoplankton species on the Baltic Sea ecosystem in 1980-2008. HELCOM Indicator Fact Sheets 2009. Available from http://www.helcom.fi/environment2/ifs/en_GB/cover/ (accessed December 2009).

Olenina, I., Wasmund N., Hajdu, S., Jurgensone, I., Gromisz, S., Kownacka, J., Toming, K., Vaiciūtė, D., and Olenin, S. Assessing impacts of invasive phytoplankton: the Baltic Sea case(in prep.).

Orendt, C., Schmitt, C., van Liefferinge, C., Wolfram, G., and de Deckere, D. 2009. Include or exclude? A review on the role and suitability of aquatic invertebrate neozoa as indicators in biological assessment with special respect to fresh and brackish European waters. Biological invasions, DOI 10.1007/s10530-009-9448-x

OSPAR 2009. Trend analysis of maritime human activities and their collective impact on the OSPAR maritime area. October 2009. Available from http://www.ospar.org/html_documents/ospar/html/p00443_09-10-28_DRAFT%20BA6%20Assessment.pdf (accessed December 2009)

Ozturk, B. 2002. The Marmara Sea, a link between the Mediterranenan and the Black Sea. In: Leppakoski, E., Gollasch, S., Olenin, S. (eds) Invasive aquatic species of Europe, distribution, impacts and management. Kluwer, Dordrecht, pp 337-340.

Paavola, M., Olenin, S., Leppäkoski, E., 2005. Are invasive species most successful in habitats of low native species richness across European brackish water seas? Estuarine, Coastal and Shelf Science 64: 738-750

Pysek, P., Hulme, P.E., and Nentwig, W. 2009. Glossary of the main technical terms used in the handbook. DAISIE, The Handbook of Alien Species in Europe, 375-381. Springer Science + Business Media B.V.

Reise, K., Bouma, T.J., Olenin, S., and Ysebert, T. 2009. Coastal habitat engineers and the biodiversity in marine sediments. Helgoland Marine Research, 63, 1-2

Reise, K., Dankers, N., and Essink, K. 2005. Intriduced species. In: Essink, K., Dettmann, C., Farke, H., Laursen, K., Lüerßen, G., Marencic, H., and Wiersing, W. (eds) Wadden Sea watre quality status report 2004. Waddensea Ecosystem No. 19. Common Wadden Sea Secretariat, Wilhelmshaven, Germany pp 155-161.

Reise, K., Gollasch, S., and Wolff, W.J. 1999. Introduced marine species of the North Sea coasts. Helgolander Meeresuntershungen 52: 219-234.

Reise, K., Olenin, S., and Thieltges, D.W. 2006. Editorial, Helgoland Marine Research, 60 (2): 75 – 76

Rilov, G., and Galil, B. 2009. Marine bioinvasions in the Mediterranean Sea – history, distribution and ecology pp549-576. In: G. Rilov and J. Crooks (eds) Biological Invasions in marine ecosystems: Ecological, management and geographic perspectives. Ecological Studies 204. Springer, Heidelberg, Germany.

Shiganova, T.A., Bulgakova Y.V., 2000. Effects of gelatinous plankton on Black Sea and Sea of Azov fish and their food resources. ICES Journal of Marine Science, 57: 641–648.

Shine, C., Genovesi, P., Gollasch, S., Kettunen, M., Pagad, S. and Starfinger, U. 2008. Technical support to EU strategy on invasive species (IAS) – Policy options to control the negative impacts of IAS on biodiversity in Europe and the EU (Final module report for the European Commission). Institute for European Environmental Policy (IEEP), Brussels, Belgium (available at http://ec.europa.eu/environment/nature/invasivealien/docs/Shine2009_IAS_Final%20report.pdf)

Stachowitz, J.J., Terwin, J.R., Whitlach, R.B., and Osman, R.W. 2002. Linking climate change and biological invasions: ocean warming facilitates nonindigenous species invasions. PNAS 99(24): 15497-15500

Streftaris, N., Zenetos, A. and Papathanassiou, E. 2005. Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. Oceanogr Mar Biol Ann Rev 43:419–453

UNCLOS, 1982. United Nations Convention on the Law of the Sea. United Nations General Assembly, Montego Bay, Jamaica. Available from www.un.org/Depts/los/index.htm (accessed September 2009)

UNESCO, 1972. Convention Concerning the Protection of the World Cultural and Natural Heritage, Paris, France.

