Directorate for **Nature Management**

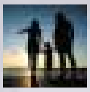
Research report 2001-1

Actual and potential effects of introduced marine organisms in Norwegian waters, including Svalbard


Environmental cooperation


Area of countryside and Land use


Animals and plants


Outdoor activities

Actual and potential effects of introduced marine organisms in Norwegian waters, including Svalbard

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Abstract:

The report focuses on actual and potential effects of introduced marine organisms in Norwegian waters, including Svalbard. The report also includes background information on relevant international agreements and general problems related to alien marine species.

Aquaculture and shipping are the main vectors responsible for the introduction of marine alien species. Organisms introduced for aqua-culturepurpose can escape and spread and can also be a vector for introducing parasites and pathogens. Alien species can be spread from ships´ ballastwater or as fouling organisms

About 45 alien species have become established in Norwegian waters.

Ekstrakt:

Rapporten fokuserer på aktuelle og potensielle effekter av introduserte marine organismer i norske farvann inkludert Svalbard. Rapporten inneholder også en del bakgrunns-informasjon bl.a. om relevante internasjonale avtaler og generelle problemer assosiert med fremmede marine arter.

Akvakultur og skipsfart er hoved-vektorene for introduksjon av fremmede arter. Oppdrettsorga-nismer kan spres etter å ha blitt innført med hensikt og kan føre med seg parasitter eller sykdomsorga-nismer. I forbindelse med skipsfart kan arter følge med i ballastvann eller som påvekst.

I Norge antar man at ca 45 fremmede marine arter er etablert.

Photo: Fiskaren

Preface

Introduced organisms in general are identified as a critical environmental issue. Such introductions can pose impacts both on biological diversity and on socioeconomics. The information in this report is gathered to clarify the state of knowledge for the topic and will hopefully provide the management with a better understanding and will be informative for others who may be interested.

The report focuses on the actual and potential effects of introduced marine organisms in Norwegian waters, including Svalbard, and also includes a registry over introduced marine organisms in Norwegian waters.

Trondheim, April 2001

Yngve Svarte
Head of Department

Abstract

The current report has been prepared for the Norwegian Directorate of Nature Management (DN) in order to provide an overview and registry of introduced (i.e. alien) marine organisms in Norwegian waters, including Svalbard, as well as to describe the actual and possible ecological and socio-economic impacts associated with such species. In so doing, it is considered important to present this against a wider background of information regarding the status of relevant work and instruments (*e.g.* agreements, treaties, conventions, codes of practice or conduct) relating to the issue of alien species, and the general nature of the problems associated with alien marine species internationally while taking particular account of Norwegian interests. Finally, the report provides conclusions and recommendations, forming a basis for possible follow-up and actions. The results arising from this project are primarily intended for use in environmental management, but institutions in other sectors (*e.g.* fisheries, business and commerce) can also be expected to benefit as the recipients of this knowledge. It is also anticipated that the report will provide useful background information for Norwegian delegations in appropriate international forums.

The issue of alien marine organisms is identified as one of the most critical environmental issues facing aquatic species and habitats, and biodiversity in general. Such introductions and transfers pose serious impacts both in terms of ecology and socioeconomics. Accordingly, a series of important international agreements and instruments (*e.g.* UNCLOS, 1982; Rio Declaration of UNCED, 1992; Convention on Biological Diversity, 1992 and its Jakarta Mandate, 1995; FAO Code of Conduct on Responsible Fisheries, 1995; Intermediate Ministerial Meeting on the North Sea: Integration of Fisheries and Environmental Issues, 1997) have played a seminal role in fostering the requirement to prevent, reduce, monitor and control the introduction and transfers of alien organisms.

Aquaculture and shipping are the main vectors responsible for the introduction of marine alien species. In the case of aquaculture, this occurs either as intended introductions of the non-indigenous target species (*e.g.* macroalgae, bivalve molluscs, fish) for industrial production purposes in a new area or as non-intended introductions and further transfers of the target species via, for example, escapement and spreading from their originally confined environment. In both intended and non-intended introductions and transfers, the further transmission and transfer of other 'stowaway' (i.e. unintentional) aliens may occur together with the original target species. Examples of such 'stowaways' occurring together with the target species are associated biota (*e.g.* spores of macrophytes and toxic phytoplankton found on or in bivalves) and parasites and pathogens/diseases. In the case of shipping, introductions and transfers of alien species mainly occurs by the transport and discharge of ballast water and, to a lesser extent, by transport of fouling organisms on hulls.

The current report documents the various alien marine organisms (i.e. phytoplankton, macrophytes, invertebrates, fish, and their associated pathogens) in Norwegian waters, including Svalbard. It estimates that about 45 alien marine species have become established in these waters, comprising about 22 plant species (ca. 12 macroalgae and 10 phytoplankton), 22 invertebrate species including parasites and pathogens), and a single vertebrate (fish) species. Attention is drawn in the report, whenever information is available, to the ecological and socioeconomic damage that has been or potentially may be caused by such introductions and transfers of free-living organisms and their associated parasites and pathogens/diseases in Norway and elsewhere. As Norway is one of the world's foremost fisheries and aquaculture nations, with the principal resource of wild anadromous Atlantic salmon found anywhere, the introduction of alien organisms forms a very serious threat to the ecological and socioeconomic basis for this production. Some of the most damaging of these alien organisms in Norway are a) toxic phytoplankton that can potentially cause substantial mortality of farmed and wild finfish and shellfish of about NOK 100 million under a single severe bloom, and b) parasites and pathogens/diseases (e.g. furunculosis and *Gyrodactylus salaris* introduced in the 1980s) that have caused more than NOK 2 billion of damage to farmed and wild Atlantic salmon over about the last 15 years.

Despite the laudable intentions of international agreements and instruments—many of which are based on the application of the Precautionary Approach elaborated under Principle 15 of UNCED—to contain the movements of alien species, there is clear evidence that they are ineffective in dealing with the problem as emphasized by the exponentially increasing establishment of marine alien species in the northeast Atlantic area and its adjacent seas (*e.g.* the North Sea and the Baltic Sea). Although several important organizations (*e.g.* EC, ICES, IMO, OSPAR Commission) currently address matters related to marine alien species in the North Atlantic and the North Sea area, the current report proposes that additional steps should be taken to place the issue of alien species high on the national and international agenda. In support of such steps, it is emphasized that a number of commitments are necessary at the scientific and policy levels to implement a series of actions in order to effectively prevent, reduce, monitor and control the introduction and transfers of alien organisms in accord with the Precautionary Approach.

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1 Introduction

Alien species (also called non-indigenous, exotic, invasive etc.) are organisms that have moved beyond their natural geographical range of habitat, and represent all phyla, from microorganisms to various plants and animals, both terrestrial and aquatic (Rosenthal 1980; Carlton 1985, 1989; Sindermann *et al*. 1992; Boudouresque *et al*. 1994; Jansson 1994, 1998; Eno 1996, Sandlund *et al*. 1996; Eno *et al*. 1997; Weidema 2000). Irrespective of whether the causes of these introductions are intentional or accidental, the occurrence of alien species in areas where they are not native can have far-reaching and harmful effects on marine biodiversity and the ecosystem into which they are introduced (Carlton & Geller 1993; Harbison & Volovick 1994; US National Research Council 1996; GESAMP 1997; Ruiz *et al*. 1997; Gollasch & Leppäkoski 1999).

The issue of alien marine species has been identified—by non-governmental and governmental organizations alike as well as being emphasized in numerous international conventions and instruments—as one of the most critical environmental issues facing aquatic species and habitats, and biodiversity in general (CBD 1992, 1995; ICES 1995a; Fauntaubert & Agardy 1996; WWF/IUCN, 1998).

A series of key international agreements and instruments (*e.g.* UNCLOS, 1982; Rio Declaration of UNCED, 1992; FAO Code of Conduct on Responsible Fisheries, 1995; Jakarta Mandate of the Convention on Biological Diversity, 1995; Intermediate Ministerial Meeting on the North Sea: Integration of Fisheries and Environmental Issues, 1997) have played a seminal role in fostering the requirement to prevent, reduce and control the introduction and transfers of alien species.

Humankind's rights to rationally utilize living resources—subject to responsible conservation and protection of species, biota, and the environment—has been established as a principle through several international treaties and instruments (UNCED, 1992). Thus, the 'precautionary principle' (i.e. erring on the side of conservation rather than of over-exploitation and pollution) should be applied and an ecosystem-based approach to management established (CBD 1998; Hopkins 1999).

Many of the above-mentioned international agreements and instruments are based on the application of the Precautionary Approach (Principle 15 of the Rio Declaration on Environment and Development, UNCED 1992), which *inter alia* determines that '*In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.*'

There have been no previous reviews in Norway that have addressed the issue of marine alien organisms in depth and that have also attempted to provide an inventory of such organisms. Tømmerås (1994) has provided a report on introduced species that was primarily terrestrial in scope and which was sparse in its focus on marine species. Brattegard & Holthe (1995) raised the issue of marine introduced species in Norway in the context of a proposal for identifying and mapping marine protected areas, drawing attention to the paucity of available information on these species. As part of a study concerning the OSPAR Commission's Convention area, a list of marine alien species was prepared for the region by Member State using information collected from national contacts, including in Norway (OSPAR 1997).

The current report has been prepared for the Norwegian Directorate of Nature Management (DN), under Contract No. 00040051, in order to provide an up-to-date review of alien marine species, especially including:
A brief introduction to the issue of alien species;
An overview of the potential vectors (i.e. transfer agents) that are associated with the introduction and transfer of such organisms;
International arrangements (e.g. work via international organizations, Conventions and Codes of Codes of Conduct) to combat introductions and transfers of marine alien species;
An overview (i.e. documentation and registry) of the alien species/organisms that have been introduced to and become established in Norwegian waters, including Svalbard, with identification of the particular ways in which they have been introduced. This also includes the impacts and consequences that have either occurred or may be expected to occur with such organisms, particularly with regard to the Norwegian environment and socio-economy;
Conclusions and recommendations.

The results arising from this project are primarily intended for use in environmental management, but institutions in other sectors (*e.g.* fisheries, business and commerce) can also be expected to benefit from this knowledge.

2 Materials & Methods

This report has been produced from a range of information available in the form of printed documents as well as accessing the websites of relevant organizations or projects via the Internet. These sources of information are acknowledged in the form of appropriate citations and references in the report.

For the purpose of this report, the boundary to Norwegian waters is the area falling within the Norwegian 200 mile exclusive economic zone (EEZ) as portrayed in **Fig. 1**, kindly provided by the Norwegian Ministry of Fisheries.

In Section 8 a synthesis is provided of the information available on Norwegian alien marine species. It draws *inter alia* on information provided to the author by the membership of the Norwegian Society of Oceanographers as well as information annually received in the form of National Reports, during the period 1980 to 1999, for alien aquatic organisms in the North Sea area by ICES Working Group on the Introductions and Transfers of Marine Organisms, WGITMO (ICES 1981-1999). Additional information for the North Sea area during the 1981-1991 period has been extracted from ICES Cooperative Research Report No. 231 'Status of Introductions of Non-Indigenous Marine Species to North Atlantic Waters 1981-1991' (Munro *et al.* 1999). This latter report followed the report for the previous period that ended in 1980 (ICES 1982a). In addition, transfers of indigenous species occur within and between countries, often on a regular basis but these are frequently difficult to follow or monitor and are generally not covered comprehensively in ICES reports. The interested reader wishing to obtain more detailed information is referred to the appropriate references that are provided in the above-mentioned ICES reports.

Information on the distribution of marine macrobenthic organisms provided by Brattegard & Holthe (1997) for the Norwegian coast (excluding Svalbard) has been used wherever appropriate as the basis for describing the distribution of the alien and cryptogenic species that have been listed in the current study. In some cases, the distributions noted in Brattegard & Holthe (1997) have not been used, e.g. whenever newer or more specific information has become available. For Svalbard (including Bear Island) and Jan Mayen, the list and distribution of marine macrobenthic organisms provided by Gulliksen *et al.* (1999) has been consulted.

A preliminary 'Register of Alien Marine Species in Norway including Svalbard' was established in Excel, and forms the basis for the information later presented in **Table 1** of the current document. The systematics and nomenclature (i.e. Division, Class) used for the algae (phytoplankton and macroalgae) in Table 1 follow that of van den Hoek (1995): Algae. Cambridge University Press.

This register, including additional information about the species, was sent out as an e-mail attachment in October 2000 to the membership of the Norwegian Society of Oceanographers ('Norske Havforskeres Forening', NHF), of which the author is a member, for possible comment and feedback concerning the assembled information as well as in the hope of gaining additional information. This process has provided a valuable verification system using the knowledge of the many expert biologists in Norway with first-hand knowledge of the particular species and taxonomic groups. In November 2000, the author presented the register to the Annual Meeting of NHF for possibilities of final comment. The names of those who have helped in the verification process, including drawing the author's attention to additional literature sources, are gratefully recognized in the Acknowledgements section of this report. However, the author wishes to emphasize that he takes full responsibility for any errors that are present.

3 Terminology

In the literature a wide range of terms, some of which are synonymous, have been used to describe species or organisms that are 'new' in an area. These include terms such as 'non-indigenous, alien, exotic, introduced, translocated, transferred, transplanted and invasive'. Common for these terms is the understanding that the species or stocks (*e.g.* genetic integrity) have been moved outside of their normal range by human activities, either intentional or unintentional.

Unless otherwise specified, definitions have been taken from the draft IUCN (International Union for the Conservation of Nature) Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion (IUCN 1999).

"**Native species**"(indigenous) means a species, subspecies, or lower taxon, occurring within its natural range and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans.)

"**Alien species**" (non-native, non-indigenous, foreign, exotic) means a species, subspecies, or lower taxon occurring outside of its natural range and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce.

"**Cryptogenic species**" is a species that is not demonstrably native or introduced. From crypt-, Greek, kryptos, secret; genic-, New Latin, genic, origin) (Carlton 1996).

"**Invasive species**" means an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

"**Introduction**" means the movement, by human agency, of a species, subspecies, or lower taxon (including any part, gametes or propagule that might survive and subsequently reproduce), outside its historically known natural range, within the same country or in another country.

"**Unintentional introduction**" means an introduction made as a result of a species utilizing humans or human delivery systems as vectors for dispersal outside its natural range. (The introduction is incidental to the main transaction taking place (often trade), but may have major environmental consequences).

"**Intentional introduction**" means an introduction made deliberately by humans, involving the purposeful movement of a species outside of its natural range and dispersal potential (Such introductions may be authorized or unauthorized).

"**Secondary introduction**" is one that takes place as the result of an intentional or unintentional introduction into a new area, when the species disperses from that point of entry into areas it could not have reached without the initial (primary) human aided introduction. (OSPAR 1997).

"**Re-introduction**" means an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct. (From IUCN Guidelines for Re-Introductions).

"Marine species" is any aquatic species that does not spend its entire life cycle in fresh water (ICES 1995b).

Other terms worth noting are:

<u>Established species</u> are species occurring as a reproducing, self-sustaining population in an open ecosystem, i.e. in waters where the organisms are able to migrate to other waters (Anon. 1996).

<u>Incidental species</u> are alien species that have been introduced through human agency into a new area, but have not become established in the wild (OSPAR 1997).

<u>Genetically modified organisms</u> (GMOs) are classified as alien and non-indigenous. There is no universally accepted definition of a GMO. However, several international organizations and countries have adopted a rather restrictive definition that states a GMO is an organism in which the genetic material has been altered anthropogenically by means of gene or cell technologies. These technologies refer primarily to gene transfer and "include the isolation, characterization, and modification of genes and their introduction into living cells or viruses of DNA as well as techniques for the production of living cells with new combination of genetic material by the fusion of two or more cells" (p. 4, ICES 1995b). The European Union defines GMO as "an organism in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination", and has excluded the products of selective breeding and organisms that have had their chromosome-s*et al*tered (polyploidy) (EC 1990). The US Department of Agriculture, however, includes chromosome manipulation and interspecific hybridization in their definition of techniques applied to organisms that should be subject to performance standards for genetically modified fish and shellfish (ABRAC 1995). The Fisheries Department of the Food and Agriculture Organization (FAO) and the International Center for Living Aquatic Resources Management (ICLARM) support an even broader definition of GMO (Pullin 1994; Pullin and Bartley 1996) that would include any genetic manipulation, including selective breeding, hybridization, sex reversal and chromosome set manipulation as well as the modern biotechnologies of gene transfer. Thus, in interpreting the term GMO, one should specify and understand what information is trying to be conveyed. In light of the internationally accepted definitions, it may be wise to simply state or list what technologies and classes of organisms are being discussed when referring to organisms that are being modified or manipulated.

There are significant consumer and environmental concerns about the possible introduction of GMOs in aquaculture. There is national legislation in most developed countries. It is likely that in the future ICES, through its Working Group on the Introductions and Transfers of Marine Organisms (WGITMO, see Section 6.4 for further details on the role of WGITMO), will be asked for advice on the release of GMOs.

4 Impacts

The role and impacts of alien species-introductions, both deliberate and accidental, are not well documented in the marine environment. In order to begin to predict the behaviour of an ecosystem when an alien species is introduced, basic information about indigenous species and their natural history, community structure, and the biodiversity of regional systems is essential. A frequently neglected aspect in the consideration of alien species introductions is the integration of economic and ecological impacts of introduced species that may occur under scenarios where species "escape" or behave unexpectedly in ways that may disrupt normal ecosystem functions. Thus, the impacts of introducing non-indigenous species can be viewed as both ecological and economic. However, these are inter-dependent as an alien species that has an ecological impact also has an economic one in the sense of affects on natural capital and services (c.f. Costanza *et al.* 1997), and *vice versa*.

Although there are many species introduced that do not survive in their new environment and may not cause damage, alien species have the potential to cause far reaching economic and ecological impacts. This uncertainty as to the impact an alien species will have in a new environment has led to Carlton & Geller (1993) describing the dangers as comparable to playing 'ecological roulette'.

The following provides a simple classification, based on Jansson (1994), regarding the different ways in which an alien introduction may affect the ecosystem, *viz.*:

Disrupt the existing interactions between species or food web links (*e.g.* predators, prey, grazers, and competition);
Produce hybrids with native species, resulting in changes in biological and genetic diversity;
Introduce parasites and diseases. The introduced species or form can function as a pathogen or parasite on indigenous species;
Utilization of marine resources may be affected by introductions with resulting harmful consequences on human health and well-being, recreation, and socio-economics.

Further consideration of some of these effects is provided in the following sections. In particular, the impacts of the alien species that have been introduced to Norway are examined in detail in Section 8.

4.1 Ecological

Relatively few organisms can survive in new aquatic surroundings because temperature, food, and salinity are less than optimal. However, those that do so and establish a population have the potential to cause substantial ecological and economic harm (Elton 1972; Carlton & Geller 1993, Eno *et al*. 1997; Gollasch & Leppäkoski 1999). Populations of invasive species may increase very quickly in the absence of natural predators. In turn these may displace native organisms by preying on them or out-competing native species for food and habitat space. Easily discernable economic damage may happen when displacement occurs of species that are harvested for food or other goods, or when structures are damaged.

Every introduction of alien species that becomes established results in changes to the host ecosystem, even if these may not be immediately apparent. Many of the observed effects have been detrimental and irreparable by displacing native species, and altering food web structure. Introduced species often prey on many parts of an already established food web or compete with indigenous species for resources such as food or space. Without natural predators, invaders can threaten or even eliminate indigenous species. They also carry with them the threat of new diseases that can destroy vulnerable native species or stocks (Stewart 1991). Occasionally, alien species reproduce with natives and produce hybrids. Hybrids not only change the gene pool of an area, but also simplify an ecosystem by causing population declines and species extinctions, thereby reducing biodiversity, i.e. the variety of genes, organisms and species found in an ecosystem (Youngson *et al*. 1998). As biodiversity decreases, the vulnerability of an ecosystem to pests and diseases increases (Begon *et al*. 1986).

