Introduced Marine Organisms in Norwegian Waters, Including Svalbard

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Abstract
This chapter documents the various alien marine organisms 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 fish species. Attention is drawn to the ecological and socio-economic damage that has been or potentially may be caused by introductions and transfers of free-living organisms and their associated parasites and pathogens/diseases in Norway.

1 Introduction

There have been no previous reviews in Norway that have addressed the issue of marine alien organisms in depth. 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 States using information collected from national contacts, including Norway (OSPAR 1997). The collected data was not subjected to an extensive verification process. A total of 109 'probably established' alien species was reported from the whole OSPAR Convention area (i.e. northeast Atlantic and North Sea), not counting cryptogenic species and incidental species. The data for Norway (36 species in total) indicated (i) 31 probably established alien species (14 plants and 17 animals), (ii) 4 cryptogenic species (i.e. of uncertain origin) and (iii) 1 incidental species (not established).

2 Overview of alien marine organisms in Norwegian waters and their impacts

This paper is based on a report prepared for the Norwegian Directorate of Nature Management (Hopkins 2001). The results are summarized in Table 1. It is emphasized that this overview is not intended to be definitive, as studies generally overlook the alien species that have become established longest, e.g. a substantial component of the cryptogenic species. Of the ca. 4,000 species of macrobenthic 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.

2.1 MACROALGAE

About 12 macroalgae species or sibling species may be considered to be alien in Norwegian waters (Table 1). In most cases the effects of these species on the environment, including other species, and commercial interests are not described. The green alga

E. Leppäkoski et al. (eds.), Invasive Aquatic Species of Europe, 240–252.

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 to North Troms (Rueness 1977). It probably eliminated the native species *C. vermilara* in Norway (Silva 1957). *C. f.* ssp. *scandinavicum* is probably a recent immigrant to Europe, first recorded in Norway in 1929. *C. f.* ssp. *atlanticum*, probably introduced from the Pacific Ocean around Japan into Europe in historical times, has been found in Norway since at least 1895 (Silva 1957). Its ability to form rafts and float helps its secondary dispersal.

The first record of the brown alga *Colpomenia peregrina* was in 1933 outside Bergen (Braarud 1950). In the early 1970s it was found as far north as the area of Ålesund, and north of Trondheim (Wiik & Nerland 1972). In the 1980s it had also spread to the Skagerrak coast (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 oysters *Crassostrea virginica.* 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 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 (Munro et al. 1990).

The Japanese large brown alga *Sargassum muticum* was first recorded in Europe in the early 1970s. 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 °C while growth and reproduction appears to be limited by a lower temperature of ca. 12 °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, reaching from the littoral down to ca 10 m depth. It has a range of opportunistic features, being particularly able to dominate (i.e. outcompete and exclude) the native algal flora in bays, marinas and similar recreational areas. It can become a nuisance factor with clogging of outboard motors and accumulation of substantial amounts of detached and drifting rotting-fronds. The large canopies hinder light penetration and water circulation, and the plant may cause problems with operating diverse fisheries gear. On the positive side, this species attracts a rich epiphytic fauna.

The red alga *Bonnemaisonia hamifera* was first recorded in Norway in 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 being first seen in the mid 1960s and the males some years later (Breeman et al. 1988). This species may have been introduced unintentionally with shellfish from Japan. The success of *B. hamifera* is probably due to its lack of grazers due to brominated bioactive compounds in its cells, rapid growth rate, and its opportunistic qualities.

The red alga *Dasya 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. The red alga *Gracilaria gracilis* has been known in Norway since the mid-1930s. 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). The first confirmed collection of the red alga *Polysiphonia 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, J. Rueness pers. comm.) and is now common in the Oslofjord and Skagerrak (Rueness 1998). It possibly came to Europe from Japan 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*). The red alga *Sphaerococcus coronopifolius* was noted from Norwegian waters in 1994 by Karlsson (1995). This species was found for the first time in Sweden in the northern part of the Swedish west coast in 1990 (Karlsson et al. 1992), so its further spread to Norway was expected.

Table 1. Alien, cryptogenic and incidental marine species recorded in Norwegian waters. A alien; C cryptogenic; I incidental; E established; ✓ included in the count of probably alien species. For references, see Hopkins (2001).

