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STATUS OF INTRODUCTIONS OF NON-INDIGENOUS

MARINE SPECIES TO NORTH ATLANTIC WATERS

1981–1991

Editors:
Dr A.L.S. Munro, Dr S.D. Utting, and Prof. I. Wallentinus

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Foreword

Recording the flora and fauna of habitats has long been practised. In more recent times much attention has been and is being paid to both the deliberate introduction by man of species exotic to marine areas and to the inadvertent appearance of such alien species by factors involving man and other agents. In the marine environment of the ICES area it is inevitable that almost all observations are confined to coastal zones in the 'open' marine habitat of the North Atlantic. For 'semi-enclosed' areas such as the Mediterranean, Baltic and North Seas and 'enclosed' areas such as the Great Lakes a greater degree of observation over the whole is possible. Part of this recording of new introductions and transfers of exotic species which are part of an established trade are observations of the impact of the exotic either because it is successful in establishing reproducing populations or because of its presence.

The First (1980) Status Report on Introductions of Non-Indigenous Marine Species to North Atlantic Waters was prepared by the ICES Working Group on Introductions and Transfers on Marine Organisms (WGITMO) (Anon 1982). This second report, also prepared by WGITMO, covers the decade 1981–1991. It includes summaries of the national reports to the working group from member countries of ICES of introductions and transfers of fish and invertebrates. Because there has been a limited response on plant introductions both in the previous and current decade a comprehensive review of plant introductions with an additional section on the threat from the green algae *Caulerpa taxifolia* has been included.

In addition to deliberate and inadvertent introductions there is much more awareness of the impact of mans increasing activities in coastal zones and adjacent seas e.g., by chemical pollution, fishing, extraction of sediments and hydrocarbons, mariculture, ballast discharge and land reclamation. These activities lead to change and often degradation of the environment a situation leading to new pressures on existing population structures and providing possible added opportunity for establishment of exotic species which did not exist before. It is therefore increasingly important that recording of the fate of introduced species continues.

Part of the duties of the Working Group is to advise and recommend acceptance or otherwise to the Council of ICES on proposals to introduce exotic species formulated in accord with the ICES Code of Practice on Introductions and Transfers (reproduced in this report as Annex 1). This is achieved by use of the scientific literature, the experience of the members of the Working Group, reports of the nature and changes of local environments, and guided by the Code.

In this volume Section 1 on 'Introductions and Transfers of Plants' and Section 2 on Status of the Invasion of the Green Alga *Caulerpa taxifolia* in the Mediterranean Sea and Prospects for the Invasion of Western Europe' were written by Inger Wallentius.

Editor: Co-Editors:

Dr A.L.S. Munro Dr S.D. Utting Prof. I. Wallentinus
Marine Laboratory CEFAS, Conwy Laboratory University of
Gothenberg
P.O. Box 101, Victoria Road Benarth Road Dept. of Marine
Botany
Aberdeen AB11 9DB Conwy North Wales LL32 8UB Carl Skottsbergsgatan 22
United Kingdom United Kingdom 413 19 Gothenburg
Sweden

1 Introduction and Transfer of Plants

1.1 Introduction

The information in this part is compiled from both the ICES reports during the 1980s and early 1990s, as well as from a literature search, since, generally, plants have only sporadically been included in the ICES reports, and many countries have not contributed with national reports. The aim has also been to follow up the fate of old introductions, and report on their present status, whenever information was available. The Laurentian Great Lakes are part of the remit of this ICES Working Group and although the non-Atlantic coasts of the ICES countries are not they have been included for completeness.

Macrophytes are listed by country (as defined by the political situation of 1990), while phytoplankton species are dealt with collectively at the end of this chapter. Generally, deliberate introductions are reported first, followed by accidental introductions with other introduced species. Finally, totally accidental introductions, including species having arrived into a country by dispersal from other countries, to which they were once introduced, in one way or another, are reported.

Not included in this report are all algal species brought to laboratories for small scale, indoor studies, in taxonomy, ecology and physiology, and for maintaining algal cultures in the laboratory. Such deliberate introductions have probably been made mostly to universities, research laboratories and field stations and would give an immense list, even if it were possible to assemble it. The same also applies to microalgae used for food in hatcheries.

The author is most indebted for all unpublished information received by several colleagues in phycology, which is gratefully acknowledged.

1.2 Introduced Species in the Different Countries

1.2.1 Belgium

A drift plant of the Japanese brown alga *Sargassum muticum* was first recorded in Belgium as early as in 1972 or 1973 (Coppejans *et al.*, 1980). During the 1980s the species was found often in huge quantities after storms, but until 1990 has never been found attached, not even in harbour areas (E Coppejans, pers. comm.). Coppejans has also seen pieces of the green alga *Codium fragile* washed ashore, but never found it attached. None of the other species accidentally introduced into Europe has been seen in the country, probably due to the mostly sandy coast.

1.2.2 Canada

During the 1980s there has been a growing interest in Canada in developing a nori (*Porphyra*) mariculture in British Columbia (Bergdahl, 1990; Mumford, 1990). Preseeded nori nets were imported from Japan during 1985-86 (ICES, 1986; Mumford, 1990), probably with the two Japanese species *Porphyra yezoensis* and *P. tenera*, which have also been imported to USA (see below).

There is a note on a map (Druehl, 1982) of the red alga *Chondrus crispus* being brought to British Columbia from Nova Scotia for farming purposes, but no details were given.

The Asiatic angiosperm *Artemisia stelleriana* was originally introduced for ornament and has escaped and spread widely along the shores of the eastern coast and the Southern Great Lakes (C Bird, pers. comm.; Scoggan, 1979).

The first Canadian record of the seagrass *Zostera japonica*, initially introduced into USA with oysters (see below), was from the Boundary Bay area of south British Columbia in 1969, after which a rapid spread in the Fraser river area occurred during the 1970s. It reached Vancouver Island in 1979, and in the early 1980s it had also colonised the south of the Strait of Georgia (for a review see Harrison and Bigley, 1982). As mentioned below for USA its further spread north is predicted.

Scagel (1956) reported the Japanese brown alga *Sargassum muticum*, which was accidentally introduced with oysters, to have been abundant in the south Strait of Georgia, British Columbia before 1941 (first verified samples from 1944) and widely spread by 1945, while it did not occur there during the first decades of this century. In many cases plants were found close to areas with imported Japanese oysters, but were not recorded from the early periods of oyster imports. During the 1970s the species became established on the west coast of Vancouver Island (Norton, 1981), having reached the northern point of the Island before 1980 (DeWreede, 1980) and later spread all through the north part of British Columbia (Scagel *et al.*, 1989). Young plants of *Sargassum* have also been transferred from San Diego, California to Bamfield, British Columbia for ecological experiments (Deysher, 1984). So far there seems to be no record of *Sargassum muticum* along the Canadian Atlantic coast (C Bird, pers. comm.).

The red alga *Bonnemaisonia hamifera* was unknown in east Canadian waters prior to 1948. Since then the species has spread northwards to Newfoundland and Laborador, although it has not been possible to conclude if the species arrived from Japan or Europe or spread from the south (McLachlan *et al.*, 1969; Breeman *et al.*, 1988 and references therein). According to references in those papers, male plants were first recorded in the late 1960s, and females in the late 1970s (see Breeman *et al.*, 1988 for a discussion of the life cycle in relation to temperatures and day lengths and to its Japanese origin). The species is still present, mostly as tetrasporophytes.

After the first record of the brown alga *Colpomenia peregrina* in Nova Scotia in 1960, it was found on several occasions during the late 1960s and 1970s (Bird and Edelstein, 1978). The sporadic occurrences were initially interpreted as immigration, but Bird and Edelstein did not discuss any possible sources of introduction. Repeated collections from specific areas in southwest Nova Scotia indicate that *C. peregrina* has become established there, but as of the early 1990s its distribution in Canada still seems to be restricted to a few scattered, moderately deep sublittoral sites in this province (C Bird, pers. comm.).

The red alga *Furcellaria lumbricalis*, a dominant plant in the eastern North Atlantic, was probably introduced in the late 19th century to the area of the Gulf of St Lawrence and has been suggested to be evidence of early ship ballast introductions (Novaczek and McLachlan, 1989). It has also expanded on the coasts of Prince Edward Island.

The brown alga *Fucus serratus*, which often grows in dense belts in Europe, was probably introduced in the 19th century to the south shores of the Gulf of St Lawrence and north Nova Scotia. It has been suggested that it is evidence of early ship ballast introductions (Edelstein *et al.*, 1972; Novaczek and McLachlan, 1989; J McLachlan, pers. comm.). It first spread rapidly along the shores of the Maritime Provinces facing the Gulf, but only slowly along the east and south coast of Nova Scotia (Edelstein *et al.*, 1972). The reason for this was discussed in a paper by Dale (1982) as probably being due to competition with the native *Fucus evanescens*. Some new localities on the shores of Nova Scotia have been found during the 1980s (Novaczek and McLachlan, 1989; J McLachlan, pers. comm.).

Bird (1978) discussed if the red alga *Lomentaria orcadensis* was an immigrant in Nova Scotia or only sparsely occurring, but the species has been increasing its distribution along the Atlantic shores of the USA (see below). The related species *L. clavellosa*, new to the western Atlantic in the 1960s (see USA below) has so far not been recorded from Canada (C Bird, pers. comm.).

1.2.3 Marine species, including phytoplankton, in the Laurentian Great Lakes (Canada and USA)

Several species of brackish and marine origin have been introduced into the Great Lakes, presumably at least in some cases due to shipping, while the vectors of other species are less certain. The increasing salinity of the lakes until the 1970s, partly due to anthropogenic discharges, is discussed as a contributing factor for their survival (Sheath, 1987).

The charophyte, *Nitellopsis obtusa* was found for the first time on the US shores near the St Lawrence River in 1978 and later on had spread along 72 km of the riverbanks (Geis *et al.*, 1981). They suggested that international shipping was the most likely reason for the sudden and successful appearance of the species in this area. However, there is no report available on its present distribution. In the Baltic Sea *Nitellopsis obtusa* occurs in bays with salinities of up to about 3‰ (Luther, 1951), thus being able to survive in slightly brackish water.

Already during the late 19th century the fresh water angiosperm *Myriophyllum spicatum* (Euroasian watermilfoil) was found in North America, possibly introduced by shipping ballast into the Chesapeake Bay area (Reed, 1977; Aikens *et al.*, 1979). During the 1950s and 1960s it developed into a nuisance weed in many widely separated lakes across the USA (Reed, 1977), and in some areas its spread was due to introductions from aquaria plants. In Canada it was found along the St Lawrence Seaway during the early 1960s, developing into a weed in the 1970s, after it had spread in lakes over the country (Aikens *et al.*, 1979). Although not a marine species, it is included here, since it occurs in brackish waters (including the Baltic Sea), and is found in North American coastal waters in salinities of up to about 15‰ (Reed, 1977; Aiken *et al.*, 1979). Reed (1977) considered the more aggressive phase in the USA to have declined temporarily in the late 1970s. There are also examples of this dominant species undergoing decline in some lakes, several reasons for which have been discussed (e.g., Reed, 1977; Carpenter, 1980).

The marine red alga *Bangia atropurpurea*, has been introduced into the lower Great Lakes, presumably by shipping, where it was also directly observed as a fouling alga on the ships (Sheath and Cole, 1980; Sheath, 1987). Since its first appearance in the mid 1960s and subsequent spread during the 1970s and early 80s it was found in all the Great Lakes except Lake Superior, as well as in several nearby inland lakes. In many localities it outcompeted the native green alga *Ulothrix zonata*, and it is the only introduced benthic alga which has become dominant in the area (Sheath, 1987).

Sheath (1987) also listed another red alga, the small epiphyte *Chroodactylon ramosum* (= *Asterocytis smaragdina*), as a possible immigrant, occurring in all the Great Lakes except Lake Superior, as well as the more sparsely occurring green algae *Enteromorpha intestinalis*, *E. prolifera* and *Monostroma wittrockii*, and possibly also the two brown algae *Sphacelaria lacustris* and *S. fluviatilis* (the latter two fresh water species, but considered originally developed from marine ancestors). None of these species have had any impact on the native benthic vegetation.

Sheath (1987) listed 11 phytoplankton species as potentially introduced with ballast water as a possible vector: the diatoms *Actinocyclus normanii*, *Biddulphia laevis*, *Cyclotella atomus*, *Chaetoceros honii*, *Skeletonema subsalsum*, *Therpsinoe musica*, *Thalassiosira guillardii*, *T. lacustris*, *T. pseudonana*, *T. weissflogii* (= *T. fluviatilis*), and the fresh water coccolithophorid *Hymenomonas roseola*, probably having evolved from the marine species *H. lacuna*. *Actinocyclus* and *Cyclotella* have displaced previously dominant phytoplankton species.

1.2.4 Denmark

The Japanese brown alga *Sargassum muticum* was first found as drift plants in Limfjorden in the winter of 1983, and in the summer of 1984 attached plants were seen along 2 km of the shores (Christensen, 1984). During the late 1980s it had spread considerably in the Limfjorden, and in 1990 it was growing in dense belts along most of the shores. At some locations in the Limfjorden area there have been problems for small boats with outboard engines (ICES, 1989). In 1990 it was found growing in the harbour of Hirtshals, NW Jutland (R Nielsen, pers. comm.). However, although looked for, it has not been found attached in the Kattegat, the Baltic or the North Sea (L Mathiesen, pers. comm.), although it can frequently be seen drifting also in the outer Kattegat.

The sporophyte generation of the red alga *Bonnemaisonia hamifera*, was accidentally introduced in Denmark and first recorded in 1901 in Limfjorden, the first record from the Kattegat being in 1909 (Rosenvinge, 1920). During the 1980s the species occurred extremely commonly in the Århus Bight, and the Kattegat, but has not been recorded south of the sea area around Samsö (L Mathiesen, pers. comm.).

Since 1972 it has been regularly found with tetraspores. No gametophytes have been recorded attached from Denmark, but they can be seen drifting off Fredrikshavn. There are no published records of the introduction to Europe of the red alga *Asparagopsis armata*.

The red alga *Dasya baillouviana*, first found drifting in the Great Belt in 1961 (G Michanek in den Hartog, 1964), has up to 1990 been found in several areas along the east Jutland coast with all three generations present (fish farm at Horsens, power plant at Åbenrå, in Flensburg and Augustenborg Fjords), but not as far north as the Århus Bight (L Mathiesen, pers. comm.). Its method of introduction to northern Europe, however, has been debated (see, e.g., den Hartog, 1964; Røsjorde, 1973).

The Pacific brown alga *Colpomenia peregrina* was first recorded in Denmark in 1939 in the Limfjorden (Lund, 1949b). It has also been found in the Kattegat off Fredrikshavn in the 1960s (Christensen, 1984; L Mathiesen, pers. comm.).

The northern Atlantic species *Fucus evanescens*, probably introduced into the Kattegat and the Öresund (Hylmö, 1933, but see also Lund, 1956), was first recorded attached from the coasts of Sealand at Charlottenlund and Copenhagen in 1948 (Lund, 1949a). Later on it increased its distribution into several areas in the Kattegat, the Öresund and the Belt Sea (Christensen *et al.*, 1985), while Lund did not find it in those waters. During surveys in 1989-1991 it was seen in several new areas in the southern Belt Sea (the islands of Fyn and Langeland, the Kattegat coast of Jutland, as well as in the western Baltic; L Mathiesen, pers. comm.). She considers its strong competitive ability in nutrient enriched water to be due to both the growth and fructification in early spring and to the small amounts of epiphytes on the thallus.

The first record of the green alga *Codium fragile* in Denmark according to Silva (1957) dates back to 1919 (ssp. *scandinavicum* at Hirsholmen) and 1920 (ssp. *tomentosoides* in Limfjorden). Up to the 1990s the species has been recorded attached in fjords throughout the Kattegat, in the sea area around the island Samsö and in Limfjorden, while drift specimens have been recorded from the coasts of the Skagerrak and the North Sea (Christensen *et al.*, 1985). The species can still be found in about the same quantities as during the 1970s (L Mathiesen, pers. comm.).

There is a possibility that the submersed angiosperm *Myriophyllum sibiricum* (= *M. exalbescens*) is growing in some bays of south Jutland (L Mathiesen, pers. comm.), but so far it is not known how it arrived there.