4.2 Economic

Introduced non-native species may cause substantial destruction by taking over an area and eliminating economically profitable native species. This can result in enormous spending by the state and national agencies in an attempt to eradicate 'pests' and restore natural species. Numerous other economic sectors may be negatively affected including aquaculture, fisheries, water use, utilities, and natural or recreational areas. Alien species may cause economic damage by (1) forming hybrids with valuable species and producing worthless crossbreeds, (2) carrying or supporting harmful pests and pathogens, and (3) possibly reducing recreational prospects in an area. Another feature of economic impact is one where social and health consequences also occur. Alien species may not only import diseases affecting related species, but they may affect humans as well. Cures or restoration measures are generally very expensive. The threat of non-indigenous species is their unpredictability (Carlton & Geller 1993).

The damage and control costs of alien species are considered low when compared with the extensive environmental damages these species cause. If we had been able to assign monetary values to species extinctions and losses in biodiversity, ecosystem services, and aesthetics, the costs of destructive alien species would be at least an order of magnitude greater than most of the current best estimates. True socio-economic evaluation, in terms of 'costing the earth' (Cairncross 1991) are complex and beyond the scope of this study, and in most cases have not been carried out at the national level for 'natural capital' (Costanza *et al.* 1997).

4.3 Examples of impacts around the World

The following impacts have been selected to illustrate only some of the significant problems that have occurred around the world due to the introduction and transfer of alien marine organisms. In the majority of cases of detrimental impact, full economic costing has only rarely been carried out. This is partly due to the lack of funding for such activities as well as the embryonic nature of the necessary basal experience for conducting such impact assessments where biological, economic and sociological sciences must meet. A registry of alien marine organisms and their associated impacts in Norway will be examined specifically in Section 8.

Probably the most substantial case of impact in terms of ecology and economics has resulted from the unintentional introduction by ballast water of the zebra mussel (*Dreissena polymorpha*), originally a Ponto-Caspian species, into the North American Great Lakes in the 1980s and into the Hudson and Mississippi rivers. In this new area the zebra mussel has taken over the niche of existing filter feeders such that native mussels have been regionally driven to extinction, and water intakes on a range of machinery ashore and on boats have been blocked, and vessels and hard port installations such as piers have been heavily fouled. It has been estimated that efforts to control and remove the species and repair resulting damage by the year 2000 have cost about US$ 5 billion/yr (Khalanski 1997). This species began to colonize a number of areas in Europe since the early 1800s, including the lowest salinity areas of the Baltic Sea, the Shannon Estuary of Ireland, the La Plata river of Argentina, and some German rivers and Lakes. The zebra mussel population continues to grow and no immediate end is foreseen.

The alien common European shore ('green') crab (*Carcinus maenas*) was introduced to the North American Atlantic coast about 200 years ago, and also arrived in Australia in the late 1800s, South Africa in the 1980s and in the Pacific coast of the USA (San Francisco area) about 1990 (Cohen & Carlton 1995; Gollasch & Leppäkoski 1999). It has been involved in the demise of the soft shell clam industry in New England and the maritime provinces of Canada (Lafferty & Kuris 1996). It can destroy commercial shellfish, e.g. native oysters and crabs (Lafferty & Kuris 1996), with an annual estimated economic impact of US$44 million/yr (Lafferty & Kuris 1996).

The ctenophore *Mnemiopsis leidyi* is endemic to the Atlantic coast of North America. In 1982, it was first recorded in the Black Sea where it may have been transported in ballast water from New England, USA (GESAMP 1997). Today this species is well established and has changed the whole pelagic food chain of the Black Sea. There, mass occurrences of this ctenophore have decimated fish larvae and the planktonic food organisms of fish with the resulting catastrophic collapse (i.e. <10% catch compared with before the invasion) of the anchovy fishing industry (GESAMP 1997) worth about US$ 250 million/yr. At its zenith, this ctenophore reached a total biomass of 900 million tons, comparable to 10 times the world's annual fish harvest. Despite subsequent decreases in the abundance of the invader, the anchovy fishery has not recovered fully. Populations of native ctenopohores have almost been eradicated by the alien species. *M. leidyi* is also found in the Azov Sea and Mediterranean Sea (Gollasch & Leppäkoski 1999).

Marine macroalgae form a significant proportion of the established alien species on a global basis. *Caulerpa taxifolia* is a green alga native to tropical waters that typically grows in small, isolated patches. In the late 1970s this species attracted attention as a fast-growing and decorative aquarium species that became popular in the saltwater aquarium trade. A clone of the species was cultured for display at the Stuttgart Aquarium in Germany and provided to aquaria in France and Monaco. In 1984, *C. taxifolia* was identified as an alien species that had become intestablished in the Mediterranean. The origin of the introduction was probably a mutant hybrid polyploid-clone of *Caulerpa* from aquaria that was accidentally discharged into the sea because of its vigour and unusual iridescent green colour. The alga has since spread to France, Spain and Italy, and is now widespread through much of the northwestern Mediterranean. By the late 1990s, C. taxifolia had spread to the Californian area of the USA and to Australia. Spread of this seaweed mainly occurs by fragmentation. Long distance transport and appearance of *C. taxifolia* is due to human assisted dispersion via the anchoring systems of pleasure boats—the main localities are far from the introduction area in either harbours or anchoring sites—or commercial fishing gear. In areas where the species has become well established it has caused severe ecological and economic impacts by overgrowing and eliminating native seaweeds, seagrasses, reefs and other communities. In the Mediterranean, it has harmed tourism, destroyed recreational diving, and had a costly impact on commercial fishing both by altering the distribution of fish as well as creating impediment to fisheries. The seaweed is very adaptable and can thrive in most environments (e.g. polluted and non-polluted, exposed and protected) and habitats, e.g. rock, sand, mud etc. It can cover almost the whole seabed from the surface to 35m depth, while below this depth it has been observed at lesser densities down to 100 m. The invasive trend of *C. taxifolia* emphasize that it represents a major risk for shallower water ecosystems. The success of the alien populations of *C. taxifolia* has occurred in waters substantially different from their original tropical ones. This alien alga shows a vigour (e.g. about three times the size) and population density not present in the parent species in tropical seas. The alga secretes toxins, such as caulerpenyne that is toxic for molluscs, sea urchins, herbivorous fish and submarine flora, but not humans. Raloff (1988) and Meinesz (1999) provide additional information on *C. taxifolia*.

The introduction of alien harmful phytoplankton species, such as toxic dinoflagellates, is one of the most prevalent global threats. A calculation of the socio-economic impacts (e.g. on tourism, aquaculture, public health) that can arise from the unintentional introductions of toxic dinoflagellates in Australia has indicated that these had amount to about A$ 200 million, and that implementation of effective ballast water management could have avoided the original introduction of the organisms concerned (ACIL Economics 1994).

The phantom dinoflagellate *Pfiesteria piscicida* occurs in several estuaries on the eastern coast of the USA (*e.g.* Chesapeake Bay), where it enjoys shallow, warm and brackish water, although it has a wide salinity tolerance if the water has high levels of calcium and it can occur at temperatures from 15-33 ^{o}C. This and other species of dinoflagellate have caused fish lesions and mortalities, and threaten human health. Since 1991 about a billion fish have been killed by *P. piscicida* and there are recent indications that shellfish can also be affected (Burkholder *et al.* 1993). As yet the species has not been found in European waters, but there is a real possibility that this may occur.

The introduction and transfer of parasites and pathogens/diseases are one of the potentially greatest areas of impact of harmful species and organisms. For example, cholera and tetanus have been documented as transported between the continents by ballast water (McCarthy & Khambaty 1994; Nauke 1995). Human pathogens such as *Vibrio cholerae, V. parahaemolyticus*, *Erysipelothrix rhusiopathiae*, and *Leptospira icterohemorrhagiae* can also be transferred with fish (Janssen 1970), drawing attention to the potential for transfers of these pathogens occurring by human-induced movements of fish outside of their natural ranges.

5 Activities and vectors for introductions and transfers of marine alien organisms

There are numerous ways in which alien aquatic species are introduced through human activities. However, the dominant vectors for the introduction of alien aquatic organisms are shipping and aquaculture. Gollasch & Leppäkoski (1999) have produced a list of the main vectors for aquatic species introductions, based on a tentative ranking according to the importance of these vectors in the past:

Ships: unintentional introductions with ballast water, hull fouling, sediments in ballast tanks, and sediments attached to anchors/chains, commercial fishing nets and gear;
Aquaculture: intentional ('target species') and unintentional introductions (non-target species, *e.g.* epibionts and endobionts, and parasites and diseases;
Stock enhancement purposes;
Removal of barriers, *e.g.* opening of canals, supporting natural migration;
Use of living organisms as bait or packing material for bait;
Ornamental trade, imports for hobby or public aquaria;
Fish processing companies: discharging waste material of imported live specimens, potentially containing parasites and diseases;
Research: accidental escapes or intentional releases after experiments;
Remaining organisms left in fish nets and traps;
On or within recreational equipment (*e.g.* fishing rods and tackle, diving gear);
Import of live animals for human consumption, accidentally released into the wild before marketing;
Ocean and coastal currents transporting organisms attached to man-made floating objects;
Species introductions as fouling organisms on migrating non-indigenous host species (*e.g.* fish and birds);
Transport of sand and gravel as construction material.

Few studies so far have attempted to determine the relative vectors of introduction or the geographical sources of these introductions for any particular country. However for British waters, Eno (1996) estimated that about 55% of primary introductions of all non-native species had probably been introduced in association with shipping. The probable geographic sources of non-indigenous marine fauna into the British Isles were North and South America, Asia, and the Antipodes (i.e. Australia and New Zealand). Movements within Europe were generally routes of secondary introduction.

Once having found their way into a region, successfully introduced alien species may effectively invade new habitats adjacent to the currently occupied sea area by natural dispersal, *e.g.* via transport by currents as in the case of many seaweeds, phytoplankton, and the pelagic larvae of zoobenthos (ICES 1982a; Munro *et al.* 1999).

Because of their importance as human-related vectors, special attention is given in this report to aquaculture and ballast water.

5.1 Aquaculture

"Aquaculture[1] is the farming of aquatic organisms including crocodiles, alligators, amphibians, finfish, molluscs, crustaceans and plants where farming refers to their rearing up to their juvenile and/or adult phase under captive conditions. Aquaculture also encompasses individual, corporate or state ownership of the organism being reared and harvested in contrast to capture fisheries in which aquatic organisms are exploited as a common property source, irrespective of whether harvest is undertaken with or without exploitation rights." This definition encompasses three components: 1) the cultured organism, 2) the practice, and 3) ownership of product. All three components must be fulfilled for an activity to be classified as aquaculture.

In order to control the cultivation of fish or other aquatic species, one of two different methods are generally used. The species are either released freely into regional water, or else they are contained in a closed or open circulation pen. In the latter case, reproduction, food, growth, and spread can be controlled, but any resulting changes in the conditions of the environment cannot. If released freely, a species can affect the ecosystem in the ways already mentioned, such as competing or breeding with the indigenous species.

Introduced species have significantly contributed to increases in aquaculture production. Aquaculture is the main reason of introduction in 38.7% of the records in the FAO Database on the Introductions of Aquatic Species (FAO DIAS). In Asia, where there are many important cultivated species native of the continent, the contribution of introduced species is a small part of overall production but still represents a substantial production. In the other continents, the introduced species form a very important part of aquaculture production: 97.1% of crustacean production in Europe, 96,2% of fish production in South America and 84.7% in Oceania. Globally, 9.7% of aquaculture production comes from introduced species. Examples of

[1] Definition advocated by FAO for the World Census of Agriculture 2000 (WCA 2000) Programme.

established alien species and organisms that have been introduced (supposed origin given in brackets below) to, and/or transferred within, the OSPAR Convention area (i.e. North Sea and Northeast Atlantic) in connection with aquaculture activities (both intensive and extensive such as stocking) include (source OSPAR 1997):

Phytoplankton
Coscinodiscus wailesi (Indo-Pacific);
Gymnodinium mikimotoi (Pacific);
Thalassiosira tealata (?);

Macroalgae
Asparagopsis armata (S. Hemisphere);
Agardhiella subulata (Pacific, N.W. Atlantic);
Bonnemaisonia hamifera (Japan);
Codium fragile ssp. *atlanticum* (Indo-Pacific, Japan);
Codium fragile ssp. *tomentosoides* (Indo-Pacific, Japan);
Colpomenia perigrina (Pacific);
Grateloupia doryphora (Pacific);
Grateloupia filicinia var. *luxurians* (Pacific);
Laurencia brogniarti (?);
Polysiphonia harveyi (Pacific);
Sargassum muticum (Japan);

Animals (Invertebrates)
Acervochalina loosanoffi (Sponge: N.W. Atlantic);
Clymenella torquata (Polychaete: W. Atlantic);
Crassostrea gigas (Bivalve: Japan, S.E. Asia);
Crepidula fornicata (Gastropod: N. America);
Eusarsiella zostericola ((Ostracod: N.W. Atlantic);
Haliplanella lineata (Anthozoa: Japan, China);
Tapes philippinarium (Bivalve: S.E. Asia);
Mercenaria mercenaria (Bivalve: N.W. Atlantic);
Paralithodes camtschatica (Crab: W. Pacific);
Pennaeus japonicus (Shrimp: Pacific);
Petricola pholadiformis (Bivalve: N. America);
Procambarus clarckii (Shrimp: N. America);
Tiostrea lutaria (Bivalve: ?).
Mytilicola orientalis (Parasitic copepod: Japan);
Anguillicola crassus (Parasitic nematode: S.E. Asia);
Bonaemia ostrea (Parasitic protozoan: ?).

Within the OSPAR Convention area, the following pathogen species have been transferred from one country to another in connection with aquaculture:

Furunculosis of Atlantic salmon *Aeromonas salmonica*;
Monogenean skin parasite of Atlantic salmon *Gyrodactylus salaris*;
Monogenean skin parasite *Pseudodactylogyrus bini*;

It should be noted that some of these aquaculture related species have also been recorded in certain cases as also being introduced and transferred by shipping.

5.2 Shipping and Ballast Water

Traditionally, shipping has been considered a major route of introductions of aquatic species. However, the agents involved may have changed. The form and amount of shipping, and the structure and speed of vessels have undergone major changes over the past decade. In conjunction with this development, dredging of harbours and river estuaries has also changed the hydrodynamics of these systems, and there are further altered environmental conditions in coastal habitats, all possibly leading to an increased opportunity for survival of alien species (Gollasch & Leppäkoski 1999). In particular, the amount of transoceanic shipping has increased greatly, and the use of anti-fouling paints and ballast tanks on large fast moving vessels became common this century. During the last decades, ballast water discharges have increased throughout the world in most of the major ports (ICES 1998a). These factors have favoured present day transport of species in ballast tanks as opposed to on hulls. Accordingly, ballast water probably provides the greatest flow of neritic species globally in modern times. In relation to Europe, it is noteworthy that numerous phytoplanktonic organisms have been recorded in ballast water in vessels entering the Baltic and the North Sea (Anon. 1994; Gollasch & Leppäkoski 1999). Because of the potential for ecological and economic damage generated by such organisms, ballast water should be managed in order to minimize the risk of species introductions.

Ballast water is fresh or saltwater held in the ballast tanks and cargo holds of ships. It is used to provide stability and manoeuvrability during a voyage when ships are not carrying cargo, not carrying heavy enough cargo, or when more stability is required due to rough seas. Ballast water may also be used to add weight so that a ship sinks low enough in the water to pass under bridges and other structures.

Usually ballast water is pumped into ballast tanks when a ship has delivered cargo to a port and is departing with less cargo or no cargo. Ballast water is then transported and released at the next port-of-call where the ship picks up more cargo. If a ship is receiving or delivering cargo to a number of ports, it may release or take on a portion of ballast water at each port. In such cases, the ship's ballast water contains a mix of waters from multiple ports.

Ballast tanks have commonly been filled and emptied off the coastline, in estuaries and bays where freshwater and salt water meet. Thus, species picked up during ballast water filling are able to survive when emptied back into conditions similar to their native community. If, instead, ballast was emptied in the ocean and filled with marine water, species would be much less likely to survive in the foreign location.

The release of ballast water is a major source of introducing non-native organisms into the port of discharge (Eno 1996; Gollasch & Leppäkoski 1999). However, it is currently difficult to predict which organisms will die during transport in a ballast tank or why some are still alive when ballast water is released. Larger organisms often survive the journey by eating smaller ones. When faced with unfavourable conditions, some microorganisms and planktonic species form spores or other tough outer coverings for protection. As a spore, an organism may survive for a long time without food or in a different salinity or temperature than its natural environment. When the environment again becomes favourable, such as in a port, the organism may revert to its active form.

Organisms may establish semi-permanent or permanent communities in the layer of water and sediment that exists in the bottom of ballast tanks. In these situations, adult organisms may reproduce and release larvae into ballast water while adults remain in the sediment. This pathway leads to the release of the same non-indigenous species into multiple ports.

In order to stop possible introductions, organisms should not be discharged from ballast tanks under unregulated situations. This can be achieved by not taking organisms into ballast tanks, killing organisms during the voyage, or not discharging organisms when ballast water is released. Unfortunately, no current ballast water treatment method is able to completely eliminate the risk of introducing alien species. The goal of managing ballast water is to minimize the risk, possibly by targetting species that are known to have the potential to cause ecological and economic harm (see Sections 6.9.4 and 7 for further details).

Because the transfer of non-indigenous species via ballast water is an international issue, regulations for the management of ballast water to prevent such introductions will be most effective if applied internationally. The UN's International Maritime Organization (IMO) recommends that ships exchange ballast water in the open ocean to minimize the risk of introducing non-indigenous organisms to coastal waters. The organization is working on adding ballast water regulations to the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL) that all member countries must follow (see Section 6.9.4 on IMO for further details).

Examples of established alien species and organisms that have been introduced (supposed origin given in brackets below) to, and/or transferred within, the OSPAR Convention area in connection with shipping activities include (source OSPAR 1997):

Plants

Phytoplankton

Coscinodiscus wailesi (Indo-Pacific);
Odontella sinensis (Indo-Pacific);
Pleurosigma simonsenii (Indian Ocean?);
Thalassiosira tealata (?);
Thalassiosira punctigera (?);

Macroalgae

Asparagopsis armata (S. Hemisphere);
Antithamnionella spirographidis (N. Pacific);
Antithamnionella temifolia (?);
Bonnemaisonia hamifera (Japan);
Dasya baillouviana (?);
Fucus evanescens (N. Atlantic/Pacific);
Pikea californica (Pacific);

Animals

Acartia tonsa (Copepod: W. Atlantic, Indo-Pacific);
Ammothea hilgendorfi (Pycnogonid: Japan);
Balanus amphitrite (Barnacle: ?);
Crassostrea gigas (Bivalve: Japan, S.E. Asia);
Clavopsella navis (Anthozoan: ?);
Crepidula fornicata (Gastropod: N. America);
Ensis americanus (Bivalve: N.W. Atlantic);
Elminius modestus (Barnacle: Australasia);
Eriocheir sinensis (Crab: S.E. Asia);
Ficopomatus enigmatus (Polychaete: Indo-Pacific?);
Gonionemus vertens (Hydrozoa: W. Pacific);
Haliplanella lineata (Anthozoa: Japan, China);
Hydroides dianthus (Polychaete: N.W. Atlantic);
Hydroides ezoensis (Polychaete: Japan);
Janua brasiliensis (Polychete: Brazil);
Lepas anatifera (Barnacle: Atlantic Subtropic & Tropic);
Mya arenaria (Bivalve: N. America);
Rithropanopeus harrisii (Shrimp: W. Atlantic);
Styela clava (Tunicate: N.W. Pacific);
Teredo navalis (Bivalve: W. Pacific).

It should be noted that some of these shipping-related species have also been recorded in certain cases as also being introduced and transferred by aquaculture.

6 International organizations, conventions, codes of conduct and other instruments

Several intergovernmental organizations are active in the field of science and policy associated with the introduction and transfers of alien species, including GMOs. Provisions covering, either in part or in whole, the introductions of alien species of relevance for this report, occur in several regional and global treaties, conventions and instruments. A presentation of these follows with respect to their particular relevance to Norway.