	Area of origin	First observed	Status	Vector
Macroalgae				
Codium fragile ssp. *atlanticum*	Indo-Pacific, Japan	1895 ?	A✓ E	
C.f. ssp.*scandinavicum*	Indo-Pacific	1929	A✓ E	
C. f. ssp. *tomentosoides*	Indo-Pacific, Japan	1946	A✓ E?	
Colpomenia peregrina	Pacific	1933	A✓ E	Aquaculture
Fucus evanescens	N Atlantic/Pacific	1900	A✓ E	Shipping
Sargassum muticum	Japan	1984/1988	A✓ E	Aquaculture
Bonnemaisonia hamifera	Japan	1902	A✓ E	Fouling
Dasya baillouviana	Mediterranean & NW Atlantic	1966	A✓ E	Shipping
Dasysiphonia sp.	North Pacific	1996	A✓ E	Shipping
Gracilaria gracilis	?	1935	A/C?✓ E	?
Polysiphonia harveyi	Pacific	ca. 1985	A/C? ✓ E	?
Sphaerococcus coronopifolius	?	1994	A/C? ✓ E	?
Phytoplankton				
Coscinodiscus wailesii	Pacific	1979	A✓ E	Aquaculture/BWT& Secondary transfer
Odontella sinensis	Indo-Pacific	1903	A✓ E	BWT & Secondary transfer
Thalassiosira punctigera	?	1979	A✓ E	Aquaculture/BWT & Secondary transfer
T. tealata	?	1968	A/C✓ E	Aquaculture/BWT & Secondary transfer
Chattonella cf. *verruculosa*	Japan	1998	A✓ E	BWT & Secondary transfer
Heterosigma akashiwo	Japan?	1964	C✓ E?	?

	Area of origin	First observed	Status	Vector
Olisthodiscus luteus	?	1999	C✓ E?	?
Alexandrium tamarense	?		C✓ E ?	BWT & Secondary transfer
Gymnodinium aureolum *G. mikimotoi* *G. nagasakiense* *Gyrodinium aureolum*	?	1966	A✓ E	BWT & Secondary transfer
Prorocentrum minimum	?	1979	C✓ E	BWT & Secondary transfer
Animals				
Scolelepsis cf.*bonnieri*	?	1995	A✓ E?	BWT
Alkmaria rominji	?		C? E ?	
Marenzelleria cf. *wireni/viridis*	NW Atlantic/Arctic		C? E ?	
Caprella mutica	Japan	1999	A✓ E?	Shipping
Balanus improvisus	America	1900	A✓ E	Fouling?
Lepas anatifera	Atlantictropic/ subtropic	<1900	A I?	Fouling/BWT
Corophiumsextonae	New Zealand?/ Mediterranean	1985	A✓ E	?
Eriocheir sinensis	SE Asia	1976	A✓ E	BWT, Sec. dispersal
Homarus americanus	NE America	1999	A✓ E?	Restaurant cuisine
Paralithodes camtschatica	W Pacific	1985	A✓ E	Stocking (Russia)
Cordylophora caspia	Ponto-Caspian	1985	A✓ E	
Gonionemus vertens	W Pacific	1921	A✓ E	Shipping/Aquaculture
Crassostrea gigas	Japan & SE Asia	1979	A I	Aquaculture
Ensis americanus	NE Atlantic	1989	A✓ E	Secondary dispersal
Mya arenaria	N America	ca. 1000	A✓ E	Bait, food or bilge water
Petricolaria pholadiformis	N America	1955	A✓ E	Aquaculture & Secondary dispersal
Tapes philippinarum	SE Asia	1987	A I?	Aquaculture
Teredo navalis	W Pacific	ca. 1700s	A✓ E	Shipping
Crepidula fornicata	NW Atlantic	1958	A✓ E	Aquaculture
Potamopyrgus antipodarum	New Zealand	1952	A✓ E	BWT
Molgula manhattensis	America		A✓ E ?	
Oncorhynchus mykiss	N America	1902	A✓ E	Sport fishing, Aquaculture
Gyrodactylus salaris	Baltic	1975	A✓ E	Aquaculture
Anguillicola crassus	SE Asia	1994	A✓ E?	?
Pseudodactylogyrus anguillae	?	Ca. 1990	A✓ E	Aquaculture
P. bin	?	Ca. 1990	A✓ E	Aquaculture
Bacteria				
Aeromonas s. salmonicida	?	1986	A✓ E	Aquaculture

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.