1.2.5 The Faroe Islands

In 1980 tetrasporophytes of the red alga *Bonnemaisonia hamifera* were found on the Faroes (Irvine, 1982). This is the only introduced species recorded in this area, and neither *Asparagopsis armata, Colpomenia peregrina* nor *Codium fragile* have been found, although searched for.

1.2.6 Finland

The submersed angiosperm *Myriophyllum sibiricum* (= *M. exalbescens*) has been seen in a bay at N Åland since 1990 (Mathiesen and Mathiesen, 1992). Any possibility of introduction, however, was not discussed by them.

A very early introduction was that of the angiosperm *Elodea canadensis*, which since the 1880s was known in Finland (Lagerberg, 1956). Besides being common in inland waters, it also occurs in slightly brackish waters up to the northern part of the Gulf of Bothnia (ICES, 1991). In the Ekenäs archipelago, south Finland, it has been found since 1935 (Luther, 1951).

1.2.7 France

The farming of the Pacific brown alga *Macrocystis pyrifera* from Chile (Braud *et al.*, 1974) was an internationally much disputed pilot scale project carried out at sea in Brittany, France, in the early 1970s (e.g., North, 1973; ICES, 1974; Boalch, 1981, 1985; Delepine, 1983). Permission for the project to be repeated was not given (ICES, 1981). The plants were brought to a hatchery from Chile and the spores gave rise to gametophytes from which young sporophytes were grown and introduced into the sea after about a month. They were allowed to grow for about seven months to a size of 13 m before being harvested in August. It was claimed that the sporophytes had not reached maturity, although young, still sterile, sporangia had differentiated (Braud *et al.*, 1974). There have been no reports during the 1980s of any accidental introductions resulting from this project.

The farming of the Japanese brown alga *Undaria pinnatifida* (e.g., Pérez *et al.*, 1984; Kaas and Pérez, 1989; Floc'h *et al.*, 1991) has been much discussed internationally (ICES, 1984, 1985, 1986, 1987, 1988, 1989; Kain and Dawes, 1987). The main argument for its introduction into the Atlantic, brought from the accidentally introduced populations in the Mediterranean (see below), was increased growth rates. It was originally cultivated at three sites: island of Ouessant (in 1983 and onwards), La Ranche (in 1986) and island of Groix (in 1983 and 1987). It was claimed by the introducers that there was little risk of the species completing its life cycle in Brittany, despite the many literature records of the opposite quoted in the ICES reports. Later surveys (Floc'h *et al.*, 1991) showed that the species did reproduce naturally in the farming area and that it was found outside the farm site. After several evalutions of the risks of continued farming (ICES, 1984, 1985, 1986, 1987) the risks were considered too small (ICES, 1989) to stop further development of farms in the area. Thus new farms have been established in 1989/90 (ICES, 1990; J-Y Floc'h, pers. comm.).

In 1990 the production of farmed *Undaria* was reported to have been 300 tons fresh weight (ICES, 1991). Six different sites, in north and south Brittany, are being tested for further farming, and the species has also been cultivated in the Mediterranean outside l'Étang de Thau (ICES, 1991), with plans to cultivate it also on the Atlantic coast of south France.

Until 1990 only short distance dispersal of *Undaria pinnatifida* has been reported within close proximity of the farming site at the island of Ouessant (Floc'h *et al.*, 1991; J-Y Floc'h, pers. comm.). However, with the spread of the species from the original accidental site of introduction in the Mediterranean in l'Étang de Thau to close to the Spanish border (see below), as well as its spreading from the site of accidental introduction in the southern hemisphere, where it was probably introduced by ships (Hay and Luckens, 1987; Hay, 1990; Sandersson, 1990), further distribution along the European Atlantic coast might be anticipated (cf also Hay, 1990). Hay also discussed the role of coastal boat traffic in the further dispersal of the species, after its introduction. So far, *U. pinnatifida* seems to have little competitive ability and it is also subject to grazing (Kaas and Pérez, 1989; Sandersson, 1990; Floc'h *et al.*, 1991; C Boudouresque, pers. comm.).

In l'Étang de Thau, *Undaria pinnatifida* was first recorded in 1971, probably accidentally introduced in importations of Japanese oysters. During 1981 it was found at Port La Nouvelle and in 1988 at Port Vendres about 10 km from the Spanish border (Peréz *et al.*, 1981; Boudouresque *et al.*, 1985a, 1985b; Floc'h *et al.*, 1991). In l'Étang de Thau it has become fully naturalised and by the late 1980s it grew abundantly, especially on structures used in mariculture, below the fringe of *Sargassum muticum* (Verlaque and Riouall, 1989; Floc'h *et al.*, 1991).

The Japanese brown alga *Laminaria japonica* was first recorded in l'Étang de Thau in 1976, accidentally introduced in importations of oysters, and by 1978 it was well established and accumulating in large mats (Anon., 1982). In the early 1980s it was reported as growing below the fringe of *Sargassum muticum* (e.g., Pérez *et al.*, 1984; Boudouresque *et al.*, 1985a). During the late 1980s it has been cultivated in the lagoon and along the open Mediterranean coast, reaching sizes of 4-5 m in cultures, while the naturally growing plants were only about 1.2 m (ICES, 1991). Since it is closely related to the European species *Laminaria saccharina* it might possibly be able to hybridise with that species (Rueness, 1989).

The red alga *Porphyra yezoensis*, probably of Japanese origin and introduced with oysters, was first reported from Bouziques in l'Étang de Thau, the Mediterranean, in 1975 (Anon., 1982; ICES, 1991). It was rather inconspicuous up to 1981, but more recently it has increased to be abundant on all the rocks around l'Étang de Thau and on the jetties in the new port of Sète, growing below the fringe of *Sargassum muticum* (ICES, 1991). Studies on cultivation of the conchocoelis phase of the species have been undertaken, including its cultivation in relation to temperature (ICES, 1991).

Farming of native populations of the red alga *Euchema spinosum* has been developed in French waters on the islands of Guadelopue and Martinique, in the Caribbean Sea. In June 1981 plants of the same species were flown straight to Guadelope from the Philippines to compare

growth rates under the same environmental conditions (Barbaroux *et al.*, 1984). The plants were put directly into the sea in less than 45 hours. They reported that the imported plants later died after having undergone necrosis, believed to be due to the 'Ice Ice' disease known in southeast Asia. They commented that the native plants at the Antilles were not affected, and thus believed them to be immune.

The red algae *Chondrus crispus* from Brittany, France, and *Hypnea musciformis* from Senegal have been introduced to Corsica, France, for farming in tanks (Mollion, 1984).

In the previous status report (Anon., 1982) the accidentally introduced Japanese brown alga *Sargassum muticum* was quoted as first recorded in France in 1973, while most references in the literature quote the first French record of attached plants to be from the coast of Normandy in 1976. According to some authors it probably was an accidental introduction through imported oysters (Gruet, 1976; Belsher *et al.*, 1984; Belsher and Pommellec, 1988) and Druehl (1973) also predicted its establishment after imports of oysters into France. In the northern most part (Gris Nez) the first drift plant was found in 1972, and the first attached plant in 1978 (Coppejans *et al.*, 1980). According to some scientists, France might also have been the initial site for its introduction in Europe, a question, however, still being discussed (for references see Critchley *et al.*, 1990a), while others emphasise that the areas for the first records of the species in France do not conform with those of imported oysters. After 1976 the species spread rapidly, and before 1983 was sighted all along the French Atlantic coast (Belsher *et al.*, 1984; Belsher and Pommellec, 1988). In many areas, including slightly brackish estuaries, it is growing vigourously, reaching sizes of up to 10 m and creating a nuisance to navigation and mariculture, as well as outcompeting the native algal flora (Belsher *et al.*, 1984; Belsher and Pommellec, 1988). The latter also reported a regression of the populations in some areas southeast of Cherbourg in the mid 1980s.

In the Mediterranean *Sargassum muticum* was first recorded in l'Étang de Thau in 1980, most probably introduced with oysters (Belsher *et al.*, 1984; Knoepffler-Peguy *et al.*, 1985). During the mid 1980s it was growing there in dense populations with up to 3-4 m long plants - on natural substrates substituting native species at depths between 0 to about 2 m - and it was also growing at the uppermost parts of mariculture structures (e.g., Boudouresque *et al.*, 1985a). In 1985 it was first found outside the lagoon, south as far as Port la Nouvelle (probably 1-2 year old populations) and east to Grau du Roi, mainly on artificial substrates down to 1.2 m and as suggested to have been spread by small boats (Knoepffler-Peguy *et al.*, 1985). In 1987 it was sighted as far west as Banyul (Belsher and Pommellec, 1988).

The brown alga *Sphaerotrichia divaricata,* found in l'Étang de Thau in 1981, 1982 and 1983, was also hypothesised to have been introduced by the import of Japanese oysters (Riouall, 1985), since the species occurs in Japan, but it is also a member of the northern Atlantic flora.

The brown alga *Colpomenia peregrina*, which was probably introduced to the Atlantic shores with oysters, was first recorded in 1905 in Vannes and Saint Vaast. By 1907 it had spread north to Wimereux and by 1911 it had spread south to the Spanish border (Sauvageau, 1918; Lund, 1949b). For the northernmost area (Gris Nez) Coppejans (pers. comm.) reported in 1991 that it had not been seen there for several years. Around Brittany, however, the species was still common in the early 1990s (J-Y Floc'h, pers. comm.). The species was first reported in the French Mediterranean in 1956 in the region of Banyul and now it also occurs in l'Étang de Thau where in 1988 it was found to be dominant (Riouall, 1985 and references therein; Verlaque and Riouall, 1989).

During the 1980s some other Japanese red algae, found in the French Mediterranean, predominantly in l'Étang de Thau, have been accidental introductions associated with the farming of imported Japanese oysters. These are *Chrysymenia wrightii* (first recorded in 1978 but also several times in the mid 1980s; Ben Maïs *et al.*, 1987), *Antithamnion nipponicum* (first recorded in 1988, but said to have been in the area for at least five years; Verlaque and Riouall, 1989), *Lomentaria hakodatensis* (quoted as dominant in 1988; Verlaque and Riouall, 1989). Some of these red algae were well developed, but none seemed to be as dominant as the accidentally introduced brown algae. It is now accepted - with some reservations - that the red alga *Grateloupia doryphora*, found in l'Étang de Thau in 1982 arrived with imported oysters (Riouall *et al.*, 1985). The species has also been found in Italy, Spain, south UK and in the south and west Atlantic and the east Pacific.

Also along the Atlantic shores in Brittany there are records of some Pacific and Caribbean red algae such as *Lomentaria hakodatensis* (in Roscoff, 1984) and *Laurencia brogniartii* (in Bay of Brest, 1989). These were probably introduced with imported oysters (Cabioch and Magne, 1987; Cabioch *et al.*, 1990). However, the occurrence of the widely spread red alga *Caulacanthus ustulatus* in the vicinity of oyster beds in Brittany (in Roscoff, 1986) was discussed by Rio and Cabioch (1988). Its introduction was possibly due to long distance dispersal from southern Europe.

The tropical green alga *Caulerpa taxifolia*, which it is believed had escaped by 1984 from the aquarium at Monaco where it was first recorded, spread rapidly and within three years had become a dominant species, occurring along 150 km of the French Mediterranean coast, almost to Toulon (Meinesz and Hesse, 1991). Despite the fact that it is normally a tropical-subtropical plant (but cf also the closely related or conspecific species *Caulerpa mexicana*, which occurs on the Canary Islands and in the east Mediterranean), it has survived winter temperatures of 11-12°C. Further dispersal of *C. taxifolia* along the Mediterranean coast is anticipated. In late 1991 the distribution was reported as from the Bay of Genoa, Italy, to Saint-Cyrien, close to the Spanish border (cf also Spain below). Meinesz and Hesse (1991) also emphasised that this alga contained a natural toxin caulerpenyne, which prevents grazing. However, the native species *Caulerpa prolifera* also contains the same toxin, and the toxicity may vary according to environmental conditions and to the species of grazers. (For more details on *C. taxifolia* see appendix).

Some species are assumed to have been introduced to the Mediterranean coast through discarded fish bait packings from the Atlantic, e.g., the red alga *Polysiphonia nigrescens*. It was first recorded in 1988 in l'Étang de Prévost and had not been seen there during the 1970s (Verlaque and Riouall, 1989), although they also listed records from Italy, Tunis, Greece (the last record doubted by Athanasiadis, 1987) and the Black Sea. The vector for the introduction of the brown alga *Fucus spiralis* to the French south coast (Gruissan, observed growing through three months in 1987; Sancholle, 1988) could not be clearly given by him, but it grew on a jetty, which might point to accidental introduction. Later Verlaque and Riouall (1989) assumed it to have been brought there by discarded bait.

Another suggested introduction is the Atlantic brown alga *Chorda filum*, which was reported as common in 1981-1982 in the l'Étang de Thau, but deteriorating in 1983 (Gerbal *et al.*, 1985; Riouall, 1985). Its way of introduction, however, was not discussed. In 1988 this species was listed as dominant in l'Étang de Thau (Verlaque and Riouall, 1989).

There are reports also of other possibly accidentally introduced red algae into the Mediterranean. Among those, *Polysiphonia setacea*, with a known distribution in the Pacific, the Indian Ocean and the tropical Atlantic, was first recorded in great abundance in 1987 at Giens, Var, sometimes clogging fish nets (Verlaque, 1989). However, the method of introduction was not stated. He also discussed the possibility of the accidental introduction, probably due to shipping, of the Atlantic red alga *Aglaothamnion feldmanniae*, recorded in Toulon, Var, in 1979, but also in northern Italy in the 1970s. The same method of introduction might also apply to the Indo-Pacific red alga *Acrothamnion preissii*, first recorded in northern Italy (Livorno) in the late 1960s and in France in Villefranche in 1981 and Var in 1984 (for references see Verlaque, 1989).

The western Atlantic red alga *Polysiphonia harveyi*, discussed as a possible, recent introduction to UK (see below), has also recently been found at Roscoff, Brittany, (J. Rueness, pers. comm.).

Another red alga of the Caribbean and the Indo-Pacific, *Mesothamnion caribaeum*, has been discussed as possibly accidentally introduced to the French Atlantic coast, first recorded in Brest in 1967 and later into the Mediterranean, as well as to south Portugal (Ardré *et al.*, 1982).

The red algae *Antithamnionella sarniensis* and *A. spirographidis* have both been recorded from the French Atlantic coast (e.g., L'Hardy-Halos, 1986; Athanasiadis, 1990). Both their origin and

taxonomic affinities have been much discussed as they might be considered accidentally introduced, *A. sarniensis* recorded in France since 1910 (Westbrook, 1930 and references therein), while *A. spirographidis* was first described from the Adriatic Sea.
Recent accidental introductions, as one of several possible explanations for their appearance, have been discussed for other groups of both warm water and cold water species new to the Mediterranean, now commonly occurring. The boreal species mentioned are from the Atlantic, the common brown algae *Leathesia difformis*, first found 1979 in l'Étang de Thau, but also known from the Black Sea (Verlaque, 1981), and *Desmarestia viridis*, found in 1979 in l'Étang de Thau (Verlaque, 1981), but also recorded during the 19th century in the Adriatic Sea, and stated as common in 1988 in l'Étang de Thau by Verlaque and Riouall (1989). The warm water species mentioned are the tropical Atlantic red alga *Laurencia microcladia*, first found in 1979 at Corsica (Verlaque, 1981), and the pantropical red alga *Dipterosiphonia dendritica*, first found in 1979 in Corsica (Verlaque, 1981).
The first gametophytes (females) of the red alga *Bonnemaisonia hamifera* were discovered in Cherbourg in 1898 (Sauvageau, 1918) and the first male plants in Brittany in 1963 (Bichard-Bréaud and Floc'h, 1966), while the tetrasporophytes are known in north France at least since 1921 (Westbrook, 1930 and references therein). Tetrasporophytes have also been recorded from the Basque coast of France at Biarritz (van den Hoek and Donze, 1966). In the early 1990s the species is common, especially the tetrasporophytes, while the gametophytes sometimes appear more irregularly, and less commonly than *Asparagopsis* (J-Y Floc'h, pers. comm.).
The red alga *Asparagopsis armata* was first recorded as tetrasporophytes in 1922 in north France (Cherbourg), and as gametophytes in 1925 (Westbrook, 1930; Dizerbo, 1964 and references therein). It has also been recorded in the Mediterranean since the early 1920s, where it was described as creating veritable prairies on the bottom (Svedelius, 1933). Westbrook and others suggested shipping as a vector for its introduction. Since that time the species has spread and in the early 1990s it was very common in suitable habitats, the gametophytes in more wave exposed areas than the tetrasporophytes. For instance gametophytes were seen as epiphytes on the introduced brown alga *Undaria* at Ouessant (ICES, 1987). Tetrasporophytes have been recorded also from Biarritz (van den Hoek and Donze, 1966).
The green alga *Codium fragile*, which after its introduction into Europe was spreading over large areas, has increased its distribution in the Mediterranean from Banyul in the 1950s to Marseille in the 1960s, Toulon and the l'Étang de Thau in the 1970s (Gerbal *et al.*, 1985; Riouall, 1985 and references therein). On the French Atlantic coast the ssp. *tomentosoides* was first reported in 1946 (Silva, 1955). Coppejans (pers. comm.) reported that during the 1980s small specimens of the species could still be seen in the northern part (Gris Nez). In the early 1990s it still occurred around Brittany (J-Y Floc'h, pers. comm.).
The small red alga *Antithamnion densum*, which might represent an introduced species, was found in Brittany in the late 1960s and in north France in the early 1980s (for references see Athanasiadis, 1990; Guiry and Maggs, 1991).