6.1 Bern Convention

The Convention on the Conservation of European Wildlife and Natural Habitat, also known as the Bern Convention (Bern 1979), was adopted on September 1979 in Bern (Switzerland) and came into force on 1 June 1982. It has 40 Contracting Parties including 35 member States of the Council of Europe as well as the European Union.

The Berne Convention requires under Chapter V Article 11 '*each Contracting Party to strictly control the introduction of non-native species*'. All the North Sea States, including Norway, are party to this Convention.

6.2 Bonn Convention

The Bonn Convention for the Conservation of Migratory Species of Wild Animals (Bonn 1979) stipulates under Article V provision for '*conservation and, where required and feasible, restoration of the habitats of importance in maintaining a favourable conservation status, and protection of such habitats from disturbances, including strict control of the introduction of, or control of already introduced, exotic species detrimental to the migratory species*'. All the North Sea States, including Norway, are party to this convention.

6.3 EU

Taken in chronological order of legislation, the following European Community Directives apply to alien species:

Council Directive (90/220/EEC) of 23 April 1990 on the 'Deliberate Release into the Environment of Genetically Modified Organisms' (EC 1990) governs the release of GMOs into the wild as well as the requirement to provide a risk assessment analysis before eventual permission to release is granted;
Council Directive (91/67/EEC) of 28 January 1991 on 'Animal health conditions governing the placing on the market of aquaculture animals and products' (so-called 'Fish Health') (EC 1991) is aimed at facilitating the trade in live fish and shellfish whilst minimizing the risk of transfer of disease. The Directive permits the free movement of live fish and shellfish across national borders between cultivation units and zones of similar health status. According to the introductory paragraph (Article 1), the Directive shall not prejudice the implementation of national legislation directed at the preservation of species. Seen with regard to unintentional introductions of alien organisms by aquaculture activities, this Directive is significantly less restrictive than the ICES 1994 Code of Practice, and many examples have occurred where clearly detrimental effects have resulted from the application of the Directive, *e.g.* the introduction of alien parasitic copepods and resting stages of potentially toxic dinoflagellates together with the target species (Minchin *et al.* 1993).
Council Directive (93/53/EEC) of 24 June 1993 introducing minimum Community measures for the control of certain fish diseases. This further expands on the 1991 Directive to address a number of the loopholes that were present;
Council Directive (95/70/EC) of 22 December 1995 introducing minimum Community measures for the control of certain diseases affecting bivalve molluscs, and likewise aims at redressing a number of the previous weaknesses in earlier legislature;
The Council Directive (92/43/EEC) of 21 May 1992 on the 'Conservation of Natural Habitats and Wild Fauna and Flora' (EC 1992) obliges Member States to ensure that the deliberate introduction to the wild of non-native species is regulated so as not to prejudice natural habitats and species.

The EU has established several research activities concerning alien organisms. The EU Concerted Action on 'Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters' includes the following objectives:

State of the art of European ballast water studies;
Documentation and intercalibration of ship sampling techniques;
An assessment of potential treatment options to reduce the risks arising from ballast water releases, and
A public awareness campaign.

In the above-mentioned Concerted Action, European waters are considered as donor areas, so documentation of information from previous European studies on introduced species (case histories) is being undertaken. Additionally, through the case histories, the Concerted Action will consider the major pathways of introductions in an attempt to understand the requirements for the development of adequate treatment techniques. At the same time, the Concerted Action will aim to create awareness about the dimension and nature of the problem within the science community, the regulatory and inter-governmental bodies as well as in the shipping industry and with the public.

During a series of land-based, ocean-going and intercalibration workshops, the Concerted Action partners and invited experts meet and work on the objectives listed. So far, eight case histories of introduced species, regional ocean-going workshops and the intercalibration of ballast water sampling techniques have been finalized. The public awareness programme is an ongoing objective during the entire period of the Concerted Action.

6.4 ICES

The International Council for the Exploration of the Sea (ICES) has played a major role in the scientific understanding of introductions and transfers of alien aquatic organisms and in providing scientific information and advice for management and regulatory purposes. 19 Member States around the North Atlantic, including Norway, are party to the ICES Convention.

The ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) was first convened in 1979, since when WGITMO has provided scientific information and advice for management and regulation purposes, via the ICES Advisory Committee on the Marine Environment (ACME) to Member Country Governments and international Commissions.

Since 1995, there has been close collaboration between ICES, the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the UN's International Maritime Organization (IMO) on ballast water matters (c.f. ICES 1997a, 1998a). This is currently manifested in the form of the joint ICES/IOC/IMO Study Group on Ballast Water and Other Ship Vectors (SGBOSV).

ICES produced its first 1973 'Code of Practice on the Movement and Translocations of Non-Native Species for Fisheries and Mariculture Purposes'. The Code has been revised and extended in 1990 and 1994.

The 1994 ICES 'Code of Practice on the Introductions and Transfers of Marine Organisms' (ICES 1995b) sets forth recommended procedures and practices to diminish the risks of detrimental effects from the intentional introduction and transfer of marine (including brackish water) organisms. The Code is aimed at a broad audience of both public and private interests engaged in activities that could lead to the intentional or accidental release of alien species.

The currently operative ICES Code is divided into five sections of recommendations relating to: (1) the steps to take prior to introducing a new species, (2) the steps to take after deciding to proceed with an introduction, (3) the prevention of unauthorized introductions by Member Countries, (4) policies for ongoing introductions or transfers which have been an established part of commercial practice, and (5) the steps to take prior to releasing genetically modified organisms. A section on "Definitions" is included with the Code.

The Code is presented in a way that permits broad and flexible application to a wide range of circumstances and requirements in many different countries, while at the same time adhering to a set of basic scientific principles and guidelines.

6.5 NASCO

The North Atlantic Salmon Conservation Organization (NASCO) was established under the Convention for the Conservation of Salmon in the North Atlantic Ocean that entered into force on 1 October 1983. The objective of the Organization is to contribute through consultation and cooperation to the conservation, restoration, enhancement and rational management of salmon stocks subject to the Convention taking into account the best scientific evidence available to it. The Convention applies to the salmon stocks that migrate beyond areas of fisheries jurisdiction of coastal States of the Atlantic Ocean north of 36°N latitude throughout their migratory range.

NASCO is an intergovernmental body with the objective of contributing through consultation and cooperation to the conservation, restoration, enhancement and rational management of salmon stocks taking into account the best scientific evidence available to it. Besides the Council (Canada, Denmark in respect of the Faroe Islands and Greenland, the European Union, Iceland, Norway, the Russian Federation and the USA), NASCO includes the three regional Commissions—the North American Commission, the North-East Atlantic Commission and the West Greenland Commission—that provide forums for consultation and cooperation on salmon stocks; to propose regulatory measures for fishing in the fishery zones of members for salmon originating in the rivers of other Parties; and to make recommendations to the Council on scientific research.

The cultivation of Atlantic salmon has been carried out for many years. The use of hatcheries and stock enhancement procedures was initiated over 100 years ago, and salmon ranching developed in the 1960s. Since it started in the 1960s, salmon farming has become a major industry in both Europe and North America. In the 1980s, scientists and managers became aware that substantial numbers of farmed salmon that had escapade from aquaculture facilities were found amongst wild stocks. From 1988, when the NASCO Council first discussed the matter, there has been increasing concern that interactions between farmed and wild salmon would be detrimental to the latter by leading to changes in their genetic composition, the introduction of pathogens/diseases and parasites and other effects with adverse ecological consequences.

In response to this situation, ICES and NASCO co-sponsored several meetings between 1989 and 1997 to consider the genetic threats to wild salmon posed by aquaculture as well as other relevant interactions. Furthermore, in 1994 the NASCO Council adopted a Resolution to Minimise Impacts from Salmon Aquaculture on the Wild Salmon Stocks that includes some provisions in relation to introductions and transfers (NASCO 1994). Subsequently in 1997 the North-East Atlantic Commission adopted a Resolution to Protect Wild Salmon Stocks from Introductions and Transfers (NASCO 1997a), and the Council adopted Guidelines for Action on Transgenic Salmon (NASCO 1997b).

The ICES/NASCO Symposium on 'Interactions between Salmon Culture and Wild Stocks of Atlantic Salmon: The Scientific and Management Issues' was held in April 1997 in Bath (UK). The symposium was structured to address the genetic impacts, disease and parasite impacts, and environmental or ecological impacts (Hutchinson 1998). The report by the Conveners of the symposium (Youngson *et al.* 1998) is a valuable document that provides an excellent overview of the problems (*e.g.* threats to the natural genomes, parasites and pathogens/diseases) faced by wild salmon and possible ways to redress the situation.

Since the 1997 ICES/NASCO Symposium, increased attention has been given to the risk for escape of genetically modified salmon, such as those developed on Prince Edward Island (Canada), that are able to grow up to about six times faster than the natural counterpart. Such transgenic salmon have recently been promoted for future farming by the parent Canadian company, despite firm opposition to the development of GM salmon being voiced by the salmon culture industry, custodians of wild salmon stocks, and environmentalists (Nuttal 2000).

6.6 OSPAR

Within OSPAR, the introduction and transfer of alien species is primarily a Joint Assessment and Monitoring Programme (JAMP) issue. At ASMO 1995, there was agreement that IMPACT should consider the issues concerning alien species, and that the Contracting Parties should submit information on introductions and transfers of such species. It is anticipated that the information received can be transferred to a database. At IMPACT 1997, a document (IMPACT 97/7/1-E) on the 'Status and National Activities in the OSPAR Convention Area' was presented. Currently, IMPACT appears not to have any special plans for continuation of this work other than establishing a database on alien species, possibly under the direction of ICES.

In OSPAR's 'Strategy on the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area" (reference no.: 1998-19), attention is drawn to item 2.2 c *viz.* 'assessment, in accordance with the criteria of Appendix 3 of the 1992 OSPAR Convention, and in the light of work in other international forums, of the following first candidate list of human activities:' where point vii refers to 'the introduction of alien or genetically modified species, whether deliberately or unintentionally'.

In the 'OSPAR Action Plan 1998-2003', Annex 1 under the list of 'Human activities to be assessed with regard to their impact on the marine environment, its species, habitats and biological diversity', the introduction of alien species is not included amongst the highest priorities. The apparent reason for such a lack of priority within OSPAR is that alien species issues are currently being handled within ICES and IMO.

In 1996, 1997, and 1998, Sweden acted as Lead Country on alien species issues in OSPAR and circulated a number of questionnaires to the Contracting Parties. These activities have resulted *inter alia* in reports being presented to OSPAR IMPACT in 1996 and 1997 (*e.g.* IMPACT 96/6/1 and 97/7/1). At the June 1998 IMPACT meeting, a manuscript was circulated by Sweden addressing introductions of alien species in the OSPAR Convention Area, with matters of relevance to the Regional Task Teams for QSR 2000. However, relatively little activity has occurred with regard to alien species issues in OSPAR circles after 1998.

6.7 NCM

The Nordic Council of Ministers (NCM) was established in 1971. It submits proposals on cooperation between the governments of the five Nordic countries (i.e. Denmark, Finland, Iceland, Sweden, Norway) to the Nordic Council, implements the Council's recommendations and reports on results, while directing the work carried out in the targeted areas.

The NCM funded from 1997-1998 the project 'Risk Assessment for Marine Alien Species in the Nordic Area'. The background for this project was the recognition that some 3,000 to 4,000 species ranging from unicellular algae to fishes travel at any given time from one of the world's seas to another in the ballast tanks of ships. Alien aquatic organisms are known to cause considerable ecological and economic harm in the new areas and environments into which they are introduced. Here are several questions to be answered: Why did they arrive at the time they did rather than at another time? Will they become established? Why are some areas more open for introductions than others? Why do some of the alien organisms spread rapidly and become pests? Some of them have appeared to be beneficial- are they a potential source or threat?

The report from this project (Gollasch & Leppäkoski, 1999) provides a first attempt to assess the environmental risks related to alien invasions into the Nordic seas. Knowing that most of the recently introduced species resulted from global introductions by ships, port studies were undertaken. Ports considered were Nordhordland region (Norway), Stenungsund (Sweden) Klaipeda (Lithuania), Turku (Finland) and St. Petersburg (Russia). By knowing port details (*e.g.*, shipping patterns, traffic routes, occurrence of previously introduced species), a risk assessment was undertaken according to known criteria for species introductions, such as matching climate and salinity in the area of origin and in Nordic waters, if shipping routes into the areas of origin exist. General discussion criteria, such as matching climate and salinity, were used to compile a target list of species that had the potential to become introduced into Nordic waters.

The NCM has also established a Working Group on Introduced Species in the Nordic Countries whose report provided the first inter-Nordic compilation of information on terrestrial, marine and limnic introduced species (Weidema 2000).

6.8 GISP

The Global Invasive Species Programme (GISP) is coordinated by the Scientific Committee on Problems of the Environment (SCOPE), in collaboration with the World Conservation Union (IUCN), the Center for Agriculture and Biosciences International (CAB International) and the United Nations Environment Programme (UNEP). Initial financial support comes from the Global Environmental Facility (GEF), the United Nations Environment Program (UNEP), UNESCO, the Norwegian Government, NASA, ICSU, La Fondation Total, the Packard Foundation and the John D. and Catherine T. MacArthur Foundation. GISP is a component of DIVERSITAS, an international programme on biodiversity science.

Managed and natural ecosystems throughout the world are under siege by a growing number of harmful invasive species; disease organisms, agricultural weeds, destructive insects and others that threaten economic productivity, ecological stability and biodiversity. This problem is growing in severity and geographic extent as global trade and travel accelerate and as ecosystems are disrupted by fragmentation and by global climate change. In spite of the serious impacts of invasive species and organisms, national and international leaders remain poorly informed regarding the scope and gravity of the invasive species and organisms problem, and no effective strategy has been developed to enable appropriate solutions.

Under GISP, an international team of biologists, natural resource managers, economists, lawyers and policy makers are developing a global strategy to address the invasive species problem. The team's goal is to enable local, national, and multinational communities to draw on the best available tools to immediately improve pest prevention and control systems, and to identify priorities for the development of new tools needed to achieve longer-term success. Further, the program will contribute to the capacity of nation's to fulfil Article 8h of the Convention on Biological Diversity (see below) that prescribes that each contracting party should, as far as possible, "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species".

With these facts in mind, GISP aims to 1) draw together the best management approaches for pest prevention and control and make these readily accessible to all nations, and, 2) lay the groundwork for new tools in science, information management, education, and policy that must be developed through collaborative international action. In addition, GISP will assess the current status of the science dealing with invasive species. The results from GISP will be disseminated via published reports, international meetings, and, especially, through a new network of information exchange and training to be developed as part of this project.

In recent years there has been increased, and focused, attention on the magnitude and impact of biological invasions. It is clear that the ecological, economic, and human health consequences of invasive species and organisms are often staggering. GISP argues that the crisis must be addressed proactively in a holistic context that will provide a strong foundation for international protection from potentially alien invasive species.

GISP promotes the urgent importance of addressing this problem in a proactive, holistic context as:

Invasive species often lead to irreversible species extinctions. They are the second greatest threat to biodiversity globally (after habitat destruction) and the first cause of species extinctions in most island states;
Invasives can result in readily accounted-for enormous short-term economic losses within managed ecosystems (crops, in particular) and, hence, the heavy use of chemical, or physical control measures, often with environmentally damaging consequences with longer term economic losses;
Invasive species and organisms can also be disruptive of "free" ecosystem services often resulting in drastic, but poorly recognized, economic consequences;
Modern modes of international transport of goods, as well as the increased volume of international trade, pose a multitude of new threats for the introduction of harmful, invasive, alien species;
The quantitative information necessary to make predictions about the impacts of invasive species and organisms on ecosystems or of their potential trajectories of movement is lacking;
No broadly agreed-upon principles or guidelines exist for the introduction or exclusion of biological material internationally;
Very elaborate and costly constraints have been developed for controlling and monitoring the release of genetically-engineered organisms, to a lesser extent on potential biological control agents; yet, generally no such constraints exist on the introduction of alien species, even though the potential consequences may be extraordinarily high.

Despite over a century of organized work on pest prevention and control, the world community today lacks many of the essential technical tools to overcome this problem. Moreover, many of the tools that do exist are not fully accessible to all nations.

The scope and magnitude of the invasive species and organism problem is so great that a clear need exists for a global strategy that would complement, reinforce and network the national efforts in a holistic context. It is the realization of this global dimension that stimulated the Conference of the Parties of the Convention on Biodiversity to encourage the initiative to develop a global strategy for dealing with invasive species.

The Global Invasive Species Programme will:

Assemble the best information and approaches for prevention and management;
Disseminate information in the form of databases, manuals and capacity-building training programs to governments and communities;
Lay the groundwork for new tools in science, information management, education and policy that must be developed through collaborative international action.

6.9 Global conventions, and un agencies

The main global Conventions and the specialized UN agencies connected with the introduction of alien species are described below.

6.9.1 CBD

The Convention on Biological Diversity (CBD 1992) is a legally binding agreement opened for signature at the Earth Summit in Rio de Janeiro in June 1992. Over 150 States are parties to the CBD. The CBD is the most far-reaching international convention covering alien species. The CBD *inter alia* requires its Contracting Parties '*to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species*', and addresses the issue of liability for damage by such introductions in situations where insufficient or ineffective eradication measures have been taken after release. Further, as decided by the Conference of the Parties (COP), the precautionary and ecosystem approaches form the primary framework for action under the CBD. All the North Sea States are party to this convention.

As requested by the Fourth Meeting of the COP, the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) has been charged with developing principles and other guidance on the ecosystem approach. These deliberations build upon the Malawi principles, developed at the Workshop on the Ecosystem Approach held in Lilongwe in January 1998, as well as the experience and conclusions of a number of other workshops and initiatives that have been organized on this matter in recent years.

The ecosystem approach is a strategy for integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization that encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems.

At its first meeting, in December 1994, the COP decided to include conservation and sustainable use of marine and coastal biological diversity in its medium-term programme and requested the advice of SBSTTA. Thus, the Conference of the Parties initiated the dialogue on this theme, which led to the adoption, at its second meeting, of decision II/10 on the conservation and sustainable use of marine and coastal biological diversity. The latter decision, which was based on SBSTTA recommendation I/8, identifies physical alteration, destruction and degradation of habitats, pollution, invasion of alien species, and over-exploitation of marine and coastal living resources as the main threats to marine and coastal biological diversity. It also depicts five themes (integrated marine and coastal area management, sustainable use of marine and coastal living resources, marine and coastal protected areas, mariculture and alien species) as priority areas for action by Parties, other Governments and organizations and bodies.

The first meeting of the Group of Experts on Marine and Coastal Biological Diversity (March 1997 in Jakarta, Indonesia) provided the basis for the elaboration by SBSTTA of its recommendation II/2. At its fourth meeting, in May 1998, the COP adopted decision IV/5, containing a multi-year programme of work. Almost two years after its adoption by the COP, implementation of the work programme has progressed substantially and has produced tangible outputs. These include a review of instruments related to integrated marine and coastal area management, marine and coastal protected areas, and marine and coastal alien species and genotypes.
At the Fifth Meeting of the COP (Nairobi, Kenya from 15-26 May 2000), they took into account the important 'Interim Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species' in the context of activities aimed at implementing Article 8(h) of the Convention on Biological Diversity.

Within the topic Conservation and Sustainable Use of Marine and Coastal Biological Diversity, the COP has adopted a Programme of Work arising from Decision II/10 (Jakarta Mandate on Marine and Coastal Biological Diversity, CBD 1995), having considered recommendation III/2 of its Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA):

The aim of this programme of work is to assist the implementation of the Jakarta Mandate on Marine and Coastal Biological Diversity at the national, regional and global levels. It identifies key operational objectives and priority activities within the five key programme elements: integrated marine and coastal area management, marine and coastal living resources, marine and coastal protected areas, mariculture and alien species and genotypes. It also provides a general programme element to encompass the coordination role of the Secretariat, the collaborative linkages required and the effective use of experts. Within the above-mentioned, emphasis has been placed *inter alia* on:

1. Ecosystem approach

The ecosystem approach should be promoted at global, regional, national and local levels taking into account the report of the Malawi workshop (document UNEP/CBD/COP/4/Inf.9) and in accordance with decision IV/1 B.