2.2 PHYTOPLANKTON

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 species have been introduced into the European area via ballast water, 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, acts as a means of transport of plankton with the current along the coast towards northern Norway. 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 (G. R. Hasle, J. Throndsen, pers. comm.).

Several nonindigenous plankton species have been reported in the North Sea since about 1900 (Carlton 1985, 1989; Hallegraeff et al. 1990). About 10 phytoplankton species may be considered as alien to Norwegian waters (Table 1). The diatom *Coscinodiscus wailesii* 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). 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 (G. R. Hasle, pers. comm.). It is likely that *C. wailesii* was introduced to England via ballast water; its introductions elsewhere in the North Sea have likely taken place by secondary dispersal by currents, and the import and transfers of nonindigenous 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 has been known to cause clogging of fishing nets and aquaculture cages.

Odontella (=*Biddulphia*) *sinensis,* native to the China Sea and Indo-Pacific area, was considered an immigrant to the North Sea in 1903 (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 (e.g., in the Skagerrak; Lange et al. 1992).

The spread of the diatoms *Thalassiosira tealata* and *T. punctigera* into the North Sea has been well documented (e.g. Hasle 1983, 1990; Rincé & Paulmier 1986). *T. tealata* was recorded in Norway in 1968, and *T. punctigera* in the Skagerrak and Oslofjord since 1979 (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 cryptogenic.

In April-May 1998 and 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 south-west 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 better. In an outbreak starting in March 2001, this alga destroyed about 700 tonnes of fish raising questions by the Norwegian marine aquaculture insurance industry as to the consequences for future insurance should the alga be considered as resident in Norwegian waters. Other ecological effects have not been reported. The actual toxicity of the class is poorly known. The mortality of fish is apparently caused by the plankton 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 Oslofjord in 1964 (Braarud & Nygaard 1967; Throndsen 1969), resulting in disinformation (c.f. Smayda 1990) and confusion (c.f. Throndsen 1990) 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) in the Oslofjord, where it was one of the most common heterotroph flagellates sampled from the surface layer of marine bottom sediments.

Alexandrium tamarensis is a cryptogenic species in Norwegian waters. It produces paralytic toxins that can be fatal for a number of biota, including humans. 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 mortality of caged sea trout, occurred along the Skagerrak coast of Norway (Braarud & Heimdal 1970), with the causative agent being identified as *Gyrodinium aureolum*. This species has become one of the most commonly reported blooming dinoflagellates 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* (=*G. 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*, *G.* 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 paper. It has bloomed on numerous occasions since 1966 in Norway, most frequently from August to September, 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.

The dinoflagellate *Prorocentrum minimum* was, first recorded in the North Sea in 1976 (Smayda 1990), and 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 nearshore 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 (HABs) 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 HABs can represent a very substantial threat in terms of toxic effects on living marine resources. 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. The potentially impacted biota include wild species that form high value harvests (e.g. via 'capture' fisheries), such as 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*, and halibut *Hippoglossus hippoglossus*), to name but a few.

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 36% (NOK 10.8 billion), with whitefish (e.g. cod), pelagic fish (e.g. herring) and other species making up the remainder in order of economic importance. 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, Chattonella, 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). The 2001 outbreak of *Chattonella* in Norway caused over US$ 10 million loss to the fish farming community (Hopkins unpubl.). 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 is currently the most important species, with 700 tonnes of mussels having been sold for NOK 5.8 million in 1999. 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 NOK if toxic blooms spread along large stretches of the coastal shelf. This is a substantial enough socio-economic threat when posed by indigenous species without adding to it by introductions of harmful phytoplankton.

2.3 INVERTEBRATES

Table 1 records a count 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.