1.2.8 Germany

The common intertidal North Atlantic red alga *Mastocarpus stellatus*, which does not grow naturally on the island of Helgoland, was transplanted to a rock on the island by a guest scientist in the late 1970s and in the early 1990s it had colonised the whole west coast of the island (K Lüning, pers. comm.). Also the Arctic red alga *Devaleraea ramentacea* (= *Halosaccion ramentaceum*) was transplanted to Helgoland from Iceland in 1975 and 1976, but apparently did not survive the high summer temperatures (Munda, 1979). It was not recorded after that.
During the 1970s hybridisation experiments were carried out at Helgoland between the European brown algae *Laminara saccharina* and the Canadian *L. longicruris* (Lüning *et al.*, 1978). F_1-generations of both hybrids and sporophytes were achieved from parents which were cultivated in the sea, but were removed after seven months before sporangia had developed. Later additional crossing experiments were made, including also the Japanese species *L. ochotensis* and *L. saccharina* from British Columbia (Bolton *et al.*, 1983), which were also removed while sterile.

Furthermore, growth experiments with *Alaria esculenta* have been carried out at sea off Helgoland, which is within its range of distribution in Europe, but where the species does not grow naturally because of too high summer temperatures (Munda and Lüning, 1977b).

Cultivation experiments were performed in tanks at Helgoland with young sporophytes reared from laboratory gametophytes of the south Atlantic *Laminaria abyssalis*, *L. pallida*, *L.schinzii*, the north Pacific *L. bongardiana* (as *L. groenlandica*), *L. setchellii,* the north Atlantic *L. ochroleuca* as well as of the native *L. digitata* and *L. hyperborea*. The tanks received fresh sea water daily, and great care was taken to prevent the escape of the non-native species (Lüning *et al.*, 1989).

The Japanese brown alga *Sargassum muticum* was found attached on the island of Helgoland (Südhafen) for the first time in 1988 and was seen again at the same place in 1990 at 1 m depth, and 10 specimens were found in a tide pool in March 1991 (K Lüning, pers. comm.). By 1981 and 1982 drift specimens were seen at several of the east Frisian Islands, and in 1982 at an island in the German Bight (Kremer *et al.*, 1983). However, there is no information available of any attached specimens in those areas. As discussed below for Sweden, the species may also reach the southwest Baltic in the future.

In 1984 the Japanese red alga *Porphyra yezoensis* was recorded on the island of Helgoland (Südhafen), the way of introduction being unknown (Kornmann, 1986). However, the species has not been recovered since in the area (K Lüning, pers. comm.).

Bonnemaisonia hamifera was first found as tetrasporophytes on Helgoland around 1900 (Koch, 1951). It is now common, and gametophytes have been found irregularly, females since the 1910s and male plants since the beginning of the 1960s (Kornmann and Sahling, 1977; Breeman *et al.*, 1988). Koch (1951) also suggested that some of the populations on Helgoland may originate from discarded material sampled on scientific expeditions to Norway.

The green alga *Codium fragile* ssp. *tomentosoides* was first seen on Helgoland in 1930 (see Silva, 1957 for references). In the 1970s it was growing in small quantitaties on the southern part of the island (Kornmann and Sahling, 1977).

In 1989-1991 *Fucus evanescens* was seen in the SW Baltic (Flensburger Fjord; L Mathiesen, pers. comm.), probably recruited from Danish populations.

There are no records in German waters of other species introduced into northern Europe such as the red algae *Dasya baillouviana* and *Asparagopsis armata*, nor of the brown alga *Colpomenia peregrina* (K Lüning, pers. comm.).

Luther (1979) thoroughly discussed the early introduction of the charophyte *Chara connivens* by solid ballast in sailing ships. On the German Baltic coast (including former DDR) it was first recorded in the 1850s and onwards to 1910s. Its present status is not known.

1.2.9 Iceland

The tetrasporophyte generation of the red alga *Bonnemaisonia hamifera* (Munda, 1979) and the green alga *Codium fragile* (Jónsson and Gunnarsson, 1975) are the only examples of the species introduced into Europe (I Munda, pers. comm.). *Bonnemaisonia* was first recorded in 1978 in northwest Iceland (Dyrafjördur) and has only been seen there.

1.2.10 Ireland

Proposals to introduce *Undaria pinnatifida* to Ireland for commercial farming have been rejected (M Guiry, pers. comm.; D Minchin, pers. comm.).

The accidental introduction of the red alga *Gracilaria multipartita* (= *G. foliifera*) by oysters from France (ICES, 1982) has not been possible to confirm, and has not resulted in attached plants. The species is now considered as totally accidentally introduced and it does not appear to have become established (M Guiry, pers. comm.). The plants, consisting of females only, were found detached and growing well in a lobster pond in 1977 at Galway (Guiry and Freamhainn, 1985). It was recovered in 1981, but no specimens have been seen later in that pond. Drift plants were also collected by J P Cullinane in the mid 1970s in Co Kerry (M. Guiry, pers. comm.). The species occurs in southern UK, France and Spain.

The red alga *Polysiphonia harveyi*, discussed as a possible recent introduction to UK (see below), was also found as a common epiphyte around

Ireland during the 1980s (Maggs and Hommersand, 1990).

Although described as a new species, the red alga *Cryptonemia hibernica* is believed to be related to a Pacific group of species, and thus has probably been introduced from the northeast Pacific (Guiry and Irvine, 1974; Cullinane *et al.*, 1984; cf also Maggs and Guiry, 1987), being the only European record of the species. It was first recorded as drift in Cork harbour in 1971, occurring there also in 1972-1973, and first recorded as attached in 1976. In 1979 it was found also in two other bays on the south coast at about 20 km distance, and was then expanding (Cullinane *et al.*, 1984 and references therein). Another less closely related species, *C. seminervis*, has been reported from the coast of Brittany and the Channel, France (for references see Guiry and Irvine, 1974), and the Scilly Islands, UK (Maggs and Guiry, 1987).

The first report of the brown alga *Colpomenia peregrina* seems to be from the southwest coast in 1931, while it was first recorded in Northern Ireland in 1934 (Lund, 1949b and references therein). During the late 1930s it had spread to almost all parts of the Irish coast. It is now locally abundant in sheltered embayments and several new localities were registered in 1988 and 1989 in Ireland (Minchin, 1991).

The red alga *Bonnemaisonnia hamifera* has been reported as gametophytes in Ireland since 1911, and in the late 1980s both generations are still present and commonly found (Breeman *et al.*, 1988). Detailed reports of the occurrence and timing of the reproductive behaviour in relation to daylength and temperature were given by Breeman *et al.* (1988) and Breeman and Guiry (1989) for populations from west Ireland (south Galway Bay).

The red alga *Asparagopsis armata* has been known in Ireland as tetrasporophytes since 1939 and as gametophytes since 1941 (for references see Guiry *et al.*, 1979), first seen on the west coast (Co Galway). During the late 1950s the tetrasporophytes were reported from the northwest, west and southwest coasts, while the gametophytes were then known only from the west coast. In 1972 the latter were also reported from the southwest coast (Guiry *et al.*, 1979). The tetrasporophytes seldom give mature spores, which may explain the different distributions of the two stages. On the southeast coast the species has only been known since 1977 (both stages), and was not seen there in the 1960s (Guiry *et al.*, 1979). Because of different ecophysiological performances the species is now believed to have originated directly from the southern hemisphere, since it differs in induction of tetrasporogenesis from the behaviour of the Mediterranean populations, the first known site in Europe (M Guiry, pers. comm.). He does not consider Australia as the source for any of these introductions.

Both ssp. *atlanticum* and ssp. *tomentosoides* of the green alga *Codium fragile* have been recorded from Ireland, the former as early as in the middle of the 19th century, the latter at least since 1950 (Silva, 1955). From a survey in the early 1980s Maggs *et al.* (1983) stated the latter to be rather common intertidally, but occasional subtidally in the marine reserve on the south coast. It is now widespread in Ireland, while the former is relatively rare (M Guiry, pers. comm.). He considered the distribution to be about the same as listed by Parkes (1975).

The diminutive red alga *Antithamnion densum* was found in 1990 off Clare Island, west Ireland, (Guiry and Maggs, 1991). The possibility that it is an introduced or a native north Atlantic, overlooked species, was discussed by the authors. They also quoted Athanasiadis (1990, p 223), who considered the species as introduced in Europe.

Although increasing along the southern shores of the UK, there are so far no records of the brown alga *Sargassum muticum* from Ireland (M Guiry, pers. comm.; D Minchin, pers. comm.).

1.2.11 The Netherlands

There are several papers (for a review see Critchley *et al.*, 1987; Critchley *et al.*, 1990b) documenting the subsequent dispersal of the brown alga *Sargassum muticum* in the Netherlands after the first accidental introduction of drift plants recorded in 1977 and the first attached ones at the island of Texel, in Lake Grevlingen and two other areas in 1980 (Prud'homme van Reine and Nienhuis, 1982). The species has been especially successful in establishing extensive populations in the non-tidal, cut off brackish lakes. In Lake Grevlingen, the maximum was reached in 1985 and the populations were after that stable, all potential sites occupied, and only minor changes were noted through the late 1980s (Critchley *et* *al.*, 1990b). The abundances of several other macroalgae had been reduced (Critchley *et al.*, 1987). They also reported wide belts of *Sargassum* sometimes up to 10 m, an almost 100% cover of the surface and decreased frequencies and sizes of native species. In the eastern Scheldt, the western parts were colonised in 1980, the species spread between 1982 and 1985, after which only slow progress towards the eastern part occurred with four new localities recorded between 1985 and 1988 (Critchley *et al.*, 1987, 1990b). Later on the authors also found *Sargassum* for the first time in the heavily eutrophic brackish lake Veere. However, the final success of the plants in such brackish conditions (23‰) is not known.

The green alga *Codium fragile*, first seen in 1900 (ssp. *tomentosoides*; Silva, 1955), has been reported as dominant in some areas along the North Sea coast (e.g., den Hartog, 1959; Nienhuis, 1980) and was considered as naturalised by den Hartog and van der Velde (1987). However, Critchley *et al.* (1987) reported that *Codium* had decreased or almost disappeared in Lake Grelingen from 1982 to 1986 as a result of the colonisation of *Sargassum muticum*, and that only small germlings were seen among the bases of the *Sargassum* plants.

The red alga *Dasya baillouviana* was found for the first time in 1950 (den Hartog, 1964 as *D. pedicellata*). It has been suggested that its discontinuous distribution might be due to specific demands on the habitats (e.g., den Hartog, 1964; Røsjorde, 1973). However, the gap between its occurrences on the Spanish coast and in the Netherlands is large. Den Hartog (1964) also discussed the possibility of imported oysters being a vector for the first established plants in the Netherlands, as well as ships, since one of the localities also had heavy boat traffic. The present status is not clearly known, but den Hartog and van der Velde (1987) reported it as not naturalised.

The red alga *Bonnemaisonia hamifera* was mentioned as occurring in drift by Lucas (1950), but there is no report available on its present status. Also the red algae *Asparagopsis armata* and *Antithamnionella sarniensis* have been recorded in drift (den Hartog, 1959), but he stated that they did not grow east of the '*Chthamalus* line' in the English Channel.

A record of the brown alga *Colpomenia peregrina* from the Frisian islands in 1921 was quoted by Lund (1949b), but no report on its present status is available.

Several angiosperms and water ferns are reported as introduced into the fresh water canals, most of them not naturalised, except for the North American *Elodea canadensis* and *E. nuttallii* and the fern *Azolla filiculoides* (den Hartog and van der Velde, 1987).

1.2.12 Norway

The Japanese brown alga *Sargassum muticum* was first found as drift plants in south Norway in 1984, and in 1988 the first attached plants were found (Rueness, 1989 and references therein). During 1989 it was found attached at several new localities along the Norwegian coast of Skagerrak, from west of the mouth of the Oslofjord in the east, to as far west as Mandal, occurring partly in large quantities and reaching sizes of 1-2 m (Rueness, 1990). Drift plants have been seen as far north as west of Stavanger. Rueness (1990) stated that it mainly occupies areas where other species of the Fucales are less well developed, but that it can be a nuisance in marinas and recreation areas. He also predicted its further dispersal along the Norwegian coast towards the north and east, including into the inner Oslofjord, where so far only drift plants have been found. During 1990-spring 1991 the species had about the same distribution as in 1989 (J Rueness, pers. comm.)

The western Atlantic red alga *Polysiphonia harveyi*, believed to be a recent introduction to UK, (see below) has recently also been found at several localities along the Norwegian Skagerrak coast (J Rueness, pers. comm.).

The first record of the brown alga *Colpomenia peregrina* dates back to 1933 outside Bergen (Grenager, 1950). The alga has since then 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 and Nerland, 1972). In the 1980s it had also spread to the Skagerrak coast, where it had not occurred previously (Rueness *et al.*, 1990). After the warm winters of 1989 and 1990, the species was found in large amounts, while, in Sweden (see below), that was not the case in the more 'normal' spring of 1991 (J Rueness, pers. comm.).

The terasporophyte generation of the red alga *Bonnemaisonia hamifera* was first recorded in 1902 and now occurs all along the Norwegian coast (Rueness, 1977; and pers. comm.). 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 (for references see Breeman *et al.*, 1988).

Fucus evanescens was introduced to south Norway about 100 years ago (Bokn and Lein, 1978 and references therein) and has since then become a rather common plant in that area, especially in harbours and nutrient enriched waters such as the inner part of the Oslofjord.

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 (Ostfold) to N Troms (Rueness, 1977). According to Silva (1957) it has probably eliminated the native species *Codium vermilara* in Norway. *C. fragile* ssp. *scandinavicum* was considered by Silva (1957) to be 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). As for the Swedish west coast, *C. fragile* seems to have been less abundant in the late 1980s (J Rueness, pers. comm.).

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 still found at suitable localities and in 1990 it occurs along the south coast from the outer Oslofjord to Kristiansand (J Rueness, pers. comm.). As stated above (see the Netherlands) its way of introduction to northern Europe has been debated.

So far there has been no record of the red alga *Asparagopsis armata*, (J Rueness, pers. comm.) although when the first tetrasporophytes were reported from the Shetland Islands in 1973 (Irvine *et al.*, 1975), they predicted its spread to Norway in the near future.

1.2.13 Poland

There is only one record available of macrophytes introduced to the Baltic coast of Poland. There was an early introduction by solid ballast in sailing ships of the charophyte *Chara connivens*, recorded during three decades at the end of the 19th century, which has been thoroughly discussed by Luther (1979). However, its present status is not known. This calciphilous fresh water species is otherwise found in fresh water and estuarine lagoons in west Europe and North Africa. Also the angiosperm *Elodea canadensis* may occur (for reference see Leppäkoski, 1984).

1.2.14 Portugal

In 1990 the Japanese brown alga *Sargassum muticum* was found as drift plants on the west coast of Portugal, north of Lisbon, probably carried by the water currents from Galicia, northwest Spain (ICES, 1992). Judging from the pattern of its accidental introduction in other European countries, an attached population could be expected to develop a few years after the first drift to the area. In May 1991 plants about 3.5 m long were found attached in small lagoons north of Oporto, where according to local fishermen it had been seen for three years (ICES, 1992).