Protected areas should be integrated into wider strategies for preventing adverse effects to marine and coastal ecosystems from external activities and take into consideration, *inter alia*, the provisions of Article 8 of the Convention.

2. Precautionary approach

The precautionary approach, as set out in decision II/10, annex II, paragraph 3 (a), should be used as a guidance for all activities affecting marine and coastal biological diversity, being also relevant to many other international agreements, *inter alia*, the United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks and the Code of Conduct for Responsible Fisheries of the Food and Agriculture Organization of the United Nations, the Washington Global Programme of Action for the Protection of the Marine Environment from Land-based Activities and regional agreements such as OSPAR.

The CBD Programme of Work includes:

Programme element 5. Alien species and genotypes

Operational objective 5.1: To achieve better understanding of the causes of the introduction of alien species and genotypes and the impact of such introductions on biological diversity.

Activities

To analyse and disseminate information, data and case-studies on the subject;
To develop collaboration with relevant organizations;
To ensure exchange of information and experience, using appropriate mechanisms.

With regard to appropriate ways and means, CBD will seek the assistance of relevant organizations through an informal inter-agency task force. In particular, the options will be investigated for collaboration with UNEP, the Scientific Committee on Problems of the Environment (SCOPE), the International Council for the Exploration of the Sea (ICES) and the World Conservation Union (IUCN) Invasive Species Specialist Group and the Global Invasive Species Programme in the development of a global strategy and action plan. In carrying out this work, it is expected that Parties or specialized institutions will second a specialist.

Operational objective 5.2: To identify gaps in existing or proposed legal instruments, guidelines and procedures to counteract the introduction of and the adverse effects exerted by alien species and genotypes which threaten ecosystems, habitats or species, paying particular attention to transboundary effects; and to collect information on national and international actions to address these problems, with a view to prepare for the development of a scientifically-based global strategy for dealing with the prevention, control and eradication of those alien species which threaten marine and coastal ecosystems, habitats and species.

Activities

To request views and information from Parties, countries and other bodies;
To analyse the information for the purpose of identifying gaps in legal instruments, guidelines and procedures;
To evaluate the information on the effectiveness of efforts to prevent the introduction of, and to control or eradicate, those alien species which may threaten ecosystems, habitats or species;
To identify means to support capacity-building in developing countries to strengthen their ability to conduct work related to alien species.

With regard to appropriate ways and means, CBD will carry these activities out in collaboration with Parties, countries and other relevant bodies and in cooperation with UNEP (UN Environment Programme), IOC and IMO. It is proposed that a conference with global participation be held and that a Party or specialized institution will be able to host the conference. It is anticipated that the peer review process will be followed for the output of this programme activity.

Operational objective 5.3: To establish an "incident list" on introductions of alien species and genotypes through the national reporting process or any other appropriate means.

Activities

To distil references of incidents from the national reports and other appropriate sources;
To make the information available through the clearing-house mechanism or other appropriate mechanisms.

6.9.2 UNCLOS

The 1982 UN Convention on the Law of the Sea (UNCLOS, 1982) is a comprehensive international agreement establishing legal principles for navigation, conservation and use of marine resources, marine environmental protection and other human conduct relating to the oceans. UNCLOS was opened for signature in 1982 but did not come into force until 16 November 1994 due to controversy involving Part XI dealing with deep seabed mining. Over 100 States, including all the North Sea States, have now ratified or acceded to the 1982 UNCLOS.

Article 22.2 of the CBD provides that it shall be implemented consistent with rights and obligations under 'the law of the sea'. Although Article 22.2 does not refer specifically to the 1982 UNCLOS, it is this 1982 Convention that is generally understood to embody the law of the sea.

Within their exclusive economic zones (EEZs), which can extend up to 200 nautical miles from their coastline, coastal States have exclusive jurisdictional rights as defined in UNCLOS over all living resources. These rights are counterbalanced by obligations to conserve these resources.

Article 196 of UNCLOS provides that States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies or introduction of alien or new species shall be prevented, reduced or controlled.

6.9.3FAO

The Parties (including Norway) to the Food and Agriculture Organization (FAO) of the UN adopted the FAO 'Code of Conduct for Responsible Fisheries' (FAO 1995). This Code provides principles and standards applicable to the conservation, management and development of all fisheries. It also covers the capture, processing and trade of fish and fishery products, fishing operations, aquaculture, fisheries research and the integration of fisheries into coastal area management.

The FAO Code of Conduct prescribes a precautionary approach to all human activities concerning living resources in all aquatic systems. Under Article 6 **General Principles** the following applies:
6.5 States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking account of the best scientific evidence available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment.

Under Article 9 Aquaculture Development, regarding the introductions and transfers of alien organisms, particular note should be taken inter alia of the following:

Article 9.1 'Responsible development of aquaculture including culture based fisheries, in areas under national jurisdiction':
9.1.2 States should promote responsible development and management of aquaculture, including an advance evaluation of the effects of aquaculture development on genetic diversity and ecosystem integrity, based on the best available scientific information.

Article 9.2 'Responsible development of aquaculture including culture based fisheries within transboundary aquatic ecosystems':
9.2.2 States should, with due respect to their neighbouring States, and in accordance with international law, ensure responsible choice of species, siting and management of aquaculture activities which could affect transboundary aquatic ecosystems.
9.2.3 States should consult with their neighbouring States, as appropriate, before introducing non-indigenous species into transboundary aquatic ecosystems.
Article 9.3 'Use of aquatic genetic resources for the purposes of aquaculture including culture-based fisheries':
9.3.1 States should conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management. In particular, efforts should be undertaken to minimize the harmful effects of introducing non-native species or genetically altered stocks used for aquaculture including culture-based fisheries into waters, especially where there is a significant potential for the spread of such non-native species or genetically altered stocks into waters under the jurisdiction of other States as well as waters under the jurisdiction of the State of origin. States should, whenever possible, promote steps to minimize adverse genetic, disease and other effects of escaped farmed fish on wild stocks.
9.3.2 States should cooperate in the elaboration, adoption and implementation of international codes of practice and procedures for introductions and transfers of aquatic organisms.
9.3.3 States should, in order to minimize risks of disease transfer and other adverse effects on wild and cultured stocks, encourage adoption of appropriate practices in the genetic improvement of broodstocks, the introduction of non-native species, and in the production, sale and transport of eggs, larvae or fry, broodstock or other live materials. States should facilitate the preparation and implementation of appropriate national codes of practice and procedures to this effect.
9.3.4 States should promote the use of appropriate procedures for the selection of broodstock and the production of eggs, larvae and fry.
9.3.5 States should, where appropriate, promote research and, when feasible, the development of culture techniques for endangered species to protect, rehabilitate and enhance their stocks, taking into account the critical need to conserve genetic diversity of endangered species.

FAO has produced a number of Technical Guidelines (e.g. FAO 1996a, 1996b, 1997a, 1997b) related to the application of the Precautionary and the issue of alien species.

FAO has a number of regional fisheries-related commissions, with the 'European Inland Fisheries Advisory Commission' (EIFAC) being the only one of direct relevance to the North Sea area. EIFAC has served since 1957 as the only international forum for collaboration and information exchange among all European countries and for advice to member Governments on the management of inland fisheries and aquaculture.

During the Eighteenth Session of EIFAC held in Rome, 1994, the Working Party on Introductions held an ad hoc meeting to discuss i) the status of and proposed changes to the ICES/EIFAC Code of Practice on Introductions and ii) the need for a user manual or guidelines to assist in the implementation of the principles of the Code in developing countries and rural areas. The Working Party recognized the need for the guidelines and welcomed the worldwide interest in utilizing and modifying the ICES/EIFAC Codes. Furthermore, it was recommended that EIFAC should review the guidelines being developed. As a result, the EIFAC Secretariat presented the draft of the guidelines (EIFAC/XIX/96/Inf.8: Framework for the Responsible Use of Introduced Species) for consideration and review by EIFAC at its Nineteenth Session, held in

Dublin (Ireland) in June 1996 (EIFAC 1996). As yet, no steps have been taken to harmonize the EIFAC and ICES Codes, although this has been proposed.

FAO established a ‘Database on Introductions of Aquatic Species’ (DIAS) in the early 1980's. It considered primarily only freshwater species of fish and formed the basis for the 1988 FAO Fisheries Technical Paper no. 294. The database has been expanded to include additional taxa, such as molluscs and crustaceans, and marine species. In the mid 1990's a questionnaire was sent to national experts to gather additional information on introductions and transfers of aquatic species in their countries. The DIAS database, which now contains about 3,150 records, can be queried through the Search Form. Users aware of other introductions of aquatic species not already included in the database or that have additional information on the records in the database are requested to fill in the Input Form. Periodically this information is validated and added to the database.

The database includes records of species introduced or transferred from one country to another and does not consider movements of species inside the same country. Coverage of accidental introductions of organisms (e.g., through ship ballast waters) is not complete and records on this topic have been generally entered only when important impacts on fisheries or on the environment have been caused.

Since 1992, a FAO/IOC (Intergovernmental Oceanographic Commission of UNESCO) Intergovernmental Panel on Harmful Algal Blooms (IPHAB, later with membership of ICES) has recognized and begun to address the problems associated with the impacts of phytoplankton blooms that negatively affect the environment and its living resources (e.g. fish and fisheries), and human health and recreational amenities. Amongst these problems is the transport of phytoplankton causing harmful and toxic blooms via ballast water. Some of the most threatening problems are posed by the introductions of alien toxic species (e.g. species of Alexandrium, Gymnodinium, Gyrodinium).

6.9.4 IMO

The International Maritime Organization (IMO), is a UN specialized agency created to provide the machinery for cooperation in establishing technical regulations and practices in international shipping, to encourage the adoption of the highest possible standards for maritime safety and navigation, and to discourage discriminatory and restrictive practices in international trade and unfair practices by shipping concerns. The current name of the organization was adopted in May 1982. A Marine Environment Protection Committee (MEPC) was established in 1973.

The potential environmental damage related to ballast water was recognized by Resolution 18 of the 1973 ‘International Conference on Marine Pollution’. This conference provided the basis for the establishment of the MARPOL Convention (to which all the North Sea States are now party), and Resolution 18 of the above-mentioned conference called on the World Health Organization (WHO) to establish collaboration with the IMO to investigate the degree to which ballast water could act as a vector for the transmission of diseases such as cholera.

The MEPC adopted guidelines by resolution in 1991 and in 1993, and these were adopted by the IMO Assembly under Resolution A.774(18) entitles ‘International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships Ballast Water and Sediment Discharges’. In 1997, the IMO Assembly adopted as Resolution A.868(20) the voluntary IMO ‘Guidelines for the Control and Management of Ship’s Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens’ (IMO 1997).

Resolution A.868(20) provides a useful global instrument for ballast water management purposes, including informing ships on areas where ballast water uptake should be avoided due to the presence of harmful algal blooms and unwanted contaminants, precautionary procedures when taking in ballast water in shallow areas, ballasting with freshwater, discharging ballast water and sediments to on-shore facilities when available, and the discharge of ballast water at sea. It recommends inter alia an exchange of ballast water in open oceans as far as possible away from the coast. This procedure is believed to be the most reliable method to minimize the risk of transfer of unwanted organisms. Compared with coastal waters, ocean waters contain fewer species and individuals and these are less likely to be able to survive in coastal and estuarine zones and vice versa.

The MEPC of IMO has been requested to develop legally binding provisions ‘Draft Regulations and Code for the Control and Management of Ship’s Ballast Water and Sediments to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens’ in the form of a new Annex to MARPOL 73/78. Although a draft document may be submitted to IMO in 2000, it is unlikely that the finalized version will be adopted by IMO before 2002 owing to the mandatory nature of this instrument.

7 Risk, monitoring, control and preventative measures

7.1 Risk and Monitoring

Areas where previous or potential further introductions are likely to occur can be identified as ‘hot spots’. Gollasch & Leppäkoski (1999) have summarized ‘hot spots’ as having the following general characteristics for the establishment and spread of the particular ‘new’ species in the recipient area:

Matching climate, salinity and habitat structure;

'Ecological Niche' (microhabitat) available;
Absence of predators, grazers and parasites;
Strong anthropogenic influence (*e.g.* pollution, power plants, aquaculture, artificial hard substrates;
Low number of native species;
Embayments, estuaries, harbours and other areas, that are frequently more conducive to establishment than habitats of the outer coast.

From this, it follows that risk assessments should be carried out taking into account the statistics related to the various likely vectors (*e.g.* shipping, aquaculture), habitat characteristics, plant and animal community structure, and the potential for secondary introductions.

Several methods have been developed to identify and quantify the risks of future species introductions and estimate the probability that the introduced species will:

Survive in the new environment;
Establish a self-reproducing population;
Cause harm.

The risk assessment may include such elements as a) establishing a 'black list' of target species representing high risk compiled by scientists and authorities in the recipient country and relevant nearby countries, b) matching environmental conditions (*e.g.* temperature, salinity, climate, appropriate habitat characteristics), c) availability of suitable ecological niches, and d) compiling case histories for the well-known alien species in the overall area (c.f. Gollasch & Leppäkoski 1999).

Other key activities are establishing appropriate monitoring programmes with databases (both for metadata and more traditional quantitative data), and encouraging various networks to interact at the national and international levels.

7.2 Control and Prevention

There are two basic approaches to dealing with alien organisms: stop them from invading in the first place, or eliminate those organisms that have actually been introduced. Since it is well known that eradication of an introduced species once it has become established in the marine environment will be very expensive, or even impossible, efforts to prevent introductions must be given high priority.

7.2.1 Voluntary Measures

One way to minimize the number of harmful introductions is to implement existing voluntary guidelines for aquaculture species, including genetically modified organisms (ICES Code of Practice), and ballast water management (IMO Guidelines). However, the IMO Guidelines do not provide for a complete solution to introductions associated with shipping. Research and development of technical solutions for ballast water management are urgently needed, as are environmentally acceptable methods for the control of fouling now that TBT-based antifoulants (*e.g.* for treating the hulls of ships) have been banned in many countries.

According to an OSPAR IMPACT report (OSPAR 1997) only one out of 12 member countries has some kind of practices in place to minimize the risk of unintentional introductions via ship's ballast water, and for that country under 25% of the ports known to receive ballast water have either local policies or require compliance with the IMO Guidelines. Regarding minimizing the risk of negative effects of introductions via aquaculture, only six countries reported that the ICES Code of Practice is applied while two countries reported that although the Code is applicable the extent to which it is actually used is uncertain.

7.2.2 Mandatory Measures

Under this heading can be classed the relevant international agreements and legally binding national and international directives.

Although several of the international agreements described under Section 6 call for the implementation of measures to eradicate alien species once they have been registered in a country, or at least control further spread within the country, it is clear that in very few countries have such prescriptive measures been either seriously or successfully applied.

Unfortunately, it is also clear that neither the mandatory nor the voluntary measures are actually working to adequately restrict the introductions and transfers of alien species as seen from the exponential rate of increase of these species in European waters (c.f. Gollasch & Leppäkoski 1999). De Klemm (1996), in reporting on the national legislation addressing alien species among the Parties to the Bern Convention (including Norway and the other North Sea States)), has drawn attention to substantial differences between countries. In this report, it was *inter alia* emphasized that generally the legislation on alien species is incomplete and insufficient to prevent and/or manage introductions, and that marine introductions are largely ignored.

7.3 Conclusions

Because a substantial "pool" of alien species is already present in European waters, **effective** measures to limit unintentional and unwanted introductions within Europe are needed. In particular, the process of secondary introductions by human means between European countries accounts for the greatest further dispersal of species within Europe. Thus, measures aimed at controlling the intra-regional movement of species are important to prevent further unintentional dispersal. Secondary introductions that are mediated by natural dispersal cannot, however, be stopped by regulations. Much of the shipping that discharges ballast in European waters, *i.e.* coastal and close continent traffic, will not be subject to the new IMO regulations and hence there is still a risk of secondary introduction of species from established populations between European ports. Thus, the development of effective monitoring programmes are necessary to aid the early detection and determination of the status of alien species, which is essential for taking measures of combat or control.

The problems associated with the introductions and transfers of alien species are likely to increase, due to expanding regional and global trade agreements. Such free-trade is *de facto* encouraging increased transport of alien species via existing vectors. Further, climate warming favours the establishment of more cosmopolitan species across wider geographic areas. Thus, **more effective steps** must be taken to prevent introductions and transfers of alien species. In order to support the practical operations drawn attention to above, it is necessary to fund and encourage focused research and development (R&D).

8 Overview of alien marine organisms in norwegian waters and impacts

In 1997, an overview was provided of the probably established alien species in the whole OSPAR Convention area, as reported to OSPAR IMPACT (OSPAR 1997). According to the OSPAR IMPACT data, which were primarily obtained from questionnaires returned by the Contracting Parties, a total of 109 'probably established' alien species were reported from within the whole OSPAR Convention area (i.e. northeast Atlantic and North Sea), not counting cryptogenic species and incidental species. From the assembled OSPAR information, the data for Norway indicated that:

Probably established alien species = 31, of which 14 were plants (phytoplankton, macroalgae, angiosperms) and 17 were animals (invertebrates, chordates/tunicates, vertebrates);
Cryptogenic species (i.e. of uncertain origin) = 4;
Incidental species (i.e. not established) = 1;
Total for Norway = 36.

As the IMPACT report (OSPAR 1997) notes, the collected data were not subjected to an extensive verification process.

The results of the current study on marine alien species in Norwegian waters (as defined in **Figure 1**) are summarized in **Table 1**. This table and the remainder of Section 8 provide an overview of the information available from the current study on Norwegian alien marine species as outlined in the Materials & Methods. It is emphasized that this overview is **not intended to be definitive**, as this and similar studies generally overlook the alien species that have become established longest, *e.g.* a substantial component of the cryptogenic species. Of the approximately 4000 species of macrobenthos flora and fauna found in Norwegian waters, 211 species have an unknown geographical distribution in the world (Brattegard & Holthe 1997), and may qualify as 'cryptogenic'. Thus, there will be obvious uncertainty as to the extent that cryptogenic species should be included with those that clearly are alien. This report aims, however, to **illustrate the nature of the continuing and, in many cases, escalating problems** concerning alien species in Norway in particular and Europe in general. Further, it is intended to provide a starting point upon which a long-term inventory of alien species can be further built.

The following sections on Plants, Invertebrates, Vertebrates, and Parasites and Diseases, draw attention to certain aspects of the particular alien species with regard to their introductions and transfer in Norway, and their ecological and socio-economic impacts. Where specific information may not yet be available from Norwegian sources, attention is drawn to knowledge arising from other geographic areas.

The reader interested in further information on the subject of macroalgal introductions, particularly in Europe is referred to Rueness (1989) and Ribera & Boudouresque (1995), and for phytoplankton introductions to Hallegraef & Bolch (1992), Boalch (1994) and Smayda (1994). On the subject of fish introductions the reader is referred to Baltz (1991) and Youngson *et al.* (1998).

8.1 Plants

This section is subdivided into macrophytes and phytoplankton.

Many macrophytes occur as alien species. In surrounding areas of Europe, they have been introduced either intentionally (as the 'target' species for the legal granting of permits or unintentionally as 'stowaways' on 'target' species such as bivalves) via aquaculture ('farming'), or unintentionally via ships (*e.g.* fouling organisms on hulls and as spores in ballast water and sediments). Because of the ability of some species to be transferred further by secondary dispersal within an area by natural drifting on currents, alien macrophytes can spread quickly within a new region, given that the recipient environment (*e.g.* substrate type, salinity, temperature and wave action) is suitable (i.e. 'matches') for establishment.

A significant number of phytoplankton species have been introduced as alien species, mainly via ballast water from ships and via aquaculture, *e.g.* as 'stowaways' in the bivalve molluscs that are intentionally being transported from one area to another.

8.1.1 Macroalgae

Table 1 records a count (marked by ✓ in the table) of about <u>12</u> macroalgae species or sibling species that may be considered to be alien in Norwegian waters. Further information on some of these is provided below. The reader's attention is not only drawn to references provided in the text of this section, but also to references in Table 1.