Wallentinus, I. 2002. Introduced Marine Algae and Vascular Plants in European Aquatic Environments. In: Invasive aquatic species of Europe – distribution, impacts and management. E. Leppäkoski, S. Gollasch and S. Olenin (eds). Kluwer Academic Publ., Dordrecht, Boston, London: 27-52.

Wallentinus, I., and Nyberg, C.D. 2007. Introduced marine organisms as habitat modifiers. Marine Pollution Bulletin. 55: 323-332

Williamson MH & Fitter A (1996) The characters of successful invaders. Biological Conservation 78: 163-170

Wolff, W.J. 2005. Non-indigenous marine and estuarine species in the The Netherlands. Zoologische

Zaiko, A., Olenin, S., Daunys, D., and Nalepa, T. 2007. Vulnerability of benthic habitats to the aquatic invasive species. Biological invasions, 9: 703–714

Zaitsev, Y., and Ozturk, B. (eds). 2002. Exotic species in the Aegean, Marmara, Black Azov and Caspian seas Turkish Marine Research Foundation, Istanbul 267pp.

9 Appendix

APPENDIX 1

Levels of certainty in relation to an arrival of an alien species

For management purposes only the first two levels (see below) should be considered. These levels of certainty may change over time as a result of improved knowledge of tolerance of a species or a better understanding of transfer processes.

1) Highest certainty: direct evidence for an importation or arrival:

Exotic species are clearly associated with a specific vector to a particular locality as in the case of species seen and recorded in association with a transmission, at the time of inspection on import or at the time of release to the wild.

Examples: The introduction of half-grown Pacific oysters *Crassostrea gigas* by aircraft from Japan to France (Gruet *et al.*, 1976): [pathway = aquaculture, vector = aircraft]; arrival of the mussel *Mytilus edulis* by hull fouling (Apte *et al.*, 2000): [pathway = vessels, vector = hull fouling].

2) Reasoned certainty: likely arrival mode

Either for a) there are records where there is a strong indication a particular pathway is involved with other known examples of transmissions elsewhere for the same species (or similar behaving species within a taxonomic group) worldwide; or, b) where a species has appeared in the same area where a known pathway is known to operate. There may be more than one explanation for an arrival. For example, the introduction to the Atlantic of *Pterois volitans* in the ornamental industry or by shipping (Hare and Whitfield, 2003), the brown alga *Undaria pinnatifida* by shipping to Australia, New Zealand and Argentina, as hitch-hiker on oysters to the Mediterranean Sea, intentionally in aquaculture to Brittany, France and China (ICES 2007). There may be more than one pathway ascribed as being the likely mode. Here expert judgement should be used to identify the most likely mode of arrival.

3) Uncertain: involving possible arrival modes

A deduction based on the pathways operating in the immediate area where the species was found and exclusion of others. The recorded appearance of a species may be some years following its arrival and establishment. As a result the true pathway may become confused as a result of the species spread over time to implicate other modes for an arrival. Normally some pathway modes can be excluded.

4) Unknown: no pathway for a transmission can be indentified with any level of certainty

Several potential modes of arrival may be involved and some that may not have been considered. An arrival can not be ascribed to any pathway process with any level of certainty.

APPENDIX 2
HELCOM approach to select the assessment units for assessment of NIS and cryptogenic species

HELCOM uses a subdivision, combining three different approached whilst addressing the non-indigenous and cryptogenic species:

- National boundaries
- Coastal and offshore waters
- Physico-chemical and biological division of the Baltic Sea area.

The division is used in the HELCOM holistic assessment on the state of the marine environment and relies on similar assessments carried out for e.g. eutrophication and biodiversity (Baltic Sea Environmental Proceedings, 115B & 116B).

The division has five advantages for the GES work:

(1) the assessment units are small enough to include regional characteristics and processes,

(2) the units are large enough to avoid "no data areas" and too heavy workload,

(3) the approach can be applied to all MSFD descriptors,

(4) the approach is in line with MSFD-WFD overlap areas, and

(5) the approach takes into account both political and natural boundaries.