A small red alga of the Caribbean and the Indo-Pacific *Mesothamnion caribaeum*, has been discussed as possibly accidentally introduced to S Portugal (Ardré *et al.*, 1982), probably in the 1970s, after first being recorded in France (see above). However, it has not been seen in later surveys (J C de Oliviera, pers. comm.).

On the Azores the Pacific red alga *Symphyocladia marchantioides* was recorded for the first time in the Atlantic during the Biaçores expedition in 1971 (Ardré *et al.*, 1974). Since the archipelago had previously been sparsely studied and the species was partly growing at depths of about 15-20 m in localities which were quite exposed to waves, they considered it difficult to judge if it was a recent introduction or not.

Ardré (1970 and references therein) listed the following species as accidentially introduced to Europe and occurring in Portugal: the red algae *Asparagopsis armata* and *Antithamnionella sarniensis*, and the brown alga *Colpomenia peregrina*. Later surveys have shown *Asparagopsis armata*, including its tetrasporophyte, to be abundant in the upper sublittoral in south and central Portugal attached to rocks or other algae, while *Colpomenia peregrina* was only rarely seen on the S coast (J

C de Oliviera, pers. comm.). He has not found *Antithamnionella spirographides*, listed for Portugal by South and Tittley (1986; but cf also L'Hardy-Halos, 1986 for taxonomy).
Ardré's flora did not include the red alga *Bonnemaisonnia hamifera*. However, since Breeman *et al.* (1988) indicated a general distribution through Europe to northwest Africa and the Canary Islands, it might occur in Portugal, although no record of its presence is available. It has not been seen in recent surveys (J C de Oliviera, pers. comm.). Nor are there any Portuguese records of the green alga *Codium fragile.*

1.2.15 Spain

In June 1990 the first record of the Japanese brown alga *Undaria pinnatifida* was reported from the Ria de Arosa (at El Grove, Pontevedra), presumably it arrived there with imported oysters (Santiago Caamaño *et al.*, 1990; ICES, 1991) It was found growing along approximately 10 km of the area, both on rocks and farm structures for blue mussels, in sizes up to 65 cm on rocks and up to 100-110 cm on the man-made structures. Santiago Caamaño *et al.* (1990) also cautioned about the probable accidental introduction into the area in the future of other species often found with imported molluscs such as *Laminaria japonica.* So far, there are no records of *U. pinnatifida* from the Mediterranean coast of Spain.
In the early 1990s several red algae, known to be introduced with oysters in other areas, have been found in Galicia, northwest Spain (ICES 1992): *Lomentaria hakodatensis* (1992), *Grateloupia doryphora* (1990) and *G. filicina* (1990). *Pikea californica*, which is assumed to have reached Europe during World War II (see below under UK), was found in Galicia in 1991 (ICES, 1992).
The first appearance of the Japanese brown alga *Sargassum muticum* in Spain was recorded in the Basque province (at Guetaria) in 1985 (Casares Pascual *et al.*, 1987), and in 1987 it was found in the northwest of Spain (Ria de Arosa, at Grove) (Pérez-Cirera *et al.*, 1989; Santiago Caamaño *et al.*, 1990). During 1988 to 1989 it was recorded for the first time (Fernández *et al.*, 1990) at three other localities along the Asturian coast in north Spain (at Aramar, Bañugues, Cudillero). In these areas it was first found growing in rock pools and later, when going through a very rapid phase of expansion, it had expanded into the intertidal and subtidal. The growth was faster in areas without large macrophytes and with low desiccation stress, reaching a maximum size of 2.7 m (Fernández *et al.*, 1990). Later the expansion has been reported to have stabilised. So far there are no reports available of any occurrence along the Mediterranean coast of Spain, although it is growing in several areas along the French Mediterranean coast as far west as Banyul (see above).
In late spring 1992 the green alga *Caulerpa taxifolia*, accidentally introduced into the Mediterranean, was reported in newspapers to have reached the Spanish Mediterranean coast (cf France above). It is expected to spread further along that area (ICES, 1992).
Verlaque (1981) discussed the pantropical red alga *Dipterosiphonia dendritica* as a potential, recent introduction to the Mediterranean, and he also quoted a record in south Spain (Cadiz) from the 1960s.
The red alga *Bonnemaisonnia hamifera* is not recorded from the Atlantic Spanish coast in the checklist by South and Tittley (1986). Breeman *et al.* (1988) quoted records of gametophytes in southeast Spain (Malaga) published by Conde and Seoane Camba (1982) and it was listed as new to the Balearic Islands in the late 1980s (Cremades, 1989). Since Breeman *et al.* (1988) also indicated a general distribution through Europe to northwest Africa and the Canary Islands, it might occur also along the Atlantic shores, although no record of its presence is available and many papers do not list it as present. As stated above it was recorded from the southernmost Basque coast of France in the mid 1960s at Biarritz (van den Hoek and Donze, 1966).
The checklist by South and Tittley (1986) includes species accidentally introduced to Europe such as the red algae *Asparagopsis armata* and *Antithamnionella spirographidis*, and the brown alga *Colpomenia peregrina* for both the south and north Atlantic coast of Spain. However, no records of their present status are available. *A. armata* has been known in south Spain and Gibraltar since the 1920s (Westbrook, 1930). Both stages, together with *Anthithamnionella sarniensis*, were listed as herbaria specimens from the Galician and

Cantabrian coasts, north Spain, in the early 1930s and late 1920s, respectively (Valenzuela and Pérez-Cirera, 1982). Both stages of *A. armata*, together with *C. peregrina,* were also found to be common in northwest Spain in the early 1960s (Donze, 1968).

The list (South and Tittley, 1986) does not include the occurrence of the green alga *Codium fragile*, but Silva (1957 p 126) reported the species to be rapidly spreading through Spain at that time. *C. fragile* ssp. *tomentosoides* was reported from several localities in north Spain (Galicia) in 1986 (Pérez-Cirera *et al.*, 1989).

A red alga, identified as the Australian species *Predaea huismanii* was found in the late 1980s on east Tenerife, and the Caribbean red alga *Platysiphonia caribaea* in north and northeast Lanzarote, Canary Islands (Sansón *et al.*, 1991). However, the possibilities of introductions were not discussed, albeit the other three Atlantic species of *Platysiphonia* are from the west Atlantic and tropical Africa. Also the red alga *Mesothamnion caribaeum* has been found on the Canary Islands at Fuerteventura (for reference see Ardré *et al.*, 1982)

1.2.16 Sweden

The red alga *Gracilaria sordida* (= *G. secundata*) has been brought from New Zealand to Sweden in 1983 for cultivation in laboratory tanks in pilot scale (Lignell *et al.*, 1987). Later on species brought from Florida, *G. lemanaeformis*, from southwest Puerto Rico, *G. verrucosa*, and from China, *Gracilaria tenuistipitata* var. *liui*, were also used for laboratory tests to produce protoplasts, (Björk *et al.*, 1990). The latter species was also cultivated in land-based fish ponds on the Baltic coast 1989-1990, where it did not survive a water temperature below 7°C (Haglund and Pedersén, 1992).

The Japanese brown alga *Sargassum muticum* was first found attached in the northern part of the province of Bohuslän in 1987 (two localities), two years after the first drift plants had been seen (Karlsson, 1988), probably arriving by drift from Denmark. In 1989 (Karlsson *et al.*, 1992) 38 sites were known in the east Skagerrak and in 1990 it was reported as growing at a total of 65 localities along the shores of Skagerrak, from the island of Orust and northwards to the Norwegian border, about 150 km. At some places it was found forming belts and occurred maximally down to a depth of 7 m. Karlsson *et al.* (1992) also reported that locally it has started to be a nuisance to the fishery, but so far it has not outcompeted native species. Although found as drift plants in the north and south Kattegat, attached plants have been recorded only in the northernmost Kattegat in 1991 (Karlsson *et al.*, 1992), although several sites in the whole area have been surveyed closely for algal vegetation during the late 1980s (M Pedersén, pers. comm.; T Wennberg, pers. comm.). It has not been possible to verify the report of drift plants in Sweden as early as in 1982 (ICES, 1982), but this is not unrealistic. In laboratory experiments tolerance for low salinity has been shown down to about 7‰ (Hales and Fletcher**,** 1989). This, as well as its presence in brackish water in other European countries, at least down to about 20‰, makes it possible that the species will finally disperse at least to the Öresund, and possibly reach the southern Baltic proper, where the salinities normally exceed 6‰ (cf discussion by Hales and Fletcher, 1989).

The brown alga *Colpomenia peregrina*, first recorded in Sweden in 1950 in Bohuslän (Suneson, 1953), has been seen in northern Bohuslän most years during the 1970s and 1980s (B Rex, pers. comm.). During the warm spring of 1990 the species was very common and unusually large specimens were found in the northern part, mainly attached to mussels (J Karlsson, pers. comm.). During the spring of 1991, when the water temperature was more normal, very few plants were seen.

The red alga *Dasya baillouviana*, first seen in the province of Bohuslän in 1953 (Suneson, 1953) still occurs at suitable localities, including the northern part of the west coast (Wallentinus own observations), but it does not seem to increase in abundance.

The tetrasporophyte generation of the red alga *Bonnemaisonia hamifera* was first recorded in the province of Bohuslän in 1902 and in Halland in 1939, although only sparsely found in the southern part (Suneson, 1939 and references therein). It is still very common in the province of Bohuslän, and north Halland, often entangled in masses among many subtidal algae, but further south in Halland and the Öresund it occurs less frequently (von Wachenfeldt, 1975; Karlsson, 1986). The first record from the Öresund proper was made in 1964, the plants being abundant for some years and then more sparse (von Wachenfeldt, 1975). So far there are no reports of the gametophyte generation from Sweden, nor of any of the generations of the red alga *Asparagopsis armata*, although they have been looked for.

The green alga *Codium fragile* ssp. *tomentosoides* was first recorded in Sweden in 1938 and ssp. *scandinavicum* in 1932 (Silva, 1957). The species was considered dominant during the 1950s (Suneson, 1953) and has since then been a common, but not dominant species in the province of Bohuslän. Further south, in the province of Halland, it has only been found sporadically (Karlsson, 1986). In the Öresund it has only been seen as drifting plants (von Wachenfeldt, 1975). However, in some areas in the middle and northern parts of Bohuslän its frequency seems to have dropped during the late 1980s (J Karlsson, pers. comm.; C Larsson, pers. comm.), and in the spring of 1991 it was sparse in northern Bohuslän.

The North Atlantic species *Fucus evanescens*, probably introduced into Sweden, was first recorded in the province of Bohuslän in 1924 and in Halland in 1928 (Hylmö, 1933). He suggested that the first plants had arrived on the Swedish west coast in the late 1920s, introducted by fishing boats, since they were found in harbour areas, where junk from boats had been frequently discarded. However, Lund (1949a, 1956), questioned that and suggested instead that the species had probably arrived there by long distance dispersal of floating plants. During the last decades the species has been recorded in several areas, from the Öresund in the south to the northernmost part of the province of Bohuslän (von Wachenfeldt, 1975; Wennberg, 1987; Wallentinus own observations). It seems to have increased in importance in nutrient enriched water, especially in the south Laholm Bay and the bay of Skälderviken, and also commonly occurs in the Göteborg archipelago.

The submersed angiosperm *Myriophyllum sibiricum* (= *M. exalbenscens*) has been found in some bays in the Öregrund archipelago (Mathiesen and Mathiesen, 1992), but the possibility of an introduction was not discussed by them.

A very early introduction was that of the angiosperm *Elodea canadensis*, which since the 1870s occurs in Sweden (Lagerberg, 1956), and is also found in slightly brackish waters.

The early introduction during the last century of *Chara connivens* into the Baltic Sea by solid ballast in sailing ships, recorded already from the mid 19th century in the south Baltic Sea, has been thoroughly discussed by Luther (1979), all sites quoted from the Baltic being known ballast sites. In Sweden it was recorded in the mid 1950s in the Öregrund archipelago. However, its present status is not known. This calciphilous fresh water species is otherwise found in fresh water and estuarine lagoons in west Europe and North Africa.

1.2.17 United Kingdom (including the Channel Islands and the Isle of Man)

So far there are no records of any algae having been brought deliberately to the UK. In the 1950s a proposal to cultivate *Macrocystis pyrifera* was turned down (ICES, 1974). Further, a request in 1987 to cultivate *Undaria pinnatifida* on the island of Guernsey was turned down (ICES, 1988) and up to 1990 this request has not been renewed (S Utting, pers. comm.).

The Japanese brown alga *Sargassum muticum* was first reported as attached on the Isle of Wight and at Portsmouth in 1973, while a drift plant was found in that area in 1971 at Southsea (Farnham, 1980). The population at Bembridge was suggested to be at least two years old (Farnham, 1980; Critchley *et al.*, 1983). The dispersal of the species has been extensively followed since its first discovery, which has been described in a large number of studies (for references see Critchley *et al.*, 1990a). During the late 1970s the population densities increased in several areas along the south coast, mainly on free substrate, and drifting plants especially caused a nuisance to navigation (e.g., Critchley, 1983). The attempts to eradicate the populations during the early years of colonisation did not succeed and were abandoned (e.g., Farnham, 1980; Critchley *et al.*, 1986). At the beginning of the 1980s the species was found along 360 km of the south coast (Eastborne to Plymouth), but has been found only once on the southeast coast (Norfolk) and has not been recovered or established there (Critchley *et al.*, 1983; W F Farnham, pers. comm.). Farnham (1980) predicted it to have a potential distribution all around the British Isles. However, despite the many records from other northern European countries, surprisingly, there have been no reports during the 1980s of attached plants from parts of the UK other than the south coast. There, however, it has been expanding in the west to the Scilly Isles and Looe, south Cornwall, and was in the late 1980s found on the SE coast in Kent at Abbotscliff and Margate (W F Farnham, pers. comm.). He also informed that it is well-established in the Channel Islands (Guernsey, Jersey, Alderney and Sark) and that drift plants were found once in south Wales, but that it has not become established there.

The potential use of the species, including a potential in mariculture, has been discussed in several countries, where it is now established, and many of these aspects, as well as earlier studies in this respect, are summarised in a recent review (Fletcher and Hales, 1989).

The western Atlantic red alga *Polysiphonia harveyi*, was discussed as a possible, recent introduction to the UK. It was first collected in 1976 in Plymouth, later being found as a common epiphyte on e.g., *Sargassum, Codium* and *Zostera* in south England and southwest Scotland (Maggs and Hommersand, 1990). However, they also mentioned a possible conspecificity with *P. insidiosa*, described from Atlantic France in the 1860s. *P. harvyei* is believed to have spread by drifting of larger seaweeds.

The red alga *Pikea californica*, previously known only from the Pacific American coast and Japan, was first recorded from the Isles of Scilly in 1967, and was found growing abundantly in the surf zone of the Isles in 1983 (Maggs and Guiry, 1987). They discussed the possibility of the species having been introduced to Scilly with flying boats during World War II, since it was immensely insensitive to harsh treatment. They also predicted its further spread in Europe, while they rejected oyster imports as the vector, since that had not occurred into the area until very recently, when quarantine restrictions were enforced. The only other report of the species in Europe is from Spain (see above).

Farnham (1980) discussed some recent accidental introductions of red algae of a suggested Pacific origin into the south coast, of which some have been spreading within the area since the first discovery: *Grateloupia filicina* var. *luxurians*, the taxon described from New South Wales, Australia, was first seen in 1947 in several localities of the Solent area, *Grateloupia doryphora* (first seen in 1969 in several localities in the Solent area; and *Neoagardiella gaudichaudii* (= *Agardhiella subulata)* was first found in 1973 in few localities in the Solent area. Farnham (1980) also discussed the possible introduction of Atlantic red algae into the south and southwest UK such as the two species of *Solieria*, *S. chordalis,* first found in 1976 in Falmouth and later in Dorset, and *S. tenera,* first found in 1978 in Milford Haven. Hiscock (1986) quoted reports that these two species may be conspecific.