The green alga *Codium fragile* ssp. *tomentosoides*, was first recorded from Norway in 1946 (Silva 1957), and during the following 30 years it had spread all along the coast from the east Skagerrak (Østfold) to North Troms (Rueness 1977). It probably eliminated the native species *Codium vermilara* in Norway (Silva 1957). *C. fragile* ssp. *scandinavicum* is probably a recent immigrant to Europe, first recorded in Norway in 1929. *C. fragile* ssp. *atlanticum*, probably introduced into Europe in historical times (Silva 1955), has been found in Norway since at least 1895 (Silva 1957). It is considered to have originated in the Pacific Ocean around Japan, and Silva (1955) considered it was introduced to Europe from there. Its ability to form rafts and float helps its secondary dispersal. It is an opportunist perennial species exhibiting vegetative propagation. It can easily be transferred with movements of shellfish. Lack of grazers has probably contributed to its success. In Europe it also found in the UK and Ireland. The effects of this species in its introduced range on the environment, including other species, and commercial interests are not described. However, it is used for human consumption in the Far East.

The first record of the brown alga *Colpomenia peregrina* was in 1933 outside Bergen (Braarud 1950; Grenager, 1950). It has since been reported from many areas of the Norwegian west coast. In the early 1970s it was found as far north as the area of Ålesund, and on the island of Bjørøya off Namsos, north of Trondheim (Wiik & Nerland 1972). In the 1980s it had also spread to the Skagerrak coast, where it had not occurred previously (Rueness *et al.* 1990). Warm winters appear to favour the abundance and dispersal of this species in Norway. The species was first introduced into Europe via France from the Pacific coast of North America with juvenile American oysters *Crassostrea virginica*. There was natural dispersal from France to Britain and many other North Sea countries, but it may also have been introduced unintentionally with commercial oysters from France. *C. peregrina* now has a world-wide distribution in temperate waters (South & Tittley 1986)• although there is debate as to whether *C. peregrina* and *C. sinuosa* are separate species or variants of a single species• and in Europe is found from Iberia to Norway. The main reason for its success appears to be the lack of species that feed on it, as well as its reproduction early in the season and rapid growth rate. The species appears to have few negative effects on other species and the environment. However, when growing attached to oysters it may float away with the oyster when the air-filled thalli grow large enough, hence its name of oyster thief.

Fucus evanescens was introduced to the Oslofjord, Norway, about 100 years ago (Bokn & Lein 1978) and has become a quite common plant in that area, especially in harbours and nutrient enriched waters such as the inner part of the Oslofjord. This connection with human caused eutrophication is supported from Sweden where this alien species also seems to have increased in importance in nutrient enriched waters, *e.g.* Gothenburg archipelago (Munro *et al.* 1990). The species has also been registered in the Kiel area of Germany.

The Japanese large brown alga or japweed (*Sargassum muticum*) was first recorded in Europe in the early 1970s. This species is now found as an established and permanent member of the algal flora along the coasts of Portugal, the Atlantic coast of Spain, the Atlantic and Mediterranean coasts of France, United Kingdom, Netherlands, North Sea coasts of Germany, North Sea and Kattegat coasts of Denmark, the west coast of Sweden and Norway. This alga was first found as drift plants in southern Norway in 1984, and in 1985 the first attached plants were found (Rueness 1989). The lower lethal temperature for the species is ca. -1 ºC while growth and reproduction appears to be limited by a lower temperature of ca. 12 degrees C, which led Rueness (1985, 1990) to predict that the species would not establish itself northwards in Norway beyond the Trøndelag coast. The species has now spread along the Norwegian Skagerrak coast, as well as westwards and northwards along the coast to Hordaland, reaching sizes of over 2 m (Rueness 1989). Expansion rates have been recorded of 100s of km per year. The species can grow in a wide range of environments from wave protected to wave hardy, reaching from the littoral down to ca. 10 m depth. This alga can grow on several types of substrate, e.g. small stones, shell debris, other plants, and ropes. It has a range of opportunistic features (e.g. fast growth, high reproductive rate and ability to spread itself), being particularly able to dominate (i.e. out-compete and exclude) the native alga flora in bays, marinas and similar recreational areas (e.g. replacement of *Zostera marina* and *Laminaria saccharina* on the French Atlantic coast), and can become a nuisance factor with clogging of outboard motors and accumulation of substantial amounts of detached and drifting rotting-fronds etc. in autumn. The large and long canopies hinder light penetration and water circulation, and the plants may cause problems with operating diverse fisheries gear. On the positive side, this species attracts a rich epiphytic fauna (ca. 150 species have been registered in a study in England) including crustaceans, snails, and juvenile fish.

The tetrasporophyte generation of the red alga *Bonnemaisonia hamifera* was first recorded in Norway 1902 and now occurs all along the Norwegian coast (Rueness 1977.). The gametophytes have been encountered only sporadically from the west and southwest coasts, the females first seen in the mid 1960s and the males some years later (see Breeman *et al.* 1988). The exact method of introduction of this species to Europe is unknown, but it is thought that it may have been introduced unintentionally with shellfish from Japan. In Europe it is found from

Norway to the Azores including Ireland. The success of *B. hamifera* is probably due to its lack of grazers due to brominated bioactive compounds in vesicular cells, rapid growth rate, and its opportunistic qualities. The effects (either beneficial or detrimental) of this species on the environment and on commercial interests are unknown.

The red alga *Dassya baillouviana* was first recorded in south Norway in 1966, and was found during the 1970s at some new localities along the southern coast (Røsjorde 1973). It is now found along the Skagerrak coast from Oslofjord to Vestfold. Its means of introduction to northern Europe is uncertain. The effects of this species in its introduced range on the environment, including other species, and commercial interests are not described.

A novel species was reported for Norwegian waters in 1999, a red alga *Dasysiphonia* sp. (Lein 1999). It was probably accidentally transported from the North Pacific Ocean (via ballast water or hull fouling) and was first observed in the Netherlands in 1994 (ICES WGITMO Report 1999). The effects of this species in its introduced range on the environment, including other species, and commercial interests are not described.

The red alga *Gracilaria gracilis* has been known in Norway since the mid-1930sw. It has only recently been harvested from naturally occurring stocks in several countries, but because of over-exploitation and the need for a constant and reliable supply, cultivation has become an important source of raw material globally. The cultivation of the agarophytic red alga *Gracilaria* has become of major importance in areas such as Asia, South America and southern Africa. *Gracilaria* is used as a source of food for both humans and shellfish (e.g. abalone). It is also used as a raw material for the extraction of the phycocolloid agar. The first source of agar was from *Gelidium* in Japan, but *Gracilaria* now plays a major role in the production of agar. The most important use of agar is in bacteriological and fungal culture work. Agar is also used in food making (e.g. ice-cream, bakery and confectionary products), as glue, and as a cleaning and polishing medium.

Polysiphonia harveyi was first described from Connecticut in 1848 and is believed to be conspecific with *P. insiduosa* described from Brittany in 1867. The taxonomy and nomenclature is further complicated by the fact that some entities described from Japan (e.g. *P. japonica*) belong to the same species (McIvor *et al.* 2000). The first confirmed collection of P. harveyi from the British Isles was in 1908. It is regarded as an alien in the northeast North Atlantic where it seems to be spreading rapidly. *P. harveyi* has now been recorded from Norway (ca. 1985, Jan Rueness pers. comm.) and is now common in the Oslofjord and Skagerrak (Rueness 1998). The source of the introduction remains unknown. It possibly came to Europe from Japan as an associated unintentional introduction with Pacific oysters. It can also probably spread through secondary dispersal through drifting with larger seaweeds as an epiphyte. The species is an opportunist, with a rapid growth rate and high tolerance of temperature changes. It can become very abundant and thus has the ability to displace native species. It is a fouling agent and can become abundant in marinas on artificial structures, although its small size precludes it from being a big problem (c.f. *S. muticum*).

Sphaerococcus coronopifolius was noted from Norwegian waters in 1994 by Karlsson (1995). This alien species was found for the first time in Sweden in the Koster islands area (northern part of the Swedish west coast) in 1990 (Karlsson *et al.* 1992), so its further spread to Norway was expected. The effects of this species in its introduced range on the environment, including other species, and commercial interests are not described.

None of the above-mentioned species is noted by Gulliksen *et al.* (1999) as being found in Svalbard (including Bear Island) and Jan Mayen waters. Thus, it appears that alien macrophyte species have not as yet been introduced into the Svalbard and Jan Mayen area.

8.1.2 Phytoplankton

In considering the specific situation with regard to alien phytoplankton species in Norway, it is also important to note the general European background against which the occurrence and further distribution of alien species in Norway should be placed in perspective.

It is important to emphasize the general difficulty in proving that the occurrence of alien phytoplankton species in an area has occurred from a particular introduction vector (i.e. human assisted introductions and transfers) due to their small size and related sampling difficulties in time and space, as well as the ease in which further dispersal occurs by natural means. Phytoplankton species can display different characteristics in different environments, thereby making it very difficult to differentiate between native, introduced and newly discovered species (Weidema 2000). However, it is highly probable that many of the alien species have been introduced into the European area by shipping activities involving ballast water discharge, and to a lesser extent by aquaculture activities. Once introduced into the European area in general, and the North Sea in particular, there is a further likelihood of secondary distribution of alien phytoplankton cells by transport with water currents. The Norwegian coastal current, starting in the Skagerrak with water exiting from the Baltic Sea and added to by outflowing water from the Norwegian fjords, acts as a means of transport of plankton with the current along the coast towards northern Norway. The ability of many phytoplankton species to produce 'resting' cells, e.g. in winter, allows a means for rapid blooms to occur when optimal environmental conditions are again presented.

It is also necessary to underline that there have been several misidentifications and some confusion regarding the identity of alien species of phytoplankton in Norwegian waters, and that there has been a tendency for such problems to be perpetuated in the literature (Grethe R. Hasle, Jahn Throndsen, *pers. comm.*). A number of these are drawn attention to below.
Several non-indigenous plankton species have been reported in the North Sea since about 1900 (Carlton 1985, 1989; Hallegraef *et al.* 1990). Some of the more notable examples of relevance to the North Sea and Norwegian waters are drawn attention to below.

The composition, both qualitative and quantitative, of inorganic nutrients is factors that have an impact on the taxonomic composition of the phytoplankton present in the environment. Likewise, the toxin production by a given phytoplankton species may also be affected by the nutrient composition in the water. Most healthy marine phytoplankton cells exhibit a nitrogen to phosphorus ratio of 16:1 atoms (Redfield ratio) under nutrient balanced conditions. Under nutrient limiting conditions the cells present become stressed, inducing a higher production of metabolites including toxins etc. In most European marine waters the ratios and concentrations of nitrogen (N) and phosphorus (P) in relation to silica (Si) have increased due to the high input of N and P from anthropogenic sources, e.g. pollution. Toxic algal blooms of non-silica requiring species, such as prymnesiophytes, dinoflagellates and blue-green algae have also increased. Outbreaks of harmful algal blooms have resulted in serious losses regarding fish industry, human health, and recreational resources. Thus, increased pollution and eutrophication may increase the likelihood that potentially harmful phytoplankton species, both indigenous and alien, will produce toxins.

Table 1 records a count (marked by ✓ in the table) of about 10 phytoplankton species that may be considered as alien to Norwegian waters. These are further described below. The reader's attention is not only drawn to references provided in the text of this section, but also to references in Table 1.

Heterokontophyta

The diatom *Coscinodiscus wailesii* was first described in 1931 from Departure Bay near Nanaimo, British Columbia, Canada. It was first noticed, due to its mucus production, in Europe 'off the coast of south-west England' (i.e. Plymouth) in 1977 and misidentified as *C. nobilis* (Boalch & Harbour 1977), a species that had been described from the Java Sea and later also found in the Indo-Pacific Ocean. It is probably correct to describe the area of origin of *C. wailesii* as the Pacific Ocean but it is probably incorrect to extend this to the Indian Ocean (Grethe R. Hasle *pers comm.*). It is likely that *C. wailesii* was introduced to England via ballast water discharge. However, it is likely that introductions elsewhere in the North Sea have taken place by secondary dispersal by the current system, and the import and transfers of non-indigenous oysters (e.g. Rincé & Paulmier 1986). The first record of *C. wailesii* from Norwegian waters is from 1979 (Hasle 1983, 1990). It forms dense blooms and can account for ca. 90% of the total phytoplankton biomass, and produces copious mucilage that aggregates and may sink to the bottom and coat the seabed. The extensive mucus produced by this species has been known to cause clogging of fishing nets and aquaculture cages. The decaying bloom can cause anoxic conditions. *C. wailesii* is not easily grazed by zooplankton due to its large size.

Odontella (=*Biddulphia*) *sinensis* was considered an immigrant to the North Sea in 1903 (Gran 1908; Ostenfeld 1908), and has become widely distributed in the North Atlantic, the North Sea and Skagerrak, and the Baltic Sea (Boalch & Harbour 1977; Leppäkoski 1984; Rincé & Paulmier 1986). It has become abundant in Norwegian coastal waters (see for example Lange *et al.* 1992 for the Skagerrak). The species appears originally to be native to the China Sea and Indo-Pacific area. Its ecological and economic impacts are not clear. This species is almost certainly a true alien species in Norway.

The spread of the diatoms *Thalassiosira tealata* and *T. punctigera* into the North Sea have been well-documented (e.g. Hasle 1983, 1990; Rincé & Paulmier 1986). Hasle (1983) showed that eight taxa should be reduced to synonymy with *T. punctigera* (Castr.) comb. nov., thereby underlining the wide distribution of this diatom species in the North Pacific and South Atlantic oceans, besides its more recent occurrences in the North Sea and Skagerrak. *T. tealata* was recorded in Norway in 1968, and *C. wailesii* and *T. punctigera* have been recorded in Norwegian waters in the Skagerrak and Oslofjord since 1979 and are now common (Hassle 1983, 1990). It is clear that *T. tealata* has been present in the North Sea long before it was first described in the area, as Hasle (*pers comm.*) has noted that it was present in samples collected in 1950 from Blakeney, England. Thus it appears that *T. punctigera* can be considered a true alien species in Norway, whereas *T. tealata* is probably best considered as a cryptogenic species in Norway that may possibly be an alien. The ecological and economic impacts of these species are not described in the literature.

Dinophyta

In April–May 1998 and again at the same time of the year in 2000, an algal bloom of *Chattonella* sp. cf. *C. verruculosa*—a species previously known from Japan—occurred in the Skagerrak and northern Kattegat waters and adjacent parts of the North Sea. Fish kills as a result of this species have been reported from the Swedish west coast, the Norwegian south and southwest coasts and the Danish coasts. This is probably the first record of the species in Europe, and it is highly likely that it was introduced via ballast water discharge. In Norway, it has been registered from the border with Sweden to Stavanger, and has had effects on fish farms in the Farsund and Flekkefjord areas where a total of 350 tonnes of large sized salmon died. Small sized salmon apparently survive much better. Other ecological effects have not been reported. In Danish waters some wild fish have been killed. In Japan the sea is often discoloured. The actual toxicity of the class is poorly known. The mortality of fish is apparently caused by the phytoplankton cells easily clogging the gills of the affected individuals. Raphidophyceans contain slime that is exuded when the algae are on the gills.

The story of *Heterosigma akashiwo* is a 'study in confusion and suppositions' as emphasized by Throndsen (1996). This species was mistakenly identified as *Olisthodiscus luteus* from Oslofjorden in 1964 (Braarud & Nygaard 1967; Throndsen 1969), resulting in disinformation (c.f. Smayda 1990) and confusion (c.f. Throndsen 1990, who commented on the misidentification) that have frequently been perpetuated in the literature regarding the phytoplankton and alien species in Norwegian waters. The 'true' *Olisthodiscus luteus* (originally described from England in 1937) was only first registered in Norway in 1999 (Grimsrud & Throndsen 2000) at Drøbak in the Oslofjord, where it was one of the most common hetertroph flagellates sampled from the surface layer of marine bottom sediments. *O. luteus* has also been found in the Danish Wadden Sea and has been reported from Japan.

Alexandrium tamarensis is a possible alien species in Norwegian waters as its area of origin is uncertain (i.e. cryptogenic). Like the rest of its genus, this produces paralytic toxins that can be fatal for a number of biota, including humans. The toxin if passed on to man occurs via contaminated shellfish irrespective of the type of shellfish, cooked or uncooked. It has caused outbreaks of Paralytic Shellfish Poisoning (PSP) on several occasions (e.g. blue mussels) in Norway and caused human health problems as well as temporary bans by the authorities on eating shellfish from the contaminated areas of the coast.

In 1966, a massive dinoflagellate bloom, accompanied by discolouration of the sea and mortality of caged sea trout, occurred along the Skagerrak coastal of Norway (Braarud & Heimdal 1970), with the causative agent being identified as *Gyrodinium aureolum* Hulbert. This species has become one of the most commonly reported blooming dunoflagellates in northern temperate waters (Hansen *et al.* 2000). Much taxonomic confusion has been connected with this species (e.g. Partensky *et al.* 1988), although it became generally accepted that the European '*G. aureolum*' is very closely related to or even synonymous with the earlier described *Gymnodinium mikimotoi* (=*Gymnodinium nagasakiense*) (Partensky *et al.* 1988). Hansen *et al.* (2000)—based on analyses involving light microscopy, nuclear-encoded genetic sequencing and pigment isolates of five geographically separate isolates of G. mikimotoi—concluded that the European isolates, formerly identified as *Gyrodinium aureolum*, *Gyrodinium* c.f. *aureolum*, or *Gymnodinium* c.f. *nagasakiense*, are conspecific with the Japanese *Gymnodinium* mikimotoi. As a result of this, and comparing the nuclear sequence from material originating from what is believed to be close to the type locality of *Gyrodinium aureolum* (Hulbert) with *Gymnodinium fuscum* (the type species of *Gymnodinium*), Hansen *et al.* (2000) have renamed *Gyrodinium aureolum* (Hulbert) *Gymnodinium aureolum* (Hulbert) G. Hansen, comb. nov. Accordingly, the species will be referred to as this in the current report. It has bloomed on numerous occasions since 1966 in Norway and has been recorded from the border with Sweden to Sør Trondelag causing the same effects, the most serious occasion being in 1981 when it caused the greatest loss to Norwegian fish farmers as a result of harmful algal blooms. This alga is most frequently registered in Norwegian waters from August to September.

The dinoflagellate *Prorocentrum minimum* was first recorded in the North Sea in 1976 (Smayda 1990). This species has a wide environmental tolerance being found in brackish as well as fully marine water. It was first registered in northern Europe during a massive bloom in the outer Oslofjord in 1979. It has become annually common in the summer in near-shore areas of Østfold within the influence of the river Glomma, where it discolours the water yellow-brown and reduces light attenuation in the water. A number of reports connect it to accumulation of toxicity in bivalve shellfish and effects on other marine species, but the actual toxicity of *P. minimum* has not been convincingly documented and this alga often appears not to be toxic. The species has extended its distribution into the Kattegat and southwest Baltic Sea in the 1980s (Granéli 1987).

There is currently no evidence to indicate that the phytoplankton species listed in **Table 1** are found in Svalbard (including Bear Island) and Jan Mayen waters.

The impact of harmful algal blooms caused by alien phytoplankton species in Norwegian waters has not been comprehensively estimated in terms of socio-economic costs. However, there is little doubt that harmful phytoplankton blooms (known as HABs, harmful algal blooms) as a whole (i.e. those caused by both indigenous and non-indigenous species) can represent a very substantial threat in terms of toxic effects (e.g. mortalities) on living marine resources (i.e. life in the sea that may or may not be economically utilized) and other impacts (e.g. recreational amenities such as the ability to maintain and use 'well-kept' beaches for swimming and walking purposes). The toxic effects of HABs can pose serious human health hazards (e.g. Paralytic Shellfish Poisoning, Diarrhoeic Shellfish Poisoning) via eating fish and shellfish that have been contaminated. Some HABs have also been registered as causing the mortality of cetaceans and seabirds.