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. comm.). 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. The effects of these polychaetes on the environment and commercial interests are not described. *Marenzelleria 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.*

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). *C. caspia* is unique among hydroids in its ability to tolerate salinities from fresh water up to 30 PSU, 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. *G. vertens* has been found at several localities in Norway from Oslofjord (Kramp 1922 as *G. murbachi*, but likely to be a misidentification of *G. vertens*) to Trondheimsfjord (Gulliksen 1971). 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. *G. vertens* probably originates from the Pacific (China, Korea and Japan) (Edwards 1976). It was probably introduced to Europe in Portugal and 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. It can also disperse in the hydromedusae stage in water currents and ballast water.

Crustacea. Crustaceans make up one of the largest groups of alien invertebrate species found in Norway. The barnacle *Balanus improvisus* became established in western Europe in the early 1800s, probably having been transported on the hulls of ships from North America (Walford & Wicklund 1973). It causes substantial economic expenses in the need to treat ships to counteract the negative effects of fouling. 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 area.

The two alien amphipod species registered in Norway are *Caprella mutica* and *Corophium sextonae*. The former species was only first found recently in Norway by Heilscher (2000). Four individuals of *C. 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 (c.f. Eno et al. 1997; OSPAR 1997); a possible Mediterranean origin could equally well be considered (see Hopkins 2001 for further discussion). The species has spread very strongly throughout European waters and the Skagerrak specimens are probably part of this European dispersal.

The Chinese mitten crab (*Eriocheir sinensis*) was found in 1977 in the estuary of the river Glomma in the Oslofjord (Christiansen 1977). In 1986-1997 further specimens were recorded in the same district (Hardeng & Viker 1997); the species has probably become fully established in the above-mentioned area. In 1999, the American lobster (*Homarus americanus*) was found in Oslofjord, having probably been discarded from the restaurant trade. *H. americanus* is affected by only one internal bacterial disease, gaffkemia, caused by *Aerococcus viridans*, a pathogen to only two hosts, the American lobster, and the European lobster, *H. gammarus*. 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. American lobster thus can transmit the disease onwards. None of the diseases that damage American lobster are otherwise recorded in European lobster.

A gross estimate of the potential economic value of the indigenous lobster in Norway 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 red king crab *Paralithodes camtschatika,* introduced by Russian scientists to the Kola Peninsula of the Barents Sea from the Russian northern Pacific, 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. Successful reproduction occurs and many large specimens have been found, many occurring as by-catch in the long-line and net fisheries. The king crab fishery is regulated as a 'research fishery' with a TAC set for equal division between Norway and Russia. 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. 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; Öberg 1997). Further, potentially serious effects might occur from parasites and pathogens associated with the crab; 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 (J-H. Sundet pers comm.).

Mollusca. Molluscs make up the largest group of alien invertebrates species found in Norway. Seed from *Crassostrea 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 is still in operation, and mainly produces seed (< a million) according to the market every two or three years. Due to the normally low 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. The oyster microcell disease (*Bonamia ostreae*) has not been recorded in Norway (S. Mortensen, pers. comm.), but it can potentially be transmitted with devastating results with imported oysters of the genus *Ostrea*. This was shown with the reintroduction 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 1993). 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 (1995).

The North American razor shell *Ensis americanus* was introduced to the German North Sea coast in 1978 and first found in Norway in 1989. 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). 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.

The false angelwing or American piddock *Petricola pholadiformis* was introduced to Europe from the USA by the end of the 1800s (ICES 1982), probably with oysters (*Crassostrea virginica*) from the USA. 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 1982). Its impact on commercial and socio-economic interests is not known, while its beneficial benefits have not been identified.

In 1987 brood stock of the Manila clam *Tapes philippinarum* were introduced to Norway from the UK for shellfish culture purposes. Large mature specimens of Manila clams have survived at three sites where cultivation trials were carried out in 1987–1991. There is apparently no evidence of successful recruitment as yet.

The alien 'shipworm' *Teredo navalis* 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. It has not been possible to determine the socio-economic problems caused by this species in Norway, although these must have been substantial.