The red alga *Bonnemaisonia hamifera* was first recorded as tetrasporophytes in 1890 (Dorset) and as gametophytes in 1893 in south Cornwall (for references see Farnham, 1980). The tetrasporophytes (no gametophytes) were first recorded from the Orkney Islands in 1929 (Westbrook, 1930) and from the Shetlands in 1949 (Irvine, 1982). Drift plants of gametophytes have been recorded from east Scotland (Wilkinson, 1975). Hiscock (1986) stated that the gametophytes occur on the south and west coast, and the sporophyte as far north as Shetland, where it is locally common.

The first record of the red alga *Asparagopsis armata* from the British mainland (for references for UK see Irvine *et al.*, 1975; Wilkinson, 1975) was that of the tetrasporophytic stage ('*Falkenbergia*') in 1949 on the southwest coast of Lundy. During the early 1950s both generations were recorded at several localities on the south coast (Cornwall, Scilly Isles, south Devon). The species was first reported (tetrasporophytes only) in the 1960s, from the west coast of Scotland and the Inner Hebrides, the first records from the Orkney and Shetland Islands in 1973, and further east than before from the south coast (Lymington, Hampshire) in 1973. Dizerbo (1964) quoted records from the English Channel Islands of the tetrasporophytes in the the early 1930s and gametophytes in the late 1930s. However, the tetrasporophytes seldom give mature spores, which may explain the difference in distribution of the two stages (M Guiry, pers. comm.). There seems to be no report of the species from the east coast of Scotland (Irvine *et al.*, 1975; Norton, 1976; Wilkinson, 1975), nor from the Outer Hebrides (Irvine *et al.*, 1975; Norton and Powell, 1979).

The origins and taxonomic affinities of the small red algae *Antithamnionella sarniensis* and *A. spirographidis* have been much discussed (see e.g., Farnham, 1980; L'Hardy-Halos, 1986; Athanasiadis, 1990), but they have also been reported as introduced species from several parts of the world. According to observations and references given by Westbrook (1930) *A. sarniensis* was first seen on Guernsey in 1921 and at several localities on the south coast of the UK in the mid 1920s and onwards, while it was not found there in earlier collections. Hiscock (1986) stated *A. spirographidis* (as *Antithamnion spirographidis*) to be common, and it has been reported from west Scotland since the 1960s (for references see Farnham, 1980).

The earliest record of the brown alga *Colpomenia peregrina* is from 1905 (Scilly Island, southwest UK), although at first described as another taxonomic affinity (e.g., Sauvageau, 1918; Lund, 1949b; Blackler, 1964), and it rapidly spread along the south coast. It has been recorded around the UK (Farnham, 1980), including the Isle of Man, first reported there in 1926 (Lund, 1949b - but there are specimens collected by H Kylin from Port Erin in 1923 named *C. sinuosa*, deposited at the Department of Marine Botany, Göteborg), the east coast of Scotland in the late 1930s (Lund, 1949b; Norton, 1976), Orkney in 1940 (Lund, 1949b; Wilkinson, 1975) and the Outer Hebrides, in the southern part in 1936 and the northern in 1947 (Lund, 1949b; Norton and Powell, 1979). In the 1980s Fletcher (1987) reported it as generally distributed around the British Isles, but more common on the southwest shores.

Of the accidentally introduced green algae *Codium fragile* both subspecies *atlanticum* (probably introduced during the early 19th century; Silva, 1955) and *tomentosoides* (first recorded in Devon in 1939; Silva, 1955) have been found. The former, especially, was present along most of the coasts. Farnham (1980) gave examples of how the species had spread and also outcompeted the native species *C. tomentosum*.

The first report of the brown alga *Fucus evanescens* from the mainland of Britain was given by Powell (1981) from a harbour in northeast Scotland in 1980, probably occurring there for some years. However, he considered it as an example of a southern expansion of its range, since it has been known from the Shetland Isles since 1902.

There are also reports of cross-Channel introductions to the UK, e.g., *Laminaria ochroleuca, Cystoseira myriaphylloides* (Farnham, 1980; W F Farnham, pers. comm.), which, however, represent a natural spread.

There is no report available of the red alga *Dasya baillouviana* occurring in the UK.

1.2.18 USA

During the 1980s there has been a growing interest in developing a nori (*Porphyra*) mariculture in the State of Washington (Merill, 1989; Bergdahl, 1990; Mumford, 1990). Within the program of the Washington State Department of Natural Resources, farm trials with the two Japanese species *Porphyra yezoensis* and *P. tenera* were performed in inshore areas in the south Puget Sound area during 1982-1984 (Merill, 1989; Bergdahl, 1990; Mumford, 1990). Bergdahl also stated that since 1987 imported seeded *Porphyra* nets have been used by private companies at more offshore localities in Washington (northwest San Juan County). So far there seems to be no development of any nori mariculture in Alaska. Seeded *Porphyra* nets from Washington have been brought to North Carolina and used in spray cultures in closed systems (Mumford, 1990), however, without success. In the early 1990s plans to start farming of *P. yezoensis* in Maine have been presented (ICES, 1991, 1992).

In Prince William Sound, Alaska, transfer of *Macrocystis integrifolia* imported from southeast Alaska, about 600 miles to the south, is frequently carried out as a base for the herring roe on kelp industry. Plants were also farmed from spores and outplanted near Sitka, although with limited success (Stekoll and Else, 1990).

In a scientific experiment algae were tested to evaluate their capacity for removing nutrients from effluents of a landbased salmon farm. Besides the use of local species, the red alga *Palmaria palmata* (according to new nomenclature = *Palmaria mollis*) was transferred from neighbouring Washington State to Oregon and was used in open race ways in a pilot project during the late 1980s (Levin, 1990, Levin, pers. comm.).

In the report from the WG (ICES, 1987) a paper by Spicher and Josselyn (1985) was quoted, reporting on both intentional and accidental introductions of species of the salt marsh grass *Spartina* from South America and from the Atlantic to the San Fransisco and Humboldt Bays. However, no details of when the introductions took place were given in the ICES report.

The Asiatic angiosperm *Artemisia stelleriana* was originally introduced for gardening and has escaped and spread widely along the shores of the eastern coast south to Virginia and the southern coasts of the Great Lakes (C Bird, pers. comm., Scoggan, 1979).

Crossing experiments have been carried out in the late 1980s in a greenhouse with through-flow system on Long Island, New York, with the native *Laminaria saccharina* and *L. longicruris* from Connecticut, the same species from Canada and the Faroe Islands, and with *L. saccharina* from Helgoland Germany (Egan *et al.*, 1990).

The seagrass *Zostera japonica* was first reported in 1957 from the state of Washington (Willapa Bay), probably introduced with imported Japanese oysters in the 1930s or 1940s (Harrison and Bigley, 1982), either as seeds or used as packing material around the oysters. After a rapid spread, probably by long distance dispersal of drift plants, the species was commonly found in the mid 1970s along the north Washington state shores and it was first reported from S Oregon (Coos Bay) in the mid 1970s (Harrison and Bigley, 1982; Posey, 1988). It continued to spread in that bay area during the 1980s and both Harrison and Bigley (1982) and Posey (1988) predicted that it would continue to spread towards the north and south as far as California. They also draw several parallels to the introduction of *Sargassum muticum* in the same area. However, they did not believe that *Z. japonica* would replace the native *Z. marina*, due to the different life strategies of the two species, but that the previously barren intertidal mudflats in those areas would be drastically changed by its spreading. Ecosystem changes in such intertidal areas invaded by *Z. japonica* have also been recorded, although were not found to be significantly different from native seagrass communities (e.g., Posey, 1988). He also discussed the possibility of using this introduced intertidal species for management of the mudflats, although this has probably not been finalised.

The first record of the accidentally introduced Japanese brown alga *Sargassum muticum,* with imports of oysters, dates from 1947 in Oregon, although it probably was introduced earlier, since oyster imports were common during several decades of the early 20th century (Scagel, 1956). In the early 1950s the same author reported it as common and growing in masses in the north part of the state of Washington. The first progress south was slow, but it finally covered most of the US Pacific coast in the early 1970s (Norton, 1981). At the end of the 1980s its southern border was in the middle part of the Pacific Mexican coast (Espinoza, 1990), having been first recorded south of the US border in 1973. In the north it has been found in southern southeast Alaska, having reached that area before 1977 (Scagel *et al.*, 1989). So far there seems to be no record of *S. muticum* along the American Atlantic coast.

The most remarkable, totally accidental, introduction to the Atlantic coast has been that of the green alga *Codium fragile* ssp. *tomentosoides*. After the first record in Long Island Sound in the winter of 1957, probably due to accidental introduction by ships, the species then rapidly spread along the east coast (see Carlton and Scanlon, 1985 for a review). In the south it reached New Jersey in 1966, Virginia in 1976 and North Carolina in 1979 (Searles *et al.*, 1984). In the north it spread to south Cape Cod in 1961 and Maine in 1964, and off New Hampshire in 1983. Prince (1988) reported a rapid spread during the 1980s around the Appledore Island at rather low water temperatures, especially in areas grazed by sea-urchins. He suggested that a new ecotype had evolved, because of its unusual mode of reproduction, while he quoted reports of a decline having occurred on the coast in Maine. Most of the North American specimens seem to have propagated by partenogenetic, probably female, gametes, drifting plants or fragmentation, but lately sexual reproduction has also been reported (Prince, 1988 and references therein). The plants have been proposed to be favoured through storage of nutrients and persistence through time (Hanisak, 1979a, 1979b; Ramus and Venable, 1987). Several authors (for references see Carlton and Scanlon, 1985) have reported that transfers of oysters had been an important way of spreading *C. fragile*

along the east coast of USA, while the review also pointed to the importance of spreading from fishing nets and packing of baits, as well as through coastal currents.
In December 1982 a species of *Polysiphonia*, previously unreported from the western Atlantic and tentatively referred to as *P. breviarcticulata*, was collected for the first time, and in 1988 it caused a planktonic bloom along 200 km of the coasts of North and South Carolina (Kapraun and Searles, 1990). Normally the plants were typical of the late winter - spring flora and they believed a cool surface temperature to have triggered the bloom, causing problems for fisheries and recreation. They proposed that this Mediterranean species, also identified from Dominica in the West Indies, had been brought across the Atlantic Ocean by currents.
The red alga *Bonnemaisonia hamifera* was first reported from south Massachusetts in 1927, both as tetrasporophytes and female gametophytes, and since then the species has spread northwards, although it has not been possible to conclude if the species arrived from Japan or Europe, or the method of introduction (McLachlan *et al.*, 1969 and references therein). Tetrasporophytes are known as far south as Virginia, while gametophytes only are known as far as Connecticut (for references see Breeman *et al.*, 1988). In general the gametophytes are often less common, due to in appropriate combinations of temperatures and day lengths in the Atlantic waters, while in Japan the life cycle is synchronised (Breeman *et al.*, 1988).
Wilce and Lee (1964) and Schneider *et al.* (1979) discussed the probability that the red alga *Lomentaria clavellosa*, common in Europe and the Mediterranean, has been introduced to the western Atlantic. It was first recorded from Boston harbor in the 1960s, and later in the 1970s reported from New Hampshire, Rhode Island and Connecticut. No explanation could be given for its appearance, more than it probably was a new immigrant. Theoretically, the same mechanism might perhaps be applied to the appearances of this species as to *Polysiphonia harvey* (dispersed as an epiphyte, see above under UK). *L. clavellosa* was found shortly after the introduction of *Codium fragile* from Europe, a plant on which it can be found in Europe. However, *Codium* has not been found in Boston in the 1980s. Another species in the genus, *L. orcadensis,* has also increased its distribution along the Atlantic shores, although earlier known from the northern states.
The importance of ships' transport for algae crossing the Panama Canal was discussed by Hay and Gaines (1984). In the Caribbean Sea they found several fouling species of red algae, e.g., *Acanthophora spicifera*, *Centroceras clavulatum*, *Hypnea musciformis* and *H. spinella*, on small boats, and also *Spyridia filamentosa* and *Laurencia papillosa* on buoys painted with antifoulants. All these are species that in tests they found to tolerate fresh water long enough to survive the time for crossing the Canal. However, although some species occurred on both sides of the Canal, none of the species tested seemed to have managed to become a significant part of the vegetation on the Pacific side, which they hypothesised was mainly due to the high grazing pressure of herbivore there.
The introduced Eurasian angiosperm *Myriophyllum spicatum* is described above under the Great Lakes. After 1960 it could be found in brackish water along the coast from Chesapeake Bay to Virginia and North Carolina (Reed, 1977).
For species introduced into the Great Lakes, see after Canada.

1.2.19 USSR

The only available records of plants introduced on the Baltic coast of the USSR are the early introductions of the charophyte *Chara connivens* (recorded in the 1870s and 1920s, for references see Luther, 1979). Also the angiosperm *Elodea canadensis* may occur (for reference see Leppäkoski, 1984).

Phytoplankton

The occurrence of new phytoplankton species in a sea area is even more difficult to relate to events of introductions than is the case for macrophytes, since especially small organisms have often been neglected or not sampled in previous surveys. Furthermore, their taxonomic affinities often have been obscure and thus the natural distribution of many species is poorly known.
However, there are several reports on phytoplankton assumed to have been introduced by ships. One of the earliest and most often quoted record is that of the diatom *Odontella* (= *Biddulphia*) *sinensis*, which after its first

appearance in European waters at the turn of the century has been widely distributed in the Atlantic (see e.g., Anon., 1972, Boalch and Harbour, 1977), including the Baltic Sea (for references see Leppäkoski, 1984; Christensen *et al.*, 1985).

During the late 1970s and early 1980s some non-indigenous plankton species were reported in Europe. There are no explanations for how they might have been introduced, but judging from all records in the literature (e.g., Carlton, 1985, 1989; Hallegraeff *et al.*, 1990 and references therein), ballast transports probably cannot be ruled out.

The diatom *Coscinodiscus wailesii* was first described from the Pacific coasts of USA and south Canada in the 1930s and was later also recognised in waters of Japan, China, New Zealand, and in 1963 in Chesapeake Bay. The first record in Europe was from the English Channel in 1977 (Boalch and Harbour, 1977 as *C. nobilis*), being much noticed because of its mucus production. It has been present in Atlantic France since 1978 and occurs off the Frisian islands and Helgoland (Rincé and Paulmier, 1986 and references therein). The latter authors also raised the question whether imported oysters were the vector for the introduction of this and some other diatom species such as *Thalassiosira tealata* and *T. punctigera*. *T. tealata* was found in Europe as early as 1950 (England) and was recorded in Norway in 1968 (G Rytter Hassle, pers. comm.). In Norway *Coscinodiscus wailesii* and *Thalassiosira punctigera* have been known since 1979 (Hasle, 1990). Hasle (1990) discussed the possibility that these species were introduced from the south into the Skagerrak and the Oslofjord, where they now commonly occur. The latter is also common in the Kattegat (G Rytter Hassle, pers. comm.). *Thalassiosira punctigera* was recorded in 1978 in the English Channel and at Helgoland 1979 and in 1981 in the Netherlands (for references see ICES, 1983; Hasle, 1990; Smayda, 1990).

In 1966 the diatom *Pleurosigma planctonicum* was first recorded in the Channel. It caused a bloom in 1974, and also that year it was first recorded in the Netherlands, but seems to have more or less disappeared since (for references see ICES, 1983; Smayda, 1990). Smayda also quoted the diatom *Stauroneis membranacea* as new for the Channel area during the 1970s. However, in fact it was described (as *Navicula membranacea*) from the English coast in 1897 (G Rytter Hasle, pers. comm.).

The dinoflagellate *Prorocentrum minimum* was first recorded in Norway in 1979, where during the 1980s it has caused several blooms, and later spread to the Kattegat in 1981, and further into the southwest Baltic in 1983, as far in as the island of Öland (for references see Granéli, 1987; Smayda, 1990). Smayda (1990) quoted the first record in the North Sea in 1976.

The toxic dinoflagellate *Gyrodinium* cf *aureolum* might also be an introduction (for references see Partensky *et al.*, 1988; Smayda 1990). The type species was first described from northeast USA in the 1950s, and it was first recorded in Europe in Norway in 1966, and is now a frequent bloom-forming organism, recorded off Plymouth in 1968 and in the Kattegat in 1981, spreading through the North Sea, the English Channel and around the UK and Ireland. Its uncertain taxonomic status and close relation to the Pacific species *Gymnodinium nagasakiense* (Partensky *et al.*, 1988, = *G. mikimotoi*; Hallegraeff, 1991) has also added to the confusion of its origin. Both these taxa have caused fish kills in many areas.