A gross starting point for examining the possible socio-economic impacts of HABs caused by alien phytoplankton species is to consider some of the possible tainting and mortality effects on commercially important marine species that are found in the area of greatest likely impact, i.e. the shelf zone along the Norwegian coastline. The potentially impacted biota include wild species that form high value harvests (e.g. via 'capture' fisheries), such as molluscs: blue mussels *Mytilus edulis*, scallops - *Chlamys islandica*; crustaceans: pink shrimp *Pandalus borealis*, Norway lobster *Nephrops norvegicus*; and fish: cod *Gadus morhua*, saithe *Pollachius virens*, haddock *Mellanogrammus aeglifinus,* herring *Clupea harengus*, Atlantic salmon *Salmo salar,* turbot *Psetta maxima*, plaice *Pleuronectes platessa*, halibut *Hippoglossus hippoglossus*, to name but a few. In addition, farmed Norwegian salmon represent a very high value product that is potentially at high risk as these fish are confined in cages and are unable to swim away from HABs.

Norway is one of the foremost fishing and aquaculture nations of the world, thereby making the potential socio-economic impacts of HABs also proportionately great. The export value of all Norwegian fish-products in 1999 was NOK 30 billion, representing 8.7% (i.e. similar to the value of natural gas) of all Norwegian exports. Of this farmed Atlantic salmon accounted for about 40% (NOK 10.77 billion), whitefish (e.g. cod, 32%), pelagic fish (e.g. herring, 14%), with other species making up the remainder[2]. Although it is improbable that all this value can be eradicated by HABs, the potential for major socio-economic impacts via alien HABs (e.g. *Alexandrium*, *Chatonella, Gyrodinium*) can be illustrated by reference to the toxic bloom of the indigenous flagellate *Chrysochromulina polylepis* in May–June 1988 that harmed and killed a large number of marine species in the upper 20 m of the sublittoral along most of the Norwegian Skagerrak coast. This resulted *inter alia* in 800 tonnes of farmed fish being killed in Norway and 100 tonnes in Sweden, resulting in an economic loss of about US$ 11 million or equivalent to more than NOK 70 million at that time (Skjoldal & Dundas 1991). There is also great optimism in Norway concerning the potential for farming and enhancement of shellfish, and the number of licences granted for such purposes by the authorities has increased substantially over the last several years. The blue mussel (*Mytilus edulis*) is currently the most important species, with 700 tonnes of mussels having been sold for NOK 5.8 million in 1999[3]. Given the full range of potential effects from HABs, the possible socio-economic consequences may amount in a worse case scenario to hundreds of millions of kroner if severely toxic blooms spread along large stretches of the Norwegian coastal shelf. This is a substantial enough socio-economic threat when posed by indigenous species causing toxic blooms without adding to it by introductions and transfers of harmful alien phytoplankton.

8.2 Invertebrates

In Europe, most of the deliberate introductions of live invertebrates have occurred for aquaculture and for human consumption (*e.g.* the restaurant trade). For aquaculture, introductions of shellfish (mainly bivalve molluscs, with some crustaceans) are the most common.

The import of living bivalve molluscs, particularly oysters, is a major source of the uncontrolled introduction of alien species. The literature emphasizes that both alien macrophytes and phytoplankton, including resting spores of potentially toxic dinoflagellates, have been introduced unwittingly together with the mollusc species for which import licenses have been granted. The import of live oysters from Japan (*Crassostrea gigas*) into Europe has led to the establishment of the parasitic copepod *Mytilicola orientalis* in a range of bivalves.

Of the molluscs, the Pacific oyster (*Crassostrea gigas*) remains of prime importance as a commercial species, with annual production increasing significantly in several North Sea countries (*e.g.* France, UK), although there is great concern that the indigenous European oyster (*Ostrea edulis*) has• partly as a result• become a threatened species. The introduction of the Manila clam (*Tapes = Ruditapes philippinarium*) has mirrored that of the Pacific oyster and has become established (i.e. reproductively viable) in several areas of the North Sea with relatively little human assistance.

In some European countries (e.g. Denmark, Netherlands, and UK), concern has been expressed about the import of bait-worms (*e.g.* from Korea via France or direct, Africa, and the USA) for angling as stocks of local worms became exhausted. It is almost certain and inevitable that many such worms are released into open waters. Furthermore, there is the potential for the release of alien macroalgae (*e.g.* from Korea), used as transit-packing material for the worms.

In Europe, the last few decades have seen the rapid spread and establishment of the parasite *Bonamia ostrea* infecting *O. edulis*, and *Anguillicola crassus* causing swim-bladder disease of the European eel *Anguilla anguilla.* Both of these parasites were introduced accidentally, and have caused major economic losses in the oyster and eel fisheries.

Many other accidental introductions of alien invertebrates have occurred in Europe outside of aquaculture. Examples of such invertebrates that are continuing to spread and establish themselves in the countries surrounding the North Sea include polychaete worms: (*e.g. Marenzellaria* spp.), barnacles (*e.g. Balanus amphitrite*, *B. improvisus*, and *Elminius*

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[2] Figures obtained from the Norwegian Central Statistical Office, Directorate of Fisheries, and Export Council for Fish

[3] Figures provided by the Norwegian Central Statistical Office

modestus), copepods (*e.g. Acartia tonsa*, *Mytilicola orientalis* and *M. ostreae*), crabs, amphipods, and shrimps: (*e.g. Eriocheir sinensis*, *Corophium sextonae*, *Gammarus tigrinus*, *Procambarus clarckii*, *Rhithropanopeus harrisii*), molluscs (*e.g. Ensis americanus = E. directus*, *Mya arenaria*, *Petricolaria pholadiformis*, *Teredo navilis*, *Crepidula fornicata*, *Potamopyrgus antipodarum*) and tunicates (*e.g. Styela clava*).

Table 1 records a count (marked by ✓ in the table) of about 22 invertebrate species, including parasites and diseases, which may be considered as alien to Norwegian waters. The instances of free-living invertebrates, as well as the parasites and pathogens/diseases connected with invertebrate hosts, are further described below. The invertebrate parasites and pathogens/diseases connected with vertebrate hosts (i.e. fish) are described under Section 8.3. The attention of the reader is not only drawn to references provided in the text of this section, but also to references given in Table 1.

Annelids

Currently there have been few records of clearly alien polychaete worms in Norway. *Scolelepsis* c.f. *bonnieri* is undergoing taxonomic verification by specialists (H. Botnen, *pers.. com.*) and its distribution in Norway currently appears to be limited. If its identification is correct, this would clearly emphasize its presence as an alien species for Norway. *Alkmaria rominji* is known from Østfold, but may be considered a cryptogenic species rather than a certain alien species for Norway. The effects of the two afore mentioned polychaete species in their introduced range on the environment, including other species, and commercial interests are not described.

For the sake of the current study, *Marenzellaria wireni* is considered as cryptogenic in Norway. This is due to the current discussion about the identity and/or taxonomy of *M. wireni* and *M. viridis*. Brattegard & Holthe (1997) describe the species *M. wireni* (Anger 1913) as having been identified in Masfjord and Sognefjord in Norway but anticipate its presence from the Skagerrak to Porsangerfjord in Finnmark County. Torleiv Brattegard (*pers. comm.*) has noted that Augener (1928) in Fauna Arctica 5(3) wrote that *M. wireni* was then known from Svalbard, Franz Josef Land and the Kara Sea. Population and genetic studies at the University of Rostok (Germany) have demonstrated that two sibling species of *Marenzelleria* are present in Europe, namely *M*. cf. *wireni* (Type I) in the North Sea (from Denmark to Belgium and the UK) and *M*. cf. *viridis* (Type II) in the Baltic Sea (from Germany to the Bothnian Bay). For each of these species, parent populations (genetically similar) were identified in coastal waters of Atlantic North America. The records from North Sea estuaries, however, may also be due to range extensions of Arctic populations of *M*. cf. *wireni*. Further details about the debate on the current taxonomic and population genetic status of *M. wireni/viridis* are provided by Röhner *et al.* (1996), Baströp *et al.* (1997), and Bick *et al.* (1997). Alien *Marenzellaria* have been shown to develop very high biomass (over 200 g live weight per m²) in the Baltic Sea (e.g. Vistula Lagoon) and may contribute as a beneficial food source for benthic fishes, as well as enhancing denitification and exchange of material and gases in deep sediments by burrowing (Gollasch & Leppäkoski 1999).

Cnidaria

Cordylophora caspia and *Gonionemus vertens* are the two prime examples of undoubted alien hydrozoans in Norway. The anthozoan *Rhizogetum nudum* has been identified as a possible cryptogenic species in Norway and the UK, with a likely chance of being alien, in an OSPAR questionnaire (Eno 1996; OSPAR 1997).

Cordylophora caspia is unique among hydroids in its ability to tolerate extremely low salinities including fresh water. The species is found in freshwater systems and it can grow in conditions ranging from fresh water to 30‰, but self-sustaining populations of *Cordylophora* spp. are reported only in brackish or freshwater. *C. caspia* is generally considered to be native to the Caspian and Black Seas, but has now been found worldwide.

The hydrozoan *Gonionemus vertens* has been found at several localities in Norway, e.g. Oslofjorden (Kramp 1922 as *G. murbachi*, but likely to be a misidentification of *G. vertens*), Hardangerfjorden (Tambs-Lyche 1964), and Trondheimsfjord (Gulliksen 1971). Gulliksen (1971) draws attention to the sampling difficulties required to find the sparse medusae specimens collected in Norway from the seagrass and macroalgal biotopes associated with them, and suggests that the species may be more common than reported particularly as the polyp is apparently only about 1 mm in size. Transport on ships' hulls in the polyp stage (Carlton 1985) from the western Pacific Ocean to Europe in the 19th century is a possible manner of introduction. However, Edwards (1976) suggested that it may have arrived much earlier from Japan with importations of Japanese oysters *Crassostrea gigas* 500 or more years ago; he also discussed other shipping- and seaplane-associated methods of transport. *G. vertens* probably originates from the western Pacific (China, Korea and Japan) (Edwards 1976). The species thrives in temperate to warm-temperate regions, and shows a variable, generally moderate rate of spread. It was probably introduced to Europe in Portugal where the population was localized due to currents, temperatures and salinities. It was exported from 1867 onwards from Portugal to France, again with oysters in the polyp stage. This allowed the dispersal to other European countries via major French oyster exports (Edwards 1976). It can also disperse in the hydromedusae stage in water currents and ballast water. The effects of this species on the environment or commercial interests are not known.

The effects of the two above-mentioned cnidarian species in their introduced range on the environment, including other species, and commercial interests are not described.

Crustaceans

Crustaceans make up one of the largest groups of alien invertebrate species found in Norway, and include barnacles and malacostracans (two amphipods, a crab and a lobster).

The barnacle *Balanus improvisus* became established as an alien species in western Europe in the early 1800s, probably having been transported on the hulls of ships from North America (Walford & Wicklund 1973), and can survive in a wide range of salinities with the result that it is now is one of the most common species in ship hull fouling (Gollasch & Leppäkoski 1999). Accordingly, it causes substantial economic expenses in the need to treat shipping to counteract the negative effects of fouling. In the natural ecosystem, this species increases the volume and area available for associated macrofauna and meiofauna, enhances detritus-based food chains by supplying their habitat with particulate detritus, and empty shells of the barnacle serve as new microhabitats for animals like small annelids, crustaceans and (Gollasch & Leppäkoski 1999).

The goose barnacle *Lepas anatifera* is found quite frequently in Norwegian waters attached to flotsam and jetsam originating from more southerly areas, as well as being introduced as larvae with ballast water. However, this species is unlikely to become fully established by natural breeding and recruitment in this geographic area. Its main negative effect is as a fouling organism on buoys and ships, but its economic effects cannot be compared with those incurred from infestations by the alien barnacle *B. improvisus*.

The two alien amphipod species registered in Norway are *Caprella mutica* and *Corophium sextonae*. The former species was only first found in recently in Norway by Heilscher (2000) and identified by W. Vader (Tromsø Museum). Four individuals of *Corophium sextonae* were found in 1985 from a single grab station in Aust-Agder (Wikander (1986). The origin of this species has generally been viewed as New Zealand in the alien species literature (c.f. Eno *et al.* 1997; OSPAR 1997). Marit E. Christensen (*pers. comm.*) notes that one specimen of *Corophium sextonae* G.I. Crawford is registered at the Zoological Museum in Oslo as Para type; the locality is Plymouth, the date is 7-9-1934, and the collector is Crawford. Since the publication date of the description is 1937, Christensen checked in J. Mar. Boil Ass. U. K. Vol. 21 and found *Corophium sextonae* n.sp. on p. 620- 623 in the article: ‘A review of the Amphipod genus *Corophium*, with notes on the British species: 589-630’. There is a description of both female holotype and male paratype. The type locality is Winter Shoal, Plymouth Sound. There are no remarks about New Zealand, but Crawford writes "*The abundance of this species is the more surprising since it is not present in the rich collections of Corophium made from the same dredging grounds in 1895-1911. It seems possible, therefore, that it is not indigenous at Plymouth. In spite of much enquiry I an unable to find any record from elsewhere, except for the single female from Portugal; and so I cannot guess at its original locality.*" Wim Vader (*pers com.*) and several of the premier international amphipod specialists contacted on the provenance of *C. sextonae* emphasize a) that the species has spread very strongly throughout European waters and that the Skagerrak specimens are probably part of this European dispersal, and b) that although Hurley (1954) reported the species from New Zealand, his arguments are not fully convincing and a possible Mediterranean origin could equally well be considered.

In Norway, an adult male individual of the Chinese Mitten Crab (*Eriocheir sinensis*) was first found in 1977 in the estuary of the river Glomma on the southeastern part of the Oslofjord (Christiansen 1977). In 1986 a female specimen was found about 10 km from the mouth of the river Glomma (Christiansen 1988). A further two specimens were found in 1995 and 1997 in the same Fredrikstad district as the others (Hardeng & Viker 1997). It is almost certain that the species has become fully established in Norway in the above-mentioned area. However, the first occurrence of this species outside of its original range in China was made in a German river in 1912. Today specimens can be found up to 700 km upstream in German rivers such as the Elbe. The species has migrated into the Baltic Sea via the Kiel Kanal. The first records in the Baltic Sea were from 1926, but the centre of occurrence in Europe today is still the German Elbe and Wiser rivers. It is generally agreed that shipping (ballast water and/or hull fouling of vessels) was the main vector of introduction. In other areas, imports of living species for aquaria or human consumption represent additional vectors. The success of this alien invasive species was positively influenced by comparable conditions of climate and salinity in the Chinese area of origin and the European recipient region. Additionally, the lack of native decapods in estuarine waters and rivers of the North Sea area supported the establishment due to low competition. The optimal abiotic conditions and low competition, as well as a substantial food supply, contributed to a mass occurrence in German waters in the 1930s and 1940s. Since then several tonnes of crabs can be caught by hand per day during peaks of mass incidence. However, during these periods, a significant decline occurs in the fisheries in the estuarine and inland waters due to the crab's feeding on fish and the food of fish. The crab causes damage by undermining the riverbanks, dams, retaining walls and irrigation channels through penetration by burrowing. Burrow openings may reach 12 cm width with a length of 50 cm, and a density of up to 30 holes per m² has been registered from the riverbanks of the Elbe. This crab has now spread to several estuaries in England, Denmark, the Netherlands and Sweden, besides Norway.

In 1999, the American lobster (*Homarus americanus*) was found in Oslofjord, having probably been discarded live from the restaurant trade. *H. americanus* is part of a unique phenomenon: it is affected by only one internal bacterial disease, gaffkemia, caused by *Aerococcus viridans*. *A. viridans* is a pathogen to only two hosts, the American lobster, and the European lobster, *H. vulgaris*. American lobster have developed a resistance resulting in a small percentage being able to survive and carry the disease with them, while this disease causes 100% mortality for European lobster. Gaffkemia resistant American lobster thus can transmit the disease onwards. None of the diseases that damage American lobster are otherwise recorded in European lobster. Thus, it is essential that one avoid the import of live and potentially disease transmitting lobsters into Norway with the possibility for further infection of American lobsters in Norwegian waters. This route for the possible infection of Norwegian *H. vulgaris* poses a very severe threat to the future viability of the indigenous species in one of the northernmost parts of its geographical range.

The official Norwegian landings of the native lobster have been about 30 metric tonnes annually for more than 10 years, but there is some uncertainty as to how reliable these are with the possible total being nearer 100 million tones than 30 (Gro van der Meeren *pers. comm.*). This is significantly less than levels of about 500-800 tonnes before the stock collapsed. The current kg price for fishers is about NOK 200-250, and this may reach as high as NOK 500-600 for consumers in mid-winter. The Norwegian Government has invested more than NOK 10 million in lobster stock enhancement research during the last 12 years with the aim of rebuilding the stock to commercial size again. A gross estimate of the potential economic value of the indigenous lobster in Norway, but not including its intrinsic value as part of the Norwegian fauna, is of the order of NOK 12-320 million based on landings of 30-800 tonnes and using a kg price of NOK 400. This can thus represent a simple estimate of the socio-economic damage on the native lobster fisheries that could be affected via pathogens transmitted by the American lobster.

The introduced red king crab *Paralithodes camtschatika* has spread westwards and southwards towards Lofoten, although its main distribution is east of the Tana river, since its first registration in 1976 in the Varangerfjord of northern Norway. Russian scientists introduced this species to the Kola Peninsula of the Barents Sea from the Russian northern Pacific. Since then it has spread in numbers and biomass through active migration of individuals. Successful reproduction occurs and many large specimens have been found, many occurring as by-catch in the long-line and net fisheries. As a result of the high value of the meat of this crab, a lucrative fishery has developed in the waters of Finnmark county and is now spreading to Troms county as the distribution of this species moves southwards. The king crab fishery, however, is regulated as a 'research fishery' with a TAC set for equal division between Norway and Russia. The TAC has risen from 22 thousand crabs in 1994 to 75 thousand crabs in 2000, with an increase to 200 crabs due in 2001. At this stage of the population development and encroachment in northern Norway, it is difficult to determine what the environmental effects and additional commercial effects may be in the future on the coastal marine ecosystem as well as that of the Barents Sea. Although being economically valuable for a fishery, the crab may have an ecological impact by feeding on and competing with both benthic invertebrates and demersal fish (e.g. eggs of capelin and lumpsucker) and destroying fish nets and eating the bait off long-lines (Olsvik 1996; Sundet 1996; Öberg 1997). Further, potentially serious effects might occur from parasites and pathogens associated with the crab (Sundet 1996); the egg eating nemertean *Carcinomertes* can destroy the eggs of berried females, and there is concern that this nemertean may be passed on to native crabs that have not built up defences against infections. Further, a trypanosome parasite has been identified in the blood of this king crab and there is a concern that the crab may act as an intermediate host in the transfer of the trypanosome to commercial fish with possible harmful effects (Jan H. Sundet *pers comm.*). Thus, it appears that eradication of the crab would be costly and even impossible to achieve, but direction of a relatively high level of fishing mortality would probably help to keep the population expansion of the crab down with the distribution restricted to Varangerfjord and eastwards. This would allow a socioeconomic return in the core area of its current distribution, while information on the impacts of the crab is collected and evaluated. *P. camtshatika* is a valuable fisheries resource in the USA, where commercial landings in 1996 were 9,526 tonnes with a value of over US$62.5 million.

Molluscs

Molluscs make up the largest group of alien invertebrates species found in Norway, and mainly comprise bivalves and gastropods.

The import of living bivalve molluscs, particularly oysters, has posed major problems with the introduction of alien marine species as well as with accidentally transfers of alien macroalgae, and phytoplankton including spores of potentially toxic dinoflagellates. The Pacific oyster (*Crassostrea gigas*) has been introduced into Europe as a commercial species of importance for aquaculture in countries such as the UK and France, although there is great concern that the indigenous European oyster (*Ostrea edulis*) has as a result become a threatened species. The European oyster was common in many places in the North Sea area until the 1870s when harvesting by fishing operations became prevalent. This species has now been decimated in abundance and distribution throughout its original geographic range in Europe. The demise of the indigenous European oyster has been due to a combination of overexploitation, pollution, habitat degradation, replacement for harvesting purposes by using non-indigenous (i.e. alien) species of oyster to achieve greater production, and severe infections by alien diseases and pathogens imported with the spread of the foreign oysters, and pollution.