The slipper shell limpet (*Crepidula fornicata*) was first recorded in Norway in 1958. This species with a high reproductive rate is easily spread attached to bivalves 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 is rarely found in abundance below 30 m depth. 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. The alien gastropod *Potamopyrgus antipodarum* has been established in Norway since about 1952. In 1889 it was first recognised in Europe 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. It was introduced to Britain from southern Australia or Tasmania in drinking water barrels onboard ships (Ponder 1988). The species can reproduce rapidly by parthenogenesis, aiding its colonization. It thrives in fresh and brackish water. In Norway, it has colonized a significant part of the country over 50 years, but it is still primarily confined in coastal areas.

Other invertebrates. *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.

2.4 VERTEBRATES

The rainbow trout (*Oncorhyncus mykiss*) is the only alien fish species in Norway (Table 1). It was introduced in 1902 for sport fishing and aquaculture purposes (Hindar et al. 1996). It can form both inland stationary as well as anadromous populations. Until recently the magnitude of *O. mykiss* introductions and transfers were substantial, with a large number of fish escaping from the confines of aquaculture. Although rainbow trout were registered in 55% of Norwegian municipalities only 3-4% could be described as self-sustaining populations (Hindar et al. 1996).

The question arises as to what prevents the establishment of this species in Norway specifically and in Europe generally? The physical and chemical habitat conditions in Norwegian rivers and lakes are well-suited to rainbow trout, a highly flexible and adaptive species (Hindar et al. 1996). 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. However, extensive work remains to be carried out to examine this hypothesis.

In the 1970s, Russia transferred substantial numbers of Pacific salmon (*Oncorhyncus keta* and *O. gorbuscha*) ova to the Kola Peninsula 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 Finmark. 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.

2.5 PARASITES AND DISEASES

The Atlantic salmon aquaculture industry in Norway has developed to be the largest of its kind anywhere. In the early 1980s this resulted in the need to import large numbers of smolts, but the 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 native, 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 s. 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 also 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.

Fish products accounted for 8.7% or about NOK 30 billion of the total Norwegian exports in 1999. Of these products, farmed salmonids (almost exclusively Atlantic salmon) accounted for NOK 10.77 billion. The Atlantic salmon aquaculture industry in Norway, with its production of about 420,000 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 socio-economic damage to the industry for several 100s of million NOK.

The wild stocks of Atlantic salmon in Norway have since 1975 been 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 PSU 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). During its maximum distribution and incidence, *G. salaris* reached 40 salmon watercourses in the Counties of Troms, Nordland, Nord-Trøndelag, Møre & Romsdal, Sogn & Fjordane, and Buskerud. By May 2000, this had been reduced to 21 salmon waterways due to rotenone treatment. 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. A gross national estimate of the value of all Norwegian wild salmon is likely to be more than NOK 10 billion, so the introduction of alien parasites and pathogens to which the indigenous salmon are not adapted may potentially result in Norwegian wild Atlantic salmon being a severely threatened species, and a substantial value in natural capital being put at risk (Hopkins 2001).

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 in Norway 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-native type of *Vibrio cholerae* that is likely to have been transferred by the discharge of ballast water (Henriksen et al. 1993).

The swimbladder nematode *Anguillicola crassus* arrived in Europe in the 1980s with shipments of eels (*Anguilla japonica*) 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 *A. anguilla*. Currently many wild stocks of European eels have been seriously depleted causing major economic losses for the eel fisheries. If infected by this parasite, *A. anguilla* may be more susceptible to bacterial infections. 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 the 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 swimbladder nematodes is also a factor in the success of *A. crassus* as there is a lack of competitors and resistance of the host. *A. crassus* has been recorded in the open sea and in brackish coastal localities. The European eel appears to be more susceptible to *A. crassus* than are their original hosts (Køie 1991). The first observation of *A. crassus* in Norwegian waters was published by Mo & Steien (1994). Within three years 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 eels from Denmark to Norway (T-A. Mo, pers. comm.).

The alien eel monogenean gill parasite *Pseudodactylogyrus anguillae* was found in two eel farms long before *A. crassus* was observed there (Tor-Atle Mo, pers comm.). In 1998, *P. anguillae* and the related *P. bini* were found in wild eels 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, Bear Island and Jan Mayen waters.

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