The origin of the dinoflagellate *Gymnodinium catenatum* has been much discussed. In 1976 (Bravo *et al.*, 1990 and references therein) it caused the first outbreak of PSP (Paralytic Shellfish Poisoning) in Spanish waters (Galicia), recurring there in 1981, when it was also found in Portugal. It was connected with a PSP outbreak recorded in Portugal in 1986, south Spain (Alboran Sea) in 1989, and was perhaps also responsible for a PSP outbreak there in 1987 and in Morocco in 1989, and it is also known from west Italy. Bravo *et al.* (1990) discussed whether the species was possibly native to Europe (see below) or if it was introduced. If it was introduced, they suggested that this might have occurred several times. The species has a disjunct distribution, occurring also in Japan, Australia and Mexico. It has been proposed that the Australian populations originated from Japan with ship transports and they were interfertile with the Japanese populations (Blackburn *et a*l., 1989). As mentioned, the species might not be new to Europe, since cysts of the species have been found in sediment probes from the Kattegat, increasing in abundances in samples 2,000 years old, having a maximum in samples 500-1,000 years old, and disappearing 300 years ago, while the living cells so far have not been found naturally occurring in the area (Nordberg, 1989). In the early 1990s it has been possible to obtain single cells in culture by hatching cysts from the upper sediment layers in Öresund (Ø Moestrup, pers. comm.).

An unusual 'brown tide' bloom was caused by the minute (about 2 mm) new chrysophyte species *Aureococcus anophagefferens*, first known outside Long Island in 1985 and 1986, but the species also occurred in lower abundances in 1987 and 1988 (e.g., Cosper *et al.*, 1990). They concluded that the species was known also in non-blooming areas and raised the question of the possibility that it may be an introduction, although described as a new species, since it was closely related to the species *Pelagococcus subviridis*, known from the open ocean. Species of that size have until the last decade been poorly described.

It may be speculated that the fish killing blooms of the 'flagellate X' in Scotland and Ireland in the late 1970s and early 1980s are connected to an introduction, since it was later identified as most probably being the Japanese raphidophycean alga *Heterosigma akashiwo* (Larsen and Moestrup, 1989). Those authors also remarked that most members of this class have earlier been little recognised in European waters and are badly preserved. Smayda (1990) quoted a report of the related species *Olisthodiscus luteus*, not known to be toxic, first being recorded in Norway in 1964. This species was also believed to be a newcomer in northwest Spain, first recorded there in 1980 (Wyatt and Reguera, 1989).

Changed currents may also be responsible for accidental introductions into new areas such as that of the toxic, NSP-producing dinoflagellate *Ptychodiscus brevis* (= *Gymnodinium breve*), which has long been known from the Mexican Gulf and Florida, but in 1987 for the first time was found as far north as North Carolina, causing closure of shellfish harvesting areas that winter (Tester and Fowler, 1990 and references therein). This species has also since 1972 been reported from Greece (Satsmadjis and Friligos, 1983; Pagou and Ignatiadis, 1990 and references therein) and it might also have occurred in Spain (Fraga and Sanchez, 1985).

It should be emphasised that many of the much-noticed toxic phytoplankton blooms are <u>not</u> species new to an area. This is the case of the bloom of the prymnesiophyte *Chrysochromulina polylepis* in Scandinavia (the Skagerrak, the Kattegat and the Öresund) found in the spring of 1988. However, its toxicity was not previously known (stated as non-toxic in tests when it was first described). A related species, *C. leadbeateri*, responsible for a bloom, causing fish kills in north Norway in late May to early June 1991 (information from HOV Centre, Bergen, Norway), is also not a new species from the Norwegian coast. Nor are introduced species responsible for the outbreak of ASP in Canada, Prince Edward Island, in 1987 and 1988, caused by the diatom *Nitzschia pungens* f. *multiseries*, a widely spread species. Furthermore, the fish kills caused by *Dictyocha speculum* in Denmark in 1983, and a toxic bloom of that species in France in 1987, as well as the toxic blooms of *Prymnesium parvum* in SW Norway in 1989-1992 and in the Baltic in 1990-1992, are all due to native species.

1.3 Summary

Eighty-seven benthic algae and higher plants (47 red, 25 brown, seven green algae, and eight higher plants) as well as 21 phytoplankton species are reported as introduced in the ICES countries, including the Laurentian Great Lakes (Table1.1). Sixty-five of the benthic algae and higher plants (37 red, 13 brown, seven green algae, and eight higher plants) have become established (marked with * in Tables 1.2-1.7), and of these 25 benthic algae and one phanerogam were new records since 1980 in at least one country. Some of the new, completely accidental introductions in the 1980s are due to 'natural' dispersal from areas into which the species was previously introduced. The phytoplankton species can all be considered as more or less established. However, in several parts of the world the marine flora has been poorly studied, and thus the distributions of many species are still unknown. This makes it difficult to judge if some of the new records reported only are due to the paucity of investigations in the past. Furthermore, assumed accidental introductions may be difficult to discriminate from events of changing climate or

natural long distance dispersal, but in many cases the species certainly have been introduced by human activities.
The 25 deliberately introduced species (12 red, 12 brown algae, and one phanerogam; Table 1.2) have been brought by aquaculture, but also for scientific experiments and coastal management. Of these species only three are known to have become established.
Six species are considered to have escaped from aquaria or ornamental displays (Table 1.3), all of which have become established.
Of the accidental introductions, 19 species (nine red, five brown, one green algae, and one phanerogam and three phytoplankton species) are discussed as presumed brought in by other deliberately introduced species, mainly oysters (Table 1.4). Almost all have settled, and many have been dominant and later spread. These introductions most probably were due to lack of quarantine treatment. With the increased awareness among those engaged in aquaculture and by following the ICES Code of Practice, introductions through this vector should decrease in the future.
Three species are thought to have spread by discarded packings to fish baits or from fishing nets (Table 1.5).
Shipping may be a vector of increasing importance for accidental introductions, mainly by releases of loaded ballast (water and/or sediment) in foreign countries, but also by transport of species attached to the hull of the ship. However, there are also some very old introductions due to dumping of solid ballast from the sailing ships. Fifteen benthic algae and two phanerogams are presumably spread by shipping activities (Table 1.6), all have been established and many have also spread further. Ballast releases may also be the main vector for the 21 phytoplankton species discussed as introduced. The new recommendations adopted in some countries, and also the concern of several other countries within the International Maritime Organisation, may hopefully reduce the risk of introductions by releases of ballast loads in the future.
For many of the plants assumed to have been accidentally introduced (39 species), no specific vector of dispersal can be identified (Table 1.7). Some of these species may be native plants, rare or previously not discovered, or may have spread by natural means or on objects drifting in the sea. Accidentally introduced species, having spread naturally from their original site of introduction, are not included in Table 1.7.
Many of the introduced species have the capacity of spreading through vegetative propagation or regrowing from thallus fragments and several of the listed species have incomplete life cycles in the new areas, thus propagating only by partenogenetic gametes, drifting plants or fragmentation.
Some accidentally introduced species have also caused problems for fisheries (net clogging or mechanical hinderance to small boats) and aquaculture (e.g., shell fish poisoning).
It is thus important that a close record is kept on all introductions and scientists should be encouraged to keep watch for further spreading and to report new records in the literature and to ICES. Furthermore, taxonomic and

phytogeographical studies, as well as tests of likely ecophysiological ranges of introduced plants should be encouraged, since the potential geographical distribution area of marine plants depends on their physiological tolerance limits, i.e., being regulated by their basic demands for growth and reproduction. Within a geographical area, where the water has the physical/chemical properties corresponding to these requirements, the establishment of a species further depends on the chance of diaspores (including vegetative dispersal) reaching a site, on the competion with other species, and on predation. Thus studies and tests such as competitive behaviour and predation pressure are much needed, too. Overall, an increased attention should be paid to the issues of both deliberately and accidentally introduced marine plants and more reports are needed on the present status of old introductions.

Table 1.1 Plants discussed in this report. Names in brackets are synonyms. Countries in [ ] = areas with records of drift plants, introductions in aquaculture tank experiments, or where the species is suggested to have developed from introductions, countries in () = areas for which the species is discussed but occurs indigenously or where no introductions have been found

Red algae	
Acanthophora spicifera (Vahl) Børg.	(Panama)
Acrothamnion preissii (Sonder) Wollaston	France
(*Agardhiella subulata* [C. Ag.] Kraft et Wynne)	UK
Aglaothamnion feldmanniae Halos	France
Antithamnion densum (Suhr) Howe	France, Ireland
Antithamnion nipponicum Yamada	France
Antithamnionella sarniensis Lyle	France, [The Netherlands], Portugal, Spain, UK
Antithamnionella spirographidis (Schiffner) Wollaston	France, Portugal, Spain, UK
Asparagopsis armata Harv.	(Denmark), (Faroe Isl), France, (Germany), Ireland, [The Netherlands], (Norway), Portugal, Spain, (Sweden), UK
(*Asterocytis smaragdina* [Reinsch] Forti)	Great Lakes
Bangia atropurpurea (Roth) C. Ag.	Great Lakes
Bonnemaisonia hamifera Hariot	Canada, Denmark, Faroe Isl, France, Germany, Iceland, Ireland, [The Netherlands], Norway, (Portugal), Spain, Sweden, UK, USA
Caulacanthus ustulatus (Mertens) Kütz.	(France)
Centroceras clavulatum (C. Ag.) Mont.	(Panama)
Chondrus cripus Stackh.	[Canada], [France]
Chroodactylon ramosum (Thwaites) Hansg.	Great Lakes
Chrysymenia wrightii (Harv.) Yamada	France
Cryptonemia hibernica Guiry et Irvine	Ireland
Cryptonemia seminervis (C. Ag.) J. Ag.	(Ireland)
Dasya baillouviana (Gmel.) Mont.	Denmark, (Germany), The Netherlands, Norway, Sweden, (UK)
(*Dasya pedicellata* [C. Ag.] C. Ag.)	The Netherlands
Devaleraea ramentacea (L.) Guiry	Germany
Dipterosiphonia dendritica (C. Ag.) Schmitz	France, Spain
Euchema spinosum (L.) J. Ag.	France
Furcellaria lumbricalis (Huds.) Lamour.	Canada
(*Gracilaria foliifera* [Forssk.] Børg.)	Ireland
Gracilaria lemanaeformis (Bory) Weber van Bosse	[Sweden]
Gracilaria multipartita (Clem.) Harv.	Ireland
Gracilaria sordida Nelson	[Sweden]
(*Gracilaria secundata* Harv.)	[Sweden]
Gracilaria tenuistipitata Chang et Xia	[Sweden]
Gracilaria verrucosa (Huds.) Papenf.	[Sweden]
Grateloupia doryphora (Mont.) Howe	France, Spain, UK
Grateloupia filicina (Lamour.) C. Ag.	Spain, UK
(*Halosaccion ramentaceum* [L.] J. Ag.)	Germany
Hypnea musciformis (Wulf.) Lamour.	[France], (Panama)
Laurencia microcladia Kütz.	France
Laurencia papillosa (C. Ag.) Grev.	(Panama)
Lomentaria clavellosa (Turn.) Gaill.	(Canada), USA
Lomentaria hakodatensis Yendo	France, Spain
Lomentaria orcadensis (Harv.) Coll.	Canada, (USA)
Mastocarpus stellatus (Stackh.) Guiry	Germany
Mesothamnion caribaeum Børg.	France, Portugal, Spain
Neoagardiella gaudichaudii (Mont.) Abbott	UK
Palmaria mollis (Setch. et Gardn.) van der Meer et Bird	USA
(*Palmaria palmata* (L.) O. Kuntze)	USA
Pikea californica Harv.	Spain, UK

Table 1.1 (continued)

Red algae	
Platysiphonia caribaea Ballantine et Wynne	Spain
Polysiphonia breviarcticulata (C. Ag.) Zanard.	USA
Polysiphonia harveyi Bail.	France, Ireland, Norway, UK, (USA)
Polysiphonia insidiosa Crouan frat.	(UK)
Polysiphonia nigrescens (Huds.) Grev.	France
Polysiphonia setacea Hollenberg	France
Porphyra tenera Kjellm.	Canada, USA
Porphyra yezoensis Ueda	Canada, France, Germany, USA
Predaea huismanii Kraft	Spain
Solieria chordalis (Ag.) J. Ag.	UK
Solieria tenera (J. Ag.) Wynne & Taylor	UK
Spyridia filamentosa (Wulf) Harv.	(Panama)
Symphyocladia marchantioides (Harv.) Falkenb.	Portugal
Brown algae	
Alaria esculenta (L.) Grev.	Germany
Chorda filum (L.) Stackh.	France
Colpomenia peregrina Sauv.	Canada, Denmark, (Faroe Isl.), France, (Germany), Ireland, The Netherlands, Norway, Portugal, Spain, Sweden, UK
Colpomenia sinuosa (Roth.) Derb. et Sol.	(UK)
Cystoseira myriaphylloides Sauv.	(UK)
Desmarestia viridis (O.F. Müller) Lamour.	France
Fucus evanescens C. Ag.	(Canada), Denmark, Germany, Norway, Sweden, (UK)
Fucus serratus L.	Canada
Fucus spiralis L.	France
Laminaria abyssalis Joly et C. de Oliviera Filho	[Germany]
Laminaria bongardiana Post. et Rupr.	[Germany]
Laminaria digitata (Huds.) Lamour.	(Germany)
(*Laminaria groenlandica* Rosenv.)	[Germany]
Laminaria hyperborea (Gunn.) Fosl.	(Germany)
Laminaria japonica Aresch.	France, (Spain),
Laminara longicruris Pyl.	Germany, [USA]
Laminaria ochotensis Miyabe	Germany
Laminaria ochroleuca Pyl.	[Germany], (UK)
Laminaria pallida Grev.	[Germany]
Laminara saccharina (L.) Lamour.	(France), (Germany), [USA]
Laminaria schinzii Fosl.	[Germany]
*Laminaria s*etchellii Silva	[Germany]
Leathesia difformis (L.) Aresch.	France
Macrocystis integrifolia Bory	(USA)
Macrocystis pyrifera (L.) C. Ag.	France, (UK)
Sargassum muticum (Yendo) Fensh.	[Belgium], Canada, Denmark, France, Germany, (Ireland), The Netherlands, Norway, Portugal, Spain, Sweden, UK, USA
Sphacelaria lacustris Schloesser et Blum	[Great Lakes]
Sphacelaria fluviatilis Jao	[Great Lakes]
Sphaerotrichia divaricata (C. Ag.) Kylin	France
Undaria pinnatifida (Harv.) Sur.	France, (Ireland), Spain, (UK)
Green algae, including charophytes	
Caulerpa mexicana [Sonder] J. Ag.	(France)
Caulerpa prolifera (Forssk.) Lamour.	(France)
Caulerpa taxifolia (Vahl) C. Ag.	France, Spain
Chara connivens Braun	Germany, Poland, Sweden, USSR

Table 1.1 (continued).