Seed from *C. gigas* was imported from the UK to Norway until about the mid 1980s. Subsequently the Norwegian industry became self-sustained for the seed of this species, and started to export surplus seed. One company ('Sealife' at Tysnes, south of Bergen) is still in operation, and mainly produce seed according to the market (i.e. less than a million) every two or three years. Due to the normally cold environmental temperature, *C. gigas* has little chance of establishing self-reproducing populations in Norway. However, elevated ambient temperatures caused by global warming may eventually allow *C. gigas* to form self-sustaining populations in Norway, with the likelihood that spat can be transported northwards by the Norwegian coastal current. Currently the indigenous oyster *O. edulis* is found from Østfold county (bordering with Sweden) in the south to the southern part of Nordland county in the north (Brattegard & Holthe 1997).

The oyster microcell disease (*Bonamia ostreae*) has not been recorded in Norway (Stein Mortensen, *per comm.*), but it can potentially be transmitted with devastating results with imported oysters of the genus *Ostrea*. This was shown with the re-introduction of infected *O. edulis* from the Pacific back to Europe resulting in the production of European *O. edulis* falling to about 10% of the levels that were present prior to infection by *B. ostreae* in 1979 (Mortensen 1993b). Thus, it is vitally important that intensive screening of all live imports occurs within the framework of an appropriate quarantine period, e.g. as recommended by ICES (1995b).

The North American razor shell *Ensis americanus* was introduced to the German North Sea coast in 1978 and has since spread rapidly to the Netherlands, Belgium, northern France, Denmark, and Sweden, and was first found in Norway in 1989. The larvae of this species are easily transported with ballast water and by secondary dispersal via currents. The formation of dense populations may change the community structure of the benthos, including competition for space and food, and by altering the sediment structure by their burrowing activities. Their sharp shells can damage the nets of bottom trawls, and deter bathers and tourists with possible cuts and bacterial infections of the resulting wounds.

The Vikings probably transported the soft-shelled clam *Mya arenaria* to Europe from the Atlantic coast of North America as early as the 1200s (Petersen *et al.* 1992). This species lived in Europe, including Scandinavia, until becoming extinct during the Pleistocene period when Europe passed through a series of ice ages. Thus, *M. arenaria* may be thought of as a recent 'alien' that has become re-established in Europe by human assisted introductions and transfers. In Europe, it is found in Britain, Ireland, the North Sea coast from northern Scandinavia, and from the Faeroe Islands to the south of France. In Norway, this species has not caused significant detrimental effects on the environment or on other species, whereas beneficial effects include it being used as bait for recreational and commercial fishing. In the USA, *M. arenaria* is considered a delicacy to be eaten (e.g. clam-bakes).

The False Angelwing or American piddock *Petricola pholadiformis* was introduced to Europe from the USA by the end of the 1800s (ICES WGITMO 1972). Its introduction to Europe was probably unintentional with oysters (*Crassostrea virginica*) from the USA, and resulted in it establishing itself in several northern European countries by means of its pelagic larvae drifting with currents and by possible spread in driftwood (Rosenthal 1980). European populations are found from Norway to the Mediterranean and the Black Seas. In some parts of its new range (e.g. Belgium, Netherlands) it has almost completely replaced the native piddock species *Barnea candida* (ICES WGITMO 1972). Its impact on commercial and socio-economic interests is not known, while its beneficial benefits have not been identified.

In 1987 broodstock of the Manila clam *Tapes philippinarum* were introduced to Norway from the UK for shellfish culture purposes. Large, live, mature specimens of Manila clams have survived at three sites where cultivation trials were carried out from 1987–1991. There is apparently no evidence of successful recruitment as yet. However, in warmer areas of Europe (e.g. some parts of France) this species has become the premier aquaculture bivalve after the oyster *C. gigas*, with the greater production of this species is based on self-sustainable populations.

The alien 'shipworm' *Teredo navalis*, which is actually a bivalve which uses its shell to bore wood, established itself in Norway about 300 years ago, probably from having bored into and been transported by wooden hulled sailing vessels as well as floating driftwood. Shipworms are hermaphrodites, so that each individual can produce from a few thousand to several million larvae. In favourable years individuals may change gender several times and reproduce two or three times. It has not been possible to determine the socioeconomic problems caused by this species in Norway, although these must have been substantial. From the ancient Egyptians protective coatings have been used for wooden ships to lessen attack from shipworms that could result in a serious loss of seaworthiness. The problems of infestation by *T. navalis* became one of the major sources of damage and economic loss to wooden ships between about 1400 and 1800. In Holland in 1731, wooden dyke gates crumbled in a major storm when *T. navalis* had eaten away the wood, and inflowing water caused substantial flooding. The greatest socioeconomic damage detailed so far occurred in San Francisco, USA, when between 1919 and 1921 damage of more than US$ 900 million occurred to wooden piers and quays. Currently, damage is estimated to be approximately US$ 200 million/yr (Cohen & Carlton 1995).

The alien slipper shell limpet (*Crepidula fornicata*) has spread through Europe since the 1940s and was first recorded in Norway in 1958. Its high reproductive rate and ability to start new populations from small inoculations allows it to drastically change benthic habitats. This species is easily spread attached to bivalves (*e.g.* oysters, mussels) and shipping to new localities. Once established, they usually remain in abundance. Its success is probably due to a lack of predators and the method of reproduction (relying on individuals settling upon each other and reproduction assisted through very close proximity); and a pelagic larval stage aids the spread once introduced. The species rarely is found in abundance below 30 m depth. *C. fornicata* competes with other filter-feeding invertebrates for food and space, and in water having large concentrations of suspended material it encourages deposition of mud via the accumulation of faeces and pseudofaeces. It can become a pest on commercial oyster beds, competing for space and food, while depositing mud on them so that the substrate is unsuitable for spat settlement. It may dominate the macrofauna and reach concentrations of up to 1750 individuals m^{-2}. In northern France its biomass has been estimated at over a million tonnes, and empty shells may litter the seabed. The slipper shell limpet's spread in Europe has, amongst other things, contributed to the demise of the native European oyster *Ostrea edulis*.

The alien gastropod *Potamopyrgus antipodarum* has been established in Norway since about 1952. In 1889 it was first recognised in Europe (as *Hydrobia jenkinsi*) in the Thames estuary, England, but it is likely that the species was present in England since about 1850. *P. antipodarum* originates in New Zealand from where it was introduced into Australia. It was introduced to Britain from southern Australia or Tasmania in drinking water barrels onboard ships (Ponder 1988). The snails were probably liberated while washing or filling barrels or tanks, and further dispersal occurred into estuarine areas (e.g. the Thames) where the species is able to survive (Ponder 1988). The species can reproduce rapidly parthenogenically, aiding its colonization. It thrives in freshwater and brackish water area, and has become the most common freshwater gastropod in parts of Europe such as Britain. The effects of this species on the natural environment have not been described beyond the ability to dominate the local community in large numbers. In Norway, the species has colonized a significant part of the country over about 50 years, but it is still primarily confined in coastal areas.

Molgula manhattensis is apparently the only alien ascidian to become established in Norway, but as yet its distribution is limited. The species is colonial and adults may become abundant fouling organisms on marine structures such as floats and wharf piles. They can also attach themselves to oysters and reduce by their filtration the availability of particulate food for oyster growth.

The import of live oysters from Japan has led to the establishment in European waters of the parasitic copepod *Mytilicola orientalis* that infects not only European oysters but also a range of other bivalve molluscs. As yet this parasite has not been recorded in Norway, but it is very probable that it is only a question of time before it is.

8.3 Vertebrates

The greatest interest concerning the introductions and transfers of fish in Norway in particular, and Europe in general, has focused on transfers of Atlantic salmon (*Salmo salar*) within their natural range in the North Atlantic. This has primarily focused on the transfer of Atlantic salmon for commercial aquaculture purposes, with the fear that escapees will cause the dilution of native gene pools resulting in possible decline of the native salmon populations. Additionally, the concerns regarding Atlantic salmon have been related to the spread of pathogens that have been documented as posing very real threats to the viability of wild salmon populations. In more recent years, the fears regarding Atlantic salmon have been increased due to the potential production of transgenic (i.e. genetically modified) salmon.

Table 1 records only a single fish species (marked by ✓ in the table) that may be considered as alien to Norwegian waters. This species and some incidental fish species are further described below. The parasites and pathogens/diseases connected with fish are also described below. The reader's attention is not only drawn to the references provided in the text of this section, but also to the references in Table 1.

The Atlantic salmon aquaculture industry in Norway has developed to be the largest of its kind anywhere (see below). Originally in the early 1980s this resulted in the need to import large numbers of smolts, but the marked home production of smolts has grown to account for almost 100% of those used by the industry.

Various diseases have affected the cultured salmon industry. Some of these are endemic, *e.g.* vibriosis, cold water vibriosis and IPN virus, while some are of unknown origin, *e.g.* infectious salmon anaemia and pancreas disease. However, others are very probably introduced, *e.g.* furunculosis caused by *Aeromonas salmonica salmonica* and the freshwater monogenean skin parasite *Gyrodactylus salaris*. The latter poses a very serious threat to wild salmonids in freshwater and can also survive in brackish water, while the IPN virus can affect salmon living in seawater and freshwater.

Furunculosis is believed to have been introduced to Norway with smolts from Scotland in 1986, and has caused mortality in caged fish as well as some mortality in wild fish. Today nearly all smolt production in Norway is home produced.

Fish products accounted for 8.7% or about NOK 30 billion of the total Norwegian exports in 1999. Of these fish products, farmed salmonids (almost exclusively Atlantic salmon) accounted for NOK 10.77 billion or 40% of the total export value of fish products. The Atlantic salmon aquaculture industry in Norway, with its production of about 420 thousand tonnes in 1999 has developed to be the largest of its kind in the world, capturing 53% of the total global market. Thus, given the size of the overall production of farmed Atlantic salmon in Norway, it is clear that alien parasites and diseases (*e.g.* furunculosis) have probably caused socioeconomic damage to the industry for several 100s of million kroner.

The wild stocks of Atlantic salmon in Norway have since 1975 been very seriously depleted in freshwater by the monogenean skin parasite *G. salaris*,. The ability of this parasite to survive in brackish water (salinities up to 20 ‰ for as much as 18 hrs) makes it possible for its dispersal between closely situated river systems along the coast. The catastrophic mortality of most wild parr in over 30 Norwegian rivers has been caused by *G. salaris* that was probably introduced via stocking parr and smolts of Baltic origin, as this parasite is not normally part of the Norwegian fauna (Johnsen *et al.* 1999). The impact has caused a very serious threat to the viability of some of the major populations of Atlantic salmon in the world that contribute towards tourism and recreational fishing. During its maximum distribution and incidence, *G. salaris* reached 40 salmon watercourses in the Counties of Troms, Nordland, Nord-Trøndelag, Møre & Romsdal, Sogn & Fjordane, & Buskerud. By May 2000, this had been reduced to 21 salmon waterways due to rotenone treatment. The intention of rotenone treatment is to exterminate the parasite from watercourses. However, rotenone treatment also has a range of negative effects of riverine fauna.

In order to evaluate the costs of effects on wild salmon caused by introductions of alien parasites and pathogens it is necessary to recognize the components that contribute to the socio-economic value of such salmon. These are considered by to be (c.f. Mørkved & Krokan 2000):

Utilizable value
Consumer use
Value of recreational fishing in rivers
Value of recreational fishing in the sea
Value of professional fishing in rivers
Value of professional fishing in the sea
Non-consumer use
Value of experiencing salmon in nature, *e.g.* in a waterfall
Optional value
Value of future possibilities for use of salmon, even if one doesn't currently use them
Existential value
Value of salmon even if one never plans to use them, i.e. as natural biodiversity

Using these considerations, the socio-economic costs and value of rotenone treatment have been estimated for the Stenkjer watercourses in Trøndelag (Mørkved & Krokan 2000). The actual cost of the treatment was calculated as NOK 4.5 million. From an economic viewpoint, the rotenone treatment has two effects: a) securing the salmon stock in the Steinkjer watercourses and b) securing the other watercourses around Trondheimsfjord against infection. The study indicated that the present (i.e. 2000) value of the total positive effects of the rotenone treatment for the Steinkjer watercourses would be NOK 17.4-44.1 million, providing a high benefit/cost ratio of 3.8-9.8. The annual socio-economic value of the salmon in the watercourses around Trondheimsfjord was estimated at NOK 87-160 million. The profitability of the rotenone treatment project when the insurance effects on near lying watercourses had been worked into the calculations provided an estimate of the total positive effects of the rotenone treatment as NOK 500-1,500 million. The infected watercourses can be grouped into major eight regions of which the Steinkjer and immediate watercourses forms for one of them (Anon. 2000). Accordingly, a gross national estimate of the value of all Norwegian wild salmon is likely to be about an order of magnitude greater than the above-mentioned figures, i.e. at least NOK 10 billion. Thus, the introduction of alien parasites and pathogens to which the indigenous salmon are not adapted may potentially result in wild Atlantic salmon in Norway being a severely threatened species, and an annual value of billions of kroner being put at risk.

The rainbow trout (*Oncorhyncus mykiss*) is an alien species in Norway that was introduced in 1902 for sport fishing and aquaculture purposes (Hindar *et al.* 1996). It can form both inland stationary populations as well as be anadromous, *i.e.* migrate from freshwater areas to brackish or marine areas, and return to freshwater for reproduction. Until recently the magnitude of *O. mykiss* introductions and transfers were substantial, with a large number of fish escaping from the confines of aquaculture into the river systems and watersheds. However, considering the number of fish found in the wild, there are relatively few self-sustaining populations of self-reproducing fish, i.e. although rainbow trout were registered in 55% of Norwegian municipalities only 3% and 4% could be described as suspected or confirmed natural (i.e. self-sustaining) populations, respectively (Hindar *et al.* 1996). Thus, the question arises as to what prevents the establishment of this species in Norway specifically and in Europe generally?

A review of the literature conducted by Hindar *et al.* (1996) indicates that the physical and chemical habitat conditions in Norwegian rivers and lakes are wellsuited to rainbow trout, a highly flexible and adaptive species. Their habitat requirements overlap with those of the endemic Atlantic salmon and brown trout. It is known that rainbow trout can readily coexist with these species of salmonid in other regions of the world, and rainbow trout may actually be competitively superior to *Salmo* species. Hindar *et al.* (1996) have tentatively put forward the hypothesis that the paucity of establishment of rainbow trout in Europe may be due to the endemic parasite fauna of Europe, particularly myxosporean parasites, that are not native to North America, i.e. rainbow trout are susceptible to parasites. However, as pointed out by Hindar *et al.* (1996), extensive work remains to be carried out to examine this hypothesis.

Although it has been possible to document the presence of rainbow trout throughout many Norwegian watercourses, it has not been possible to predict the long-term impact of this species. However, as rainbow trout can live in both freshwater and brackish water, it can act as a host for the parasite *G. salaris* that in turn can be transmitted to indigenous salmonids.

In the 1970s, Russia transferred substantial numbers of Pacific salmon (*Oncorhyncus keta* and *O. gorbuscha*) ova to the Kola Peninsula, situated close to the county of Finnmark in northern Norway, and juvenile fish were liberated into the sea. In the late 1970s and 1980s, Norwegian fishermen frequently caught Pacific ('pink') salmon in commercial nets and adults were observed spawning in some rivers in Finnmark. After the cessation of the Russian introductions about 1980, the Norwegian catches decreased until it was reported in 1990 that no pink salmon were found in Norwegian coastal waters or rivers. However, this experiment posed a threat to Atlantic salmon in Norway through possible competition for food and habitats.

The swimbladder nematode *Anguillicola crassus* (so-called 'Asian eel parasite) arrived in Europe in the 1980s with shipments of live foreign eels (*A. japonica*) species from Asia. This species is now found in most European countries (except Ireland) including in the Baltic Sea (Kennedy & Fitch 1990) and Iceland. *A. crassus* has caused major problems with both farmed and wild European eels (i.e. *A. anguilla*). Currently many wild stocks of European eels have been seriously depleted due to infections by this parasite causing major economic losses for the eel fisheries. If infected by this parasite, *A. anguilla* may be more susceptibility to bacterial infections and death. The wall of the swim bladder may thicken and inflammation may occur. Growth may be slowed down, the swimbladder may burst in bad infestations, and swimbladder damage may prevent the spawning migration to the western Atlantic (Køie 1991). A variety of crustacean intermediate hosts and fish parasitic hosts are known for this parasitic swimbladder nematode, increasing the chances of its survival. There is high resistance of the sheathed, second stage, larvae to adverse conditions and the species has a well-developed colonizing ability (Kennedy & Fitch 1990). An absence of native swim-bladder nematodes is also a factor in the success of *A. crassus* as there is a lack of competitors and resistance of the host. Transmission within an aquatic system is generally through intermediate hosts and movements of other fish, while transmission between localities is generally through transport of infected eels. *A. crassus* has been recorded in the open sea and in brackish coastal localities (Køie 1991). The European eel appears to be more susceptible to A. crassus than are their original hosts (Køie 1991).

In 1994, the first observation of *A. crassus* in Norwegian waters was published (Mo & Steien 1994). As the observation was made on a farmed eel in Norway that apparently had been originally caught when small on the coast of Østfold, immediately north of the border with Sweden, Mo & Steien (1994) considered that this parasite had become established in Norway. Each year for two years after this, the authors investigated 150 adult eels caught in the above-mentioned area without finding any *A. crassus*. However, within three years of the first observation of *A. crassus*, the parasite was found in an eel farm near Kristiansand, far south in Norway, but no investigations were carried out on wild eels in that area. There is a possibility that the above-mentioned finds of this parasite are connected with transfers of live eels from Denmark to Norway, as both the eel farms were involved in boat traffic of live eels to and from Denmark (Tor-Atle Mo, *pers com.*). Both of the above-mentioned eel farms have now gone out of business, and today there is no evidence to either substantiate or refute the presence of this species in Norway.

The alien eel monogenean gill parasite *Pseudodactylogyrus anguillae* was also found in the two above-mentioned eel farms long before *A. crassus* was observed there (Tor-Atle Mo, *pers com.*). In 1998, *P. anguillae* and the related gill parasite *P. bini* were found in wild eels from Årungen, just south of Oslo (Mo & Sterud 1998). Buchmann *et al.* (1987) and Køie (1991) provide information on *Pseudodactylogyrus* infections of eels and their effects on the host.

There is currently no evidence to indicate that the alien fish species, or associated pathogens, listed in **Table 1** are found in Svalbard (including Bear Island) and Jan Mayen waters.

8.4 Parasites & Diseases

Sections 8.2 and 8.3 have drawn attention to parasites and pathogens/diseases (e.g. for eels the nematode *A. crassus*, and the monogeneans *P. anguillae* and *P. bini*; for salmon furunculosis caused by *A. salmonica salmonica* and the monogenean *G. salaris*) that have been introduced to Norway together with their hosts. The area of introduced parasites and diseases is one of the most harmful in terms of ecological and socio-economic effects.

Another area of possible impact via introductions and transfers of alien organisms is that where human pathogens are involved. In 1993, a case of serious human intestinal infection occurred where the two patients had not travelled outside the country. One of the two persons infected had eaten a substantial amount of crabs where the infection was shown to involve a non-endemic type of *Vibrio cholerae* that is likely to have been transferred by the discharge of ballast water (Henriksen *et al*. 1993).

In reviewing the literature, it is evident that little attention has been given to documenting alien aquatic parasites and pathogens/diseases, either in Norway or elsewhere. There is a pressing need for this situation to be redressed.