Green algae, including charophytes	
Codium fragile (Sur.) Hariot	[Belgium], Denmark, (Faroe Isl), France, Germany, Iceland, Ireland, The Netherlands, Norway, (Portugal), Spain, Sweden, UK, USA
Codium tomentosum Stackh.	(UK)
Codium vermilara (Olivi) Delle Chiaje	(Norway)
Enteromorpha intestinalis (L.) Link	Great Lakes
Enteromorpha prolifera (O.F. Müll.) J. Ag.	Great Lakes
Monostroma wittrockii Bornet	Great Lakes
Nitellopsis obtusa (Desv.) J. Gr.	Great Lakes
Ulothrix zonata (Weber et Mohr) Kütz.	(Great Lakes)
Phytoplankton	
Actinocyclus normanii (Greg.) Hust.	Great Lakes
Aureococcus anophagefferens Hargraves et Sieburth	(W Atlantic)
Biddulphia laevis Ehr.	Great Lakes
(*Biddulphia sinensis* Grev.)	Atlantic, Baltic Sea
Chaetoceros honii Wujek et Graebn.	Great Lakes
Chrysochromulina leadbeateri Estep et al.	(E Atlantic)
Chrysochromulina polylepis Manton et Parke	(E Atlantic)
(*Coscinodiscus nobilis* Grun.)	E Atlantic
Coscinodiscus wailesii Gran et Angst	(Pacific), (W Atlantic), E Atlantic
Cyclotella atomus Hust.	Great Lakes
Dictyocha speculum Ehrenb.	(W Atlantic)
(*Gymnodinium breve* Davis)	(W Atlantic), E Atlantic, Mediterranean
Gymnodinium catenatum Graham	Spain, Portugal, (Kattegat), Mediterranean, (Pacific)
Gymnodinium mikimotoi Miyake et Kominami	(Pacific)
(*Gymnodinium nagasakiense* Takayama et Adachi)	(Pacific)
Gyrodinium cf. *aureolum* Hulbert	Atlantic
Heterosigma akashiwo Hada (Hada)	(Pacific), (E Atlantic)
Hymenomonas roseola Stein.	[Great Lakes]
Hymenomonas lacuna Pienaar	(Great Lakes)
(*Navicula membranacea* Cleve)	(Atlantic)
Nitzschia pungens Grun.	(W Atlantic)
Odontella sinensis (Grev.) Grun.	Atlantic, Baltic Sea
Olisthodiscus luteus N. Carter	E Atlantic
Pelagococcus subviridis Norris	(Atlantic)
Pleurosigma planctonicum Simonsen	E Atlantic
Prorocentrum minimum (Pav.) Schiller	E Atlantic, Baltic Sea
Prymnesium parvum N. Carter	(E Atlantic), (Baltic Sea)
Ptychodiscus brevis (Davis) Steidinger	(W Atlantic), E Atlantic, Mediterranean
Skeletonema subsalsum (A. Cleve) Bethge	Great Lakes
Stauroneis membranacea (Cleve) F.W. Mills	(Atlantic)
(*Thalassiosira fluviatilis* Hust.)	Great Lakes
Thalassiosira guillardii Hasle	Great Lakes
Thalassiosira lacustris (Grun.) Hasle	Great Lakes
Thalassiosira pseudonana Hasle et Heimdal	Great Lakes
Thalassiosira punctigera (Castr.) Hasle	Atlantic
Thalassiosira tealata Takano	Atlantic
Thalassiosira weissflogii (Grun.) Fryxell & Hasle	Great Lakes
Therpsinoe musica Ehr.	Great Lakes

Table 1.1 (continued).

Phanerogams and ferns	
Artemisia stelleriana Bess.	Canada, USA
Azolla filiculoides Lamk.	The Netherlands
Elodea canadensis Michx.	Finland, The Netherlands, (Poland), Sweden, (USSR)
Elodea nuttallii (Planch.) St. John	The Netherlands,
(*Myriophyllum exalbescens* Fern.)	Denmark, Finland, Sweden
Myriophyllum sibiricum Komarov.	Denmark, Finland, Sweden
Myriophyllum spicatum L.	Canada, Great Lakes, USA
Spartina sp.	USA
Zostera japonica Aschers. et Graebn.	Canada, USA
Zostera marina L.	(USA)

Table 1.2 Plants. Deliberate introductions for aquaculture, coastal management or scientific experiments (not including small-scale, indoor laboratory experiments). * = established in the area, ** = dominant or forming blooms, species in [ ] are also native in the area.

	To	Origin
a) Cultivated in the sea		
The Atlantic and the Mediterranean		
Devaleraea ramentacea	Helgoland, Germany	Iceland
[Euchema spinosum]	Caribbean, France	Philippines
***Mastocarpus stellatus*	Helgoland, Germany	Europe
Alaria esculenta	Helgoland, Germany	Europe
Laminaria longicruris	Helgoland, Germany	Canada
Laminaria ochotensis	Helgoland, Germany	Japan
[Laminaria saccharina]	Helgoland, Germany	BC, Canada
[Laminaria saccharina]	Long Island, USA	Europe, Canada
Macrocystis pyrifera	Brittany, France	Chile
**Undaria pinnatifida*	Brittany, France	Mediterranean
The Pacific Ocean		
Palmaria mollis	Oregon, USA	Washington, USA
Porphyra tenera	Washington, USA; BC, Canada	Japan
Porphyra yezoensis	Washington, USA; BC, Canada	Japan
**Spartina sp.*	W USA	Atlantic, S America
b) Tank experiments		
The Atlantic and the Mediterranean		
Chondrus crispus	Corsica, France	Brittany, France
Chondrus crispus	BC, Canada	NS, Canada
Gracilaria lemanaeformis	Sweden	Florida
Gracilaria sordida	Sweden	New Zealand
Gracilaria tenuistipitata	Sweden	China
[Gracilaria verrucosa]	Sweden	Puerto Rico
Hypnea musciformis	Corsica, France	Senegal
Laminaria abyssalis	Helgoland, Germany	S Atlantic
Laminaria bongardiana	Helgoland, Germany	N Pacific
Laminaria ochroleuca	Helgoland, Germany	N Atlantic
Laminaria pallida	Helgoland, Germany	S Atlantic
Laminaria schintzii	Helgoland, Germany	S Atlantic
Laminaria setchelli	Helgoland, Germany	N Pacific

Table 1.3 Plants accidentally introduced from aquaria or ornamental plants. * = established in the area, ** = dominant or forming blooms, for species in () the vector is uncertain

	To
The Atlantic and the Great Lakes	
**Artemisia stellariana*	E Canada, E USA, Great Lakes
**(Azolla filiculoides)*	The Netherlands (canals)
**(Elodea canadensis)*	The Netherlands (canals), countries around the Baltic Sea
**(Elodea nuttallii)*	The Netherlands (canals)
***Myriophyllum spicatum*	E Canada, E USA (brackish water and lakes)
The Mediterranean	
***Caulerpa taxifolia*	France

Table 1.4 Plants accidentally introduced with imported oysters. * = established in the area, ** = dominant or forming blooms, for species in () the vector is uncertain, in [ ] the species may be native or have spread naturally.

	To	Origin
The Atlantic (including the North Sea-Baltic Sea)		
**[(Caulacanthus ustulatus)]*	Brittany, France	S Europe?
**(Dasya baillouviana)*	The Netherlands	S Europe?
**(Grateloupia doryphora)*	NW Spain	Japan?
**(Grateloupia filicina)*	NW Spain	Japan?
**Laurencia brogniartii*	Brittany, France	Japan
**Lomentaria hakodatensis*	Brittany, France; Spain	Japan
**Colpomenia peregrina*	France, S UK?	Pacific
***(Sargassum muticum)*	Europe	Japan?
**Undaria pinnatifida*	Spain	Japan?
***Codium fragile*	within E USA	E USA
***(Coscinodiscus wailesii)*	W and E Atlantic	Pacific?
***(Thalassiosira punctigera)*	E Atlantic	?
***(Thalassiosira tealata)*	E Atlantic	?
The Mediterranean		
**Antithamnion nipponicum*	France	Japan
**Chrysymenia wrightii*	France	Japan
**[(Grateloupia doryphora)]*	France	Japan?, Atlantic?
***Lomentaria hakodatensis*	France	Japan
***Porphyra yezoensis*	France	Japan
***Laminaria japonica*	France	Japan
***Sargassum muticum*	France	Japan
**(Sphaerotrichia divaricata)*	France	Japan?, Atlantic?
***Undaria pinnatifida*	France	Japan
The Pacific		
***Sargassum muticum*	W USA, W Canada	Japan
***Zostera japonica*	W USA	Japan

Table 1.5 Plants accidentally introduced with discarded fishing baits or fishing nets. * = established in the area, ** = dominant or forming blooms, for species in () the vector is uncertain.

	To	From
The Atlantic		
***Codium fragile*	E USA	E USA
The Mediterranean		
**Polysiphonia nigrescens*	France	Atlantic
** Fucus spiralis*	France	Atlantic

Table 1.6 Plants accidentally introduced with ships including ballast (solid or water). * = established in the area, ** = dominant or forming blooms, for species in () the vector is uncertain.

	To	Origin
The Atlantic (including the North Sea-Baltic)		
***Asparagopsis armata*	Europe	(Australia?)
***(Bonnemaisonia hamifera)*	Europe	Japan
**(Dasya baillouviana)*	The Netherlands, Scandinavia	S Europe?
***Furcellaria lumbricalis*	E Canada	Europe
**(Pikea californica)*	S UK, Spain	Pacific
***Fucus serratus*	E Canada	Europe
***(Fucus evanescens)*	W Sweden, S Norway, Denmark	N Atlantic
**Chara connivens*	Countries around the Baltic Sea	W Europe
***Codium fragile*	E USA	Europe
**(Codium fragile)*	Europe	Japan, W Pacific
**(Elodea canadensis)*	Countries around the Baltic Sea	N America
***Myriophyllum spicatum*	USA, Canada	Europe
***(Coscinodiscus wailesii)*	W and E Atlantic	Pacific?
***[(Gymnodinium catenatum)]*	Spain, Portugal	?
***(Gyrodinium cf aureolum)*	E Atlantic	W Atlantic
***Odontella sinensis*	Europe	Indo-Pacific
**Pleurosigma planctonicum*	S UK, The Netherlands	?
***(Prorocentrum minimum)*	North Sea	?
***(Thalassiosira punctigera)*	E Atlantic	?
***(Thalassiosira tealata)*	E Atlantic	?
The Mediterranean		
**(Aglaothamnion feldmanniae)*	France, Italy	Atlantic?
**(Acrothamnion preissii)*	France, Italy	Indo-Pacific
***Asparagopsis armata*	France	(Australia?)
***Sargassum muticum*	France	France
***(Undaria pinnatifida)*	France	France
The Great Lakes		
***Bangia atropurpurea*	Great Lakes	Atlantic
**Nitellopsis obtusa*	Great Lakes	Europe?
***Myriophyllum spicatum*	Great Lakes	Europe
***Actinocyclus normanii*	Great Lakes	Atlantic
**Biddulphia laevis*	Great Lakes	Atlantic
**Chaetoceros honii*	Great Lakes	Atlantic
***Cyclotella atomus*	Great Lakes	Atlantic
**(Hymenomonas roseola)*	Great Lakes	Atlantic
**Skeletonema subsalsum*	Great Lakes	Atlantic
**Thalassiosira guillardii*	Great Lakes	Atlantic
**Thalassiosira lacustris*	Great Lakes	Atlantic
**Thalassiosira pseudonana*	Great Lakes	Atlantic
**Thalassiosira weissflogii*	Great Lakes	Atlantic
**Therpsinoe musica*	Great Lakes	Atlantic

Table 1.7 New accidental introductions, but dispersal mechanisms unknown. * = established in the area, ** = dominant or forming blooms, species in [ ] may be native. Introduced species believed to have spread naturally from previous introductions are not included.

	To	**Origin**
The Atlantic		
**Antithamnion densum]*	Europe	
**Antithamnionella sarniensis*	Europe	
**Antithamnionella spirographides*	Europe	Mediterranean?
**Bonnemaisonnia hamifera*	E Canada, E USA	Japan?, Europe?, USA?
**[Cryptonemia hibernica]*	Ireland	Pacific?
**[Dipterosiphonia dendritica]*	S Spain	pantropic
Gracilaria multipartita	Ireland	S UK?, France?
**Grateloupia doryphora*	S UK	Pacific?
**Grateloupia filicina var. luxurians*	S UK	Australia?
**[Lomentaira clavellosa]*	E USA	Europe?
**[Lomentaira orcadensis]*	E Canada	Europe?, USA?
**Mesothamnion caribaeum*	France, S Portugal	Caribbean Sea
**Neoagardhiella gaudichaudii*	S UK	Pacific?
**[Platysiphonia caribaea]*	Canary Isl	W Atlantic?
***Polysiphonia breviarticulata drift?*	N.& S. C., USA	Mediterranean? Caribbean?
**[Polysiphonia harveyi] on drift algae?*	S UK, Ireland, France, Norway	W Atlantic
Porphyra yezoensis	Helgoland?	
**[Predaea huismanii]*	Canary Isl	Australia?
**Solieria chordalis*	S UK	warm Atlantic
**Solieria tenera*	S UK	warm Atlantic
**[Symphyocladia marchantioides]*	Azores	Pacific?
**Colpomenia peregrina*	N.S., Canada	?
**Codium fragile*	Europe	Pacific
**Myriophyllum sibiricum*	Denmark, Finland, Sweden	?
***[Asperococcus anophagefferens]*	E USA	?
***[Heterosigma akashiwo]*	Scotland, Ireland	Japan?
***[Olisthodiscus luteus]*	Atlantic	?
***[Ptychodiscus breve]*	Spain, Greece	W Atlantic?
The Mediterranean		
**[Dipterosiphonia dendritica]*	Corsica, France	pantropic
**[Laurencia microcladia]*	Corsica, France	tropical Atlantic
**Mesothamnion caribaeum*	France	Caribbean Sea
***Polysiphonia setacea*	France	tropical Atlantic?, Indo-Pacific?
***Chorda filum*	France	Atlantic?
**Colpomenia peregrina*	France	Japan?
***Desmarestia viridis*	France	Atlantic?, Adraiatic Sea?
**Leathesia difformis*	France	Atlantic?, Black Sea?
**Codium fragile*	France	Atlantic?
The Great Lakes		
**Chroodactylon ramosum*	Great Lakes	Atlantic?
**[Sphacelaria fluviatilis]*	Great Lakes	Atlantic?
**[Sphacelaria lacustris]*	Great Lakes	Atlantic?
**Enteromorpha intestinalis*	Great Lakes	Atlantic?
**Enteromorpha prolifera*	Great Lakes	Atlantic?
**Monostroma wittrockii*	Great Lakes	Atlantic?

2 Status of the Invasion of the Green Alga *Caulerpa taxifolia* in the Mediterranean Sea and Prospects for the Invasion of Western Europe

2.1 Background

A survey of the dispersal of the accidentally introduced green alga *Caulerpa taxifolia* (Vahl) C. Agardh along *ca* 150 km of the Mediterranean coast from west of the Italian border to Toulon, France, was published by Meinesz and Hesse (1991). The species was first recorded in 1984 in the area just outside the aquarium of Monaco, and they claimed the introduction was due to accidental release from the aquarium, where it has been displayed since 1975. The survey showed that the species could be found in depths down to *ca* 35 m, in 'extensive areas' reaching a degree of cover of the bottom area of 100% between 5 and 25 m. The plants were up to 45 (60) cm long at greater depths. They also emphasised the contents of toxic substances in the species, making it less susceptible to grazers and thus having a competitive advantage compared to other species. This was reflected in the dominance of the species, replacing other species in some areas, and the few epiphytes found as well as an apparently low grazing pressure.

In December a public seminar was held in France, resulting in several articles in popular magazines with strong warnings for the consequences of this accidentally introduced alga. The distribution was then reported as from the Bay of Genoa, Italy to Saint-Cyrien, close to the Spanish border. The situation was discussed in many popular articles also including interviews with staff of the aquarium. In press accounts of interviews with the director of the museum it was reported that the discharges from the museum prior to 1986 had gone to the city sewage treatment plant but subsequently were treated by the museum itself. Some of these articles also reported of traces of grazing on the alga.

According to the Spanish National Report to WGITMO meeting in Lisbon April 1992, the species then had not reached the Spanish border, but newspaper reviews later in spring 1992 have claimed that the species (called 'the AIDS of the Sea') was found as far west as Barcelona, Spain. It should also be pointed out that *C. prolifera* in a recently published popular photoflora of the Caribbean Sea (Littler *et al.*, 1989) is described as an easily grown and excellent plant for marine aquaria.

2.2 Taxonomy and Distribution of the Genus Caulerpa

The genus caulerpa, recognised by Lamoroux as early as in 1809, encompasses around 70 species. The plants have a siphonous organisation, i.e., morphologically composed of one cell, which, however, has both structural and physiological differentiations. The plants are differentiated into the upright photosynthesising fronds emerging from the creeping stolons, which are often buried in the sand. From the stolons rhizoids are developed, which can act as anchorage in the sediment and also take up nutrients from the interstitial water (Williams and Fisher, 1985) and translocate them to the photosynthetic parts of the plants by means of cytoplasmic streaming. The stolons and rhizoids can stabilise the sediments and the plants thus can act as primary colonisers in areas with mobile substrates.