9 Conclusions and recommendations

The current report leads to the following conclusions and recommendations:

Alien species are being introduced and transferred (including 'secondary' transfers) at exponentially increasing rates throughout the world, and there is no evidence to indicate that the situation is different in Norway. The current report identifies a total of about 47 established alien marine species, including parasites and pathogens. Of these about 22 are plants (ca. 12 macroalgae and 10 phytoplankton), about 25 are invertebrates (free-living and parasites/pathogens), as well as and a single vertebrate (fish);

Little attention has been given to documenting a) the ecological and economic impacts of aquatic alien species and organisms, and b) the introduction and transfer of alien aquatic parasites and pathogens/diseases, either in Norway or elsewhere. The current report draws attention to a number of the more easily estimated impacts, and demonstrates that these are very substantial, particularly regarding harmful algal blooms and parasites and pathogens/diseases associated with alien species and organisms. The most easily discernable impacts are connected with farmed and wild Atlantic salmon;

The many—but ineffective—national and international instruments do not work to prevent the introduction and transfer of alien species and organisms;

The current situation is clearly in contravention of numerous Conventions and instruments that specifically mention the need to prevent the introductions and transfers of alien species and to apply a precautionary approach to such matters;

To redress this situation, it is recommended that the following steps be taken:

Ensure that the issue of alien species and organisms is given high profile in Norway, and supported by high priority actions in relevant international forums (*e.g.* Fifth North Sea Conference in 2002). Although several international forums acknowledge the importance of alien species, it is clear that this issue has been dissipated rather than being strengthened and focused. Active collaboration must occur, despite existing sectorial interests, between the key national and international players;

Prepare a Norwegian national policy, with supporting strategies for implementation, on the introduction and spread of alien marine organisms, clarifying the role of the various national institutions (e.g. ministries and agencies), and develop associated national legislation with a view to fulfilling the intentions of the international agreements that Norway has endorsed.

Develop a list of 'target' species and organisms, i.e. those introduced to areas outside their native range and which potentially are able to survive introduction to the recipient country. A list of target species may be used as a first step to evaluate the potential danger to the recipient area in question. The likelihood of introduction increases with the presence of viable populations of the particular species in surrounding countries;

Develop the establishment of relational databases for alien species and organisms (both for free-living ones as well as parasites and pathogens/diseases), containing *inter alia* case histories, information on distributions, literature references, and networks of experts and key persons;

Support the establishment of relevant monitoring programmes for alien species as part of the national scheme of monitoring, and produce annual reports updating the available information on the introduction and spread of alien organisms;

Develop an appropriate system of risk assessment and risk profiles connected with appropriate human activities (*e.g.* shipping, aquaculture) in particular regions and localities;

Motivate and fund the establishment of bioeconomic and socioeconomic analyses to provide integrated and comprehensive assessments of the consequences of introducing and transferring alien species in terms of the value of **natural capital ('ecological goods and services')**. Attention has been drawn (Costanza *et al.* 1997) to the total value of ocean and coastal ecosystem services (*e.g.* nutrient cycling, waste treatment in coastal systems) being an impressive 21 trillion US$. This is ca. 60% of the value of the estimated global ecosystem services, and 21 times more than the total gross domestic product of marine industries (*e.g.* fisheries, transport, tourism, oil and gas exploitation, which amount to about one trillion US$. By comparison marine industries account for only about 4% of the global GDP, indicating that the life support system of the globe is connected with the oceans. The spread of alien species represents a major threat to the degradation of biodiversity in such systems.

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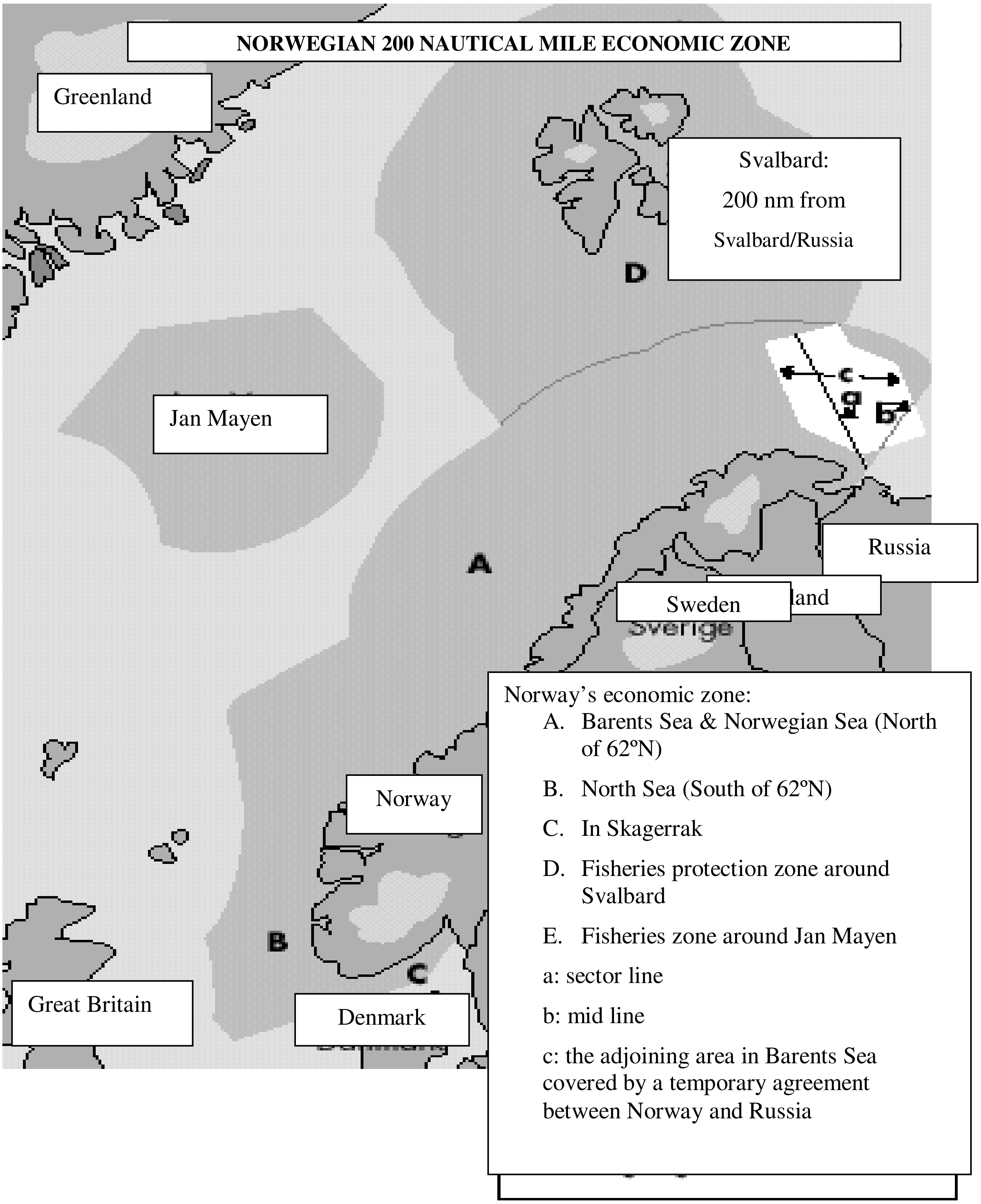
12 FIGURES AND TABLES

12.1 Figure 1. The Norwegian marine economic zone for considering alien marine organisms.



12.2 Table 1. Alien, cryptogenic and incidental marine species established in Norwegian waters.

A = alien; C = cryptogenic; I = incidental; E = established. ✓ = included in the count of probably alien species presented in Section 8.

12.1.1 Macroalgae

SPECIES	SYNONYM MISIDENTIFICATION	DIVISION	CLASS	AREA OF ORIGIN	TYPE	STATUS	FIRST OBSERV.	VECTOR	LOCATION	REFERANCES
Codium fragile ssp atlanticum		Chlorophyta	Chlorophyceae	Indo-Pacific, Japan	A✓	E	1895	?	Hordaland – Møre & Romsdal	Faegri & Moss; Silva 1955; Silva 1957; Munro *et al.* 1999
Codium fragile ssp scandinavicum		Chlorophyta	Chlorophyceae	Indo-Pacific	A✓	E	1929	?	Skagerrak – Nord Troms	Faegri & Moss 1952; Silva 1957; Stellander 1969; Munro *et al.* 1999
Codium fragile ssp tomentosoides		Chlorophyta	Chlorophyceae	Indo-Pacific, Japan	A✓	E	1946	?	Skagerrak – Møre & Romsdal	Faegri & Moss 1952; Silva 1957; Rueness 1977; Munro *et al.* 1999
Colpomenia peregrina	*C. sinuosa var. Peregrina*	Heterokontophyta	Phaeophyceae	Pacific	A✓	E	1933	Aquaculture	First recorded outside Bergen, now found from Østfold – Nord Trøndelag	Braarud 1950; Grenager 1950; Wiik & Nerland 1972; Rueness 1977; Rueness *et al.* 1990; Brattegard & Holthe 1995; Brattegard & Holthe 1997; Munro *et al.* 1999
Fucus evanescens		Heterokontophyta	Phaeophyceae	North Atlantic/Pacific	A✓	E	1900	Shipping	Skagerrak – SW coast & Trondheimsfjord - Finnmark	Bokn & Lein 1978; Brattegard & Holthe 1997; Munro *et al.* 1999

Sargassum muticum		Heterokontophyta	Phaeophyceae	Japan	A✓	E	1984/1988	Aquaculture	Østfold - Hordaland	Rueness 1985, 1989, 1998; Thélin 1989; Wrånes 1989; Rueness & Steen 1991; Brattegard & Holthe 1995; Brattegard & Holthe 1997
Bonnemaisonia hamifera	*Trailiella intricata* (part of life cycle)	Rhodophyta	Florideophyceae	Japan	A✓	E	1902	Fouling	First recorded near Ålesund & spread to whole coastline	Rueness 1977; South & Titley 1986; Breeman *et al.* 1988; Brattegard & Holthe 1997; Munro *et al.* 1999
Dasya baillouviana		Rhodophyta	Florideophyceae	Mediterranean & N.W. Atlantic (Caribbean – Nova Scotia)	A✓	E	1966	Shipping	Vestfold, Skagerrak	Røsjorde 1973; Brattegard & Holthe 1997; Maggs & Stegenga 1999; Munro 1999
Dasysiphonia sp.		Rhodophyta	Florideophyceae	North Pacific?	A✓	E	1996	Shipping	Hordaland – Sogn & Fjordane	Lein 1999, Maggs & Stegenga 1999
Gracilaria gracilis		Rhodophyta	Florideophyceae	?	A/C?✓	E	1935	?	Oslofjord - Nordmøre	Brattegard & Holthe 1997
Polysiphonia harveyi	P. insidiosa	Rhodophyta	Florideophyceae	Pacific	A/C?✓	E	ca. 1985	?	First recorded Oslofjord, now Oslofjord – Bergen	Rueness 1994, 1998; McIvor *et al.* 2000
Sphaerococcus coronopifolius		Rhodophyta	Florideophyceae	?	A/C?✓	E	1994	?	Oslofjord	Brattegard & Holthe 1997; Karlsson 1995; Rueness pers. comm.

12.2.2 Phytoplankton

SPECIES	SYNONYM MISIDENTIFICATION	DIVISION	CLASS	AREA OF ORIGIN	TYPE	STATUS	FIRST OBSERV.	VECTOR	LOCATION	REFERANCES
Coscinodiscus wailesii		Heterokontophyta	Diatomophyceae	Pacific	A✓	E	1979	Aquaculture/BWT & Secondary transfer	Oslofjord, Skagerrak	Hasle 1983; Hasle 1990
Odontella sinensis	*Biddulphia sinensis*	Heterokontophyta	Diatomophyceae	Indo-Pacific	A✓	E	1903	BWT & Secondary transfer	?	Gran 1908; Ostenfeld 1908; Lange *et al.* 1992; Anon. 1997
Thalassiosira punctigera	*T. angstii*	Heterokontophyta	Diatomophyceae	?	A✓	E	1979	Aquaculture/BWT & Secondary transfer	Oslofjord	Hasle 1983; Munro *et al.* 1999
Thalassiosira tealata		Heterokontophyta	Diatomophyceae	?	A/C✓	E	1968	Aquaculture/BWT & Secondary transfer	Oslofjord	Munro *et al.* 1999
Chatonella cf verruculosa		Heterokontophyta	Raphidophyceae	Japan	A✓	E	1998	BWT & Secondary transfer	Skagerrak - Stavanger	Horstmann *et al.* 1998; Aure *et al.* 2000; Aure *et al.* in press; Backe-Hansen *et al.* in press
Heterosigma akashiwo	*H. carterae*	Heterokontophyta	Raphidophyceae	Japan?	C✓	E	1964	?	?	Braarud & Nygaard 1967; Throndsen 1969, 1990
Olisthodiscus luteus		Heterokontophyta	Raphidophyceae	?	C✓	E	1999	?	?	Grimsrud & Throndsen 2000; Throndsen *pers.com.*
Alexandrium 0tamarensis		Dinophyta	Dinophyceae	?	C✓	E	?	BWT & Secondary transfer	Oslofjord	Granéli 1987

Gymnodinium aureolum (Hulbert) G. Hansen, comb. nov.	*Gymnoginium mikimotoi, Gymnodinium. nagasakiense, Gyrodinium aureolum*	Dinophyta	Dinophyceae	?	A✓	E	1966	BWT & Secondary transfer	Skagerrak – Sør Trøndelag	Braarud & Heimdal 1970; OSPAR 1993; Hansen *et al.* 2000.
Prorocentrum minimum		Dinophyta	Dinophyceae	?	C✓	E	1979	BWT & Secondary transfer	Oslofjord, Iddefjord	OSPAR 1997

12.1.3 Animals

SPECIES	SYNONYM/ MISIDENTIFICATION	PHYL/SUB-PHYL	CLASS	AREA OF ORIGIN	TYPE	STATUS	FIRST OBSERV.	VECTOR	LOCATION	REFERANCES
Scolelepsis c.f. bonnieri		Annelida	Polychaeta	?	A✓	E?	1995	BWT	Hordaland (Sture)	Botnen *et al.* 1995; Johansen *et al.* 2000
Alkmaria rominji		Annelida	Polychaeta	?	C?	E	?	?	Østfold	Brattegard & Holthe 1997; OSPAR 1997
Marenzelleria cf wireni/viridis		Annelida	Polychaeta	N.W. Atlantic/ Arctic	C?	E	?	?	Aust-Agder - Finnmark	Brattegard & Holthe 1997
Caprella mutica		Crustacea	Amphipoda	Japan	A✓	E?	1999	Shipping	Hordaland (Austevoll)	Heilscher 2000
Balanus improvisus		Crustacea	Cirripedia	America	A✓	E	1900	Fouling?	Østfold – Sydlige Nordland	Snelli 1972; Brattegard & Holthe 1995, 1997; OSPAR 1997
Lepas anatifera		Crustacea	Cirrepedia	Atlantic tropic/s-tropic	A	I?	<1900	Fouling/ BWT	West coast	Nilsson-Cantell 1978; Snelli 1968, 1983
Corophium sextonae		Crustacea	Malacostraca	New Zealand ?/Mediterranean	A✓	E	1985	?	Skagerrak	Wikander 1986; Brattegard & Holthe 1997; Eno *et al.* 1997; OSPAR 1997

Eriocheir sinensis		Crustacea	Malacostraca	S.E. Asia	A✓	E	1976	BWT, Secondary dispersal	Østfold – Oslofjord	Christiansen 1977, 1988; Harden 1988; Knudsen 1989; OSPAR 1997; Hardeng & Viker 1997
Hommarus americanus		Crustacea	Malacostraca	N.E. America	A✓	E?	1999	Restaurant cuisine	Oslofjord	Aure *et al.* 2000
Paralithodes camtschatica		Crustacea	Malacostraca	W. Pacific	A✓	E	1985	Stocking (Russia)	Finnmark, Troms	Kuzumin & Olsen 1994; Brattegard & Holthe 1995; Olsvik 1996; Sundet 1996
Cordylophora caspia		Cnidaria	Hydrozoa	Ponto-Caspian area	A✓	E	1985	?	Stavanger, Bergen, Idefjord	Brattegard & Holthe 1997; OSPAR 1997
Gonionemus vertens	*G. murbachi*	Cnidaria	Hydrozoa	W. Pacific	A✓	E	1921	Shipping/ Aquaculture	Oslofjord, Trondheimsfjord	Kramp 1922; Tambs-Lyche 1964; Gullik-sen 1971; Carl-ton 1985, Han-sson 1998
Crassostrea gigas		Mollusca	Bivalvia	Japan & S.E. Asia	A	I	1979	Aquaculture	Hordaland – Nordland	Brattegard & Holthe 1995; OSPAR 1997
Ensis americanus	*E. directus*	Mollusca	Bivalvia	N.E. Atlantic	A✓	E	1989	Secondary dispersal	Østfold – Aust-Agder	Knudsen 1989; Wikander 1993; Brattegard & Holthe 1995, 1997

Mya arenaria		Mollusca	Bivalvia	N. America	A✓	E	ca. 1000	Bait, food or bilge water	Whole coastline	Stokland 1985; Petersen *et al.* 1992; Brattegard & Holthe 1995, 1997; OSPAR 1997
Petricolaria foladiformis		Mollusca	Bivalvia	N. America	A✓	E	1955	Aquaculture & Secondary dispersal	Østfold – Vest-Agder	Rustad 1955
Tapes philippinarum	*Ruditapes philippinarum, Venerupis semideussata*	Mollusca	Bivalvia	S.E. Asia	A	I?	1987	Aquaculture	Hordaland, Trøndelag, Nordland	Mortensen 1993b; Brattegard & Holthe 1995
Teredo navalis		Mollusca	Bivalvia	W. Pacific	A✓	E	ca. 1700s	Shipping	Østfold – Trøndelag	Carlton 1985; Brattegard & Holthe 1995, 1997
Crepidula fornicata		Mollusca	Gastropoda	N.W. Atlantic	A✓	E	1958	Aquaculture	Oslofjord – Hordaland	Bergan 1969; Mortensen 1989; Brattegard & Holthe 1995, 1997; Sjøtun 1997
Potamopyrgus antipodarum	*P. jenkinsi, Paludestrina jenkinsi*	Mollusca	Gastropoda	New Zealand	A✓	E	1952	BWT	Østfold – Stavanger	Økland 1962; Brattegard & Holthe 1995, 1997; OSPAR 1997
Molgula manhattensis		Tunicata	Ascidiacea	America	A✓	E	?	?	Hordaland, Trondheimsfjord	Brattegard & Holthe 1997; OSPAR 1997

Oncorhyncus mykiss	*Salmo gairdneri*	Gnathostomata	Pisces	N. America	A✓	E	1902	Sport fishing, Aquaculture	Suspected or confirmed reproduction found in the Counties of Akershus, Hedmark, Oppland, Buskerud, Rogaland, Hordaland, Møre & Romsdal, Sør Trøndelag, Nord Trøndelag, Nordland, Troms	Brattegard & Holthe 1995; Hindar *et al.* 1996; OSPAR 1997
Gyrodactylus salaris		Platyhelminthes	Monogenea	Baltic	A✓	E	1975	Aquaculture	Max. Distrib-ution reached Troms, Nord-land, Nord-Trøndelag, Møre & Roms-dal, Sogn & Fjordane, & Buskerud.	Johnsen *et al.* 1999, Munro *et al.* 1999, Anon. 2000, Mørkved & Krokan 2000
Anguillicola crassus		Nematoda	Dracunculoidea	S.E. Asia	A✓	E?	1994	?	Østfold, Vest-Agder	Mo & Steien 1994
Pseudodactylogyrus anguillae		Platyhelminthes	Monogenea	?	A✓	E	Ca. 1990	Aquaculture	Østfold, Vest-Agder	Mo & Sterud 1998; Mo *pers.com.*
Pseudodactylogyrus bini		Platyhelminthes	Monogenea	?	A✓	E	Ca. 1990	Aquaculture	Østfold, Vest-Agder	Mo & Sterud 1998; Mo *pers.com.*
Aeromonas salmonicida salmonicida	Furunculosis			?	A✓	E	1986	Aquaculture	Whole country	Munro *et al.* 1999

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