Caulerpa species occupy several substrates: 1) muddy or sandy substrates, 2) rocks or other hard substrates (e.g., dead corals), 3) epiphytes on e.g., mangrove roots, 4) and less commonly as free-floating plants. According to records in the literature *C. taxifolia* occurs on both soft and hard substrates and as *C. mexica*na it is also recorded from mangrove roots. For many species only vegetative proliferation is known through dispersal of new plantlets cut off from the stolons. This dispersal mechanism is of great importance in all species, and also for those having sexual reproduction. According to Meinsez (1979a) sexual reproduction is exceptional and incomplete in the native species *C. prolifera* in the western Mediterranean Sea. Meinesz and Hesse (1991) speculated on the importance of sexual reproduction of *C. taxifolia* for the local distribution in the Mediterranean, but had not found any reproductive plants there. Reproductive plants of the closely related (same?) species *C. mexica*na were described from Israel by Rayss (1941) (as *C. crassifolia*). The environmentally influenced high plasticity in the morphology of several caulerpa species, resulted in a large number of morphologically different forms being recognised as species.

Taxonomic affinities are now being studied by molecular biological techniques (eg Lehman and Manhurt, 1991; Subramanian, 1991) which may change the species concept in the future. Characters such as chloroplast structure have also been used to study the phylogenetic relationships within the genus (Calvert *et al.*, 1976). Several monographs or detailed studies of the genus have been published, the most well known by Agardh (1872), Weber van Bosse (1898), Svedelius (1906), Børgesen (1907), Taylor (1960, 1977 and references therein), Womersley (1984 and references therein).

The genus can be subdivided into several sections. *C. taxifolia* belongs to the section Filicoideae, which further comprises the following species: *C. mexicana* (see also below), *C. scalpelliformis*, *C. ashmaedii*, *C. sertularioides*, *C. alternans* (endemic to Australia), *C. remotifolia* (endemic to Australia), and *C. distichophylla* (endemic to Australia). Several authors consider *C. taxifolia* and *C. mexicana* as conspecific (for a discussion see Lawson and Price, 1969 and references therein, but cf also Taylor, 1977). Thus a recent paper on the biogeography of Macaronesian algae by the experienced phycologists Prud'homme van Reine and van den Hoek (1990) only listed *C. taxifolia* for this area (which includes the Canary Islands), while several older papers for the same area only mentioned *C. mexicana*. This taxonomic confusion has implications for the interpretation of the potential dispersal of the species *C. taxifolia*.

The species *C. taxifolia* occurs almost worldwide being recorded from the Caribbean Sea, the west African coast, the east African coast, the Indian Ocean from the Red Sea to Indonesia, the Pacific Ocean, from Rukuy Islands (Japan), Taiwan and the Philippines in the north to Lord Howe Island (west of New South Wales) in the south. The closely related species (same?, see remarks above) *C. mexicana* has a similar distribution, being recorded from the Caribbean Sea - west Atlantic, north to Georgia, USA, south to Brazil, the west African coast between Canary Island-Mauretania and central west Africa, the east African coast south to Durban, and the Indian Ocean from the Red Sea to the Pacific Ocean.

Generally caulerpa species are described as belonging to the flora of subtropical and tropical waters. However, several species also occur in the cold temperate waters of southern Australia (average water temperatures in winter *ca* 12-14°C, several endemic species) - Tasmania (average water temperatures in winter *ca* 10°C) - New Zealand, and Japan - Korea (Table 2.1). Many species also occupy areas of large depths and commonly occur down to 50 and sometimes even below 100 m (e.g., Lüning, 1990), the deepest caulerpa plants alive being recorded by divers in the submersible Johnson-Sea-Link at 210 m (Earle, 1985).

2.3 Mediterranean Caulerpa Species

The caulerpa species occurring in the Mediterranean are listed in Table 2.2 (cf also Anon., 1990). *C. prolifera* and *C. olliviera* comprise the native species, while *C. racemosa*, *C. scalpelliformis* and *C. mexicana* are considered as Lessepsian immigrants into the east Mediterranean (e.g., Lipkin, 1972). The record of *C. racemosa* in the harbour of Sousse (Hamel, 1930) might point to a possible accidental introduction of that species by ships.

2.4 Drastic Increases, New or Cyclic Appearances of Caulerpa Species

There are a few other reports of drastic increased biomasses or new appearances of caulerpa species in the literature. *C. filiformis* was described by May 1976) as having developed into a dominant plant in several areas north of Sydney, Australia, having first been recorded there in the mid 1920s as *C. ligulata*. The increase, which in some areas had occurred within a period of about 10 years (although during different decades), was discussed as due to either that it was an introduced species (occurring in south Africa) or to its positive response to increased sewage discharges in the area. Taylor (1977) reported that *C. scalpelliformis* had recently turned up in Brazil and Guadeloupe, and was new for Barbados and Antigua in 1966, remarking that such a distinctive species could not previously have been overlooked. A cyclic appearance of the species *C. prolifera* native to the Mediterranean was described by Meinesz and Hesse (1991) with periods of extension in 1920-1950, regression in 1960-1975, and extension after 1975. The extension in the 1920s off Naples, Italy was attributed by Funk (1927) to mild winters, the same pattern as was found by Meinesz (1979b) for the French coast. Aleem (1992) reported a sudden extension in 1991 of the distribution of *C. racemosa* in Egypt to the area in the vicinity of Alexandria, whereas previously it had been only recorded on the east coast from Port Said and El-Arish. He reckoned that the appearance of the species was due to the reduced discharge of fresh water to the area after the building of the Aswan High Dam.

2.5 Sizes and Growth Rates

The length of the assimilating fronds of *C. taxifolia* from the French Mediterreanean coast was described by Meinesz and Hesse (1991) as unusually long for the species, reaching sizes up to about 60 cm in deeper waters, while more normal sizes of 5-10 cm were encountered in more shallow waters. This is in accordance with most sizes given in the literature for this species, the range being mainly between *ca* 5 and 15 (25) cm (cf also Meinesz and Hesse, 1991).

However, Børgesen (1907) had remarked that plants from greater depths (30 m) in the Caribbean Sea were larger (16 cm and more) than plants from shallow waters. Sizes comparable to those of the introduced *C. taxifolia* have been found for other species, e.g., in the Mediterranean *C. scalpelliformis* up to 50 cm in dim light (Lipkin, 1975), in Australia *C. longifolia* up to 65 cm, *C. brownii* up to 40 cm, *C. flexilis* up to 40 cm, and *C. cactoides* up to 40 cm (Womersley, 1984). The large size may be caused by poorer light conditions on the French Mediterranean coast than in the clearer tropical waters at the same depths (cf Lipkin, 1975). The large plants of *C. taxifolia* and dense stands have evidently further reduced available light for the species previously occupying those areas (Meinesz and Hesse, 1991).

Meinesz and Hesse (1991) also discussed the rapid growth of *C. taxifolia* in the area giving density values of the stands of up to 8,225 fronds m^{-2} and stolon lengths up to 244 m m^{-2} and biomasses reaching *ca* 400-600 g dw m^{-2}. The areas covered by 100% were mainly described as being up to 10 m^2, but also a continuous 800 m long band was reported from the area east of Monaco. For the native Mediterranean species *C. prolifera* Meinesz (1979b) had previously recorded densities of up to 6,360 primary fronds and 8,320 secondary assimilators m^{-2} and stolon lengths of *ca* 11 m m^{-2} in about the same area. Meinesz (1979c) calculated the annual biomass increase at 3 m depth of *C. prolifera* (based on standing crop dry weight values) to about 235 g dw m^{-2}, with a biomass maximum of 223 g dw m^{-2} in November.

Johnston (1969) in the Canary Islands measured net production rates of 4.5 mg C (g dw)$^{-1}$ day^{-1} for *C. prolifera*, but only 1.5 mg C (g dw)$^{-1}$ day^{-1} for *C. mexicana*, quoting about the same rate for measurements on *C. prolifera* in the Mediterranean. These rates were considered by him to allow these species to grow only in areas with low competition. However, a considerably higher rate of 0.5 mg C (g dw)$^{-1}$ h^{-1} was measured for *C. mexicana* by Taylor *et al.* (1986) in the Caribbean Sea, although that value represents productivity at surface light intensity. An elongation rate of about 1 cm day^{-1} was measured *in situ* (16 m) for *C. cupressoides* in the Caribbean (Williams and Dennison, 1990), with about the same rate for day and night. They reported the same uncoupling to light also for *C. taxifolia*.

2.6 Temperature Tolerance and Other Factors Affecting Growth and Distribution

The Mediterranean population of *C. taxifolia* has survived winter temperatures of about 11-12°C (Meinesz and Hesse, 1991), the fronds surviving also at times when the apical fronds of the native *C. prolifera* were affected by cold necrosis. However, they did report an effect by cold water also on 10% of the population of *C. taxifolia*. Since the species can disperse vegetatively, the distribution limit is thus set by survival and growth. According to Prud'homme van den Reine and van den Hoek (1990) the winter isotherm between the southern and northern cooler warm temperate subregions are 12.5°C, corresponding to northwest Spain, and that between the northern cooler warm temperate subregion and the cold temperate region 10°C, corresponding to Ireland and north England. Breeman (1988) gave temperature curves over the year which roughly correspond to those areas. Judging from the survival in winter in the Mediterranean, it might be possible that the plants could tolerate the winters at least as far north as northwest Spain, possibly even further north within the limit of the whole warm temperate subregion.

However, if growth is hampered by low temperatures in summer, the distribution limit might be set by summer rather than winter temperatures. The summer temperatures in the west Mediterranean are higher (*ca* 26°C in August, Meinesz, 1979b) than the August isotherms for the southern cooler warm temperate subregion which range between 21.5 and 18.5°C, and decreases to 15°C at the border to the cold temperate area, although coastal areas might have temperatures several degrees higher. This probably excludes the species from the northern cooler warm temperate subregion.

Since the main distribution of caulerpa species are in tropical to subtropical waters, it has not been possible to find any published tolerance tests of any species in the low temperature range below 15°C. O'Neal and Prince (1988) at 15°C found highly surpressed rhizome elongation and frond initiation of *C. paspaloides* from Florida, where winter temperatures range between 13 and 23°C. They concluded that temperature was a major factor controlling growth of that species, and also that minor reductions of salinity from 32 to 29 resulted in increased mortality of the rhizome apices.

For the cultured species *C. racemosa* in the Philippines Horstmann (1983) found photosynthesis to be strongly reduced in salinities below 30‰, and further that strong light was detrimental for those plants. He also tested temperature effects in those experiments, but not below 28°C. Furthermore, Aleem (1992) regarded increased salinities as a factor promoting establishment of *C. racemosa* in Egypt.

However, the growth of some caulerpa species on roots of mangroves, which mainly grow in brackish areas, indicates that some species might be less sensitive to reduced salinities, and the culture of caulerpa in Taiwan is reported to take place in brackish ponds (Tseng, 1982).

Nizamuddin (1964) found *C. taxifolia* also in ‘heavily polluted’ waters in Pakistan, as well as in areas with clear water. This reflects that nutrient conditions play a minor role for the distribution of *C. taxifolia*.

2.7 Toxicity/Palatability

Meinesz and Hesse (1991) strongly emphasised the risk of toxic compounds in the introduced caulerpa taxifolia, while they only briefly indicated that the other Mediterranean species contain the same compounds. The toxicity of at least 10 caulerpa species has in recent years been attributed mainly to the sesquiterpenoid metabolite caulerpenyne, (Paul *et al.*, 1987 and references therein), while the non-terpenoid substances caulerpin and caulerpicin, previously considered to be the responsible toxin (e.g., Doty and Aguilar-Santos, 1970) in most later tests have shown little activity (e.g., Paul *et al.*, 1987; Table 10). Several studies (e.g., Paul and Hay, 1986; Paul *et al.*, 1987) have shown that the concentrations of caulerpenyne, which can reach up to 40-50% of the organic extract, may vary in different populations and also may affect various grazers differently (e.g., Paul *et al.*, 1990 and references therein). This can be witnessed by the very different results of field and laboratory tests carried out (Table 1.3). Thus in several tests no toxic effects of *C. mexicana* were found (see above for species concept), while *C. prolifera* was deterrent or toxic. Other studies showed the opposite or no toxic effects at all of caulerpa species. Furthermore, it has been demonstrated (Paul *et al.*, 1987 and references therein) that there are more sesquiterpenoid metabolites in some species (including *C. prolifera*) with ichthyological and antimicrobial activities. Meinesz and Hesse (1991) also quoted papers where fish grazing caulerpa species may accumulate toxins which, when consumed, can affect humans. Chevaldonné (1990) discussed the possibilities that Mediterranean saupe (*Sarpa salpa*) can eat the unpreferred caulerpa species due to competition and/or climatic reasons. However, the examples he gave refer to other species of the genus including the native species *C. prolifera.* The risk thus seems to depend both on the availability of other algae for this herbivorous fish as well as on the toxic content of the caulerpa species if eaten. Thus it may be advisable to test how long the caulerpa toxins are stored in the fish in an active form, and also to advise checking the stomach contents before consumption and sale. Several studies (e.g., Doty and Aguilar-Santos, 1970; Cimino *et al.*, 1990 and references therein) have shown that grazing molluscs feeding on various species of caulerpa produce ichthyotoxic compounds in their mucus. Cimino *et al.* (1990) isolated and characterised two new ichthyotoxic substances from a opistobranchiate species living on *C. prolifera* in the Mediterranean which were produced *in vivo* from metabolites of the alga. The role of those substances in the food-web ought to be studied more.

Despite many caulerpa species having been recorded as containing toxic compounds some species, mainly *C. racemosa,* are also used for human food. The culture of *C. racemosa* in the Philippines has been described by, e.g., Horstmann (1983). Other areas where caulerpa is used as food are Malaysia and Indonesia (Michanek, 1975), Tonga (especially by pregnant women; Wood in Lucas, 1927) and Taiwan (Tseng, 1982).

Horstmann (1983) reported that the cultured *C. racemosa* apparently was not grazed, although some of the ponds were polycultures. This may point to a low grazing pressure. However, grazing by gastropods, shrimps and crabs was reported from Philippine caulerpa farms by Doty and Aguilar-Santos (1970). Harada and Kawasaki (1982) found *C. okamurai* to be effective in attracting young herbivorous abalone in tank experiments in Japan.

2.8 Conclusions

In the Mediterranean *C. taxifolia* has the ability to grow in winter temperatures of around 11-12°C (Meisnesz and Hesse 1991). Areas with corresponding winter temperatures encompass at least the Mediterranean and Atlantic coasts up to northwest Spain, and include some of the coasts further north within the warm temperate subregion.

Although many caulerpa species are considered as generally typical for tropical and subtropical waters several species of the genus can tolerate rather low winter temperatures. However, the report of some cold necrosis of *C. taxifolia* on the French coast may indicate that low temperatures can be detrimental.
Several other introduced algal species have been found in areas where water temperatures are colder than in its original distribution area (e.g., the Japanese brown alga *Sargassum muticum,* occurring also in areas with ice cover), and ecotypes may have developed (cf eg *Undaria pinnatifida*, Floc'h *et al.*, 1991). This makes the evaluation of its dispersal more difficult. Tests of temperature tolerances of the introduced *C. taxifolia* population are thus recommended.
On the other hand the very closely related (same?) species *C. mexica*na has a natural northern distribution limit in the Canary Islands and in the USA on the Georgia coast, but has not been found further north where other caulerpa species do occur. This might indicate that water temperatures in winter might be too low on most of the European Atlantic coasts for establishment of *C. taxifolia.* The ability to disperse through fragmentation would facilitate the dispersal of *C. taxifolia* along the European coasts providing temperatures and salinities are high enough for its establishment and growth. This also emphasises that mechanical removal of plants would have little success.
Toxic compounds may contribute to low grazing pressure making *C. taxifolia* more competitive, once established. However, toxicity may be highly dependent on environmental conditions and affect grazers differently. Chemical analyses on plants grown under different conditions (light intensities, photoperiods, temperature, nutrients) and preference experiments with different grazers on the introduced population in comparison to the native species are recommended. Although the origin of the introduced Mediterranean populations of *C. taxifolia* may not be traced with certainty, the rapid dispersal, once the species was accidentally introduced, emphasises the risks of release of ornamental plants as well as those introduced by scientists. The ICES Code of Practice which includes quarantine procedures should be undertaken in such cases.

Table 2.1 Occurrences of some Caulerpa species in cold water areas.

Species	Area	Comments	Reference
C. prolifera	N Carolina	to 48 m, winter temperatures may drop	Schneider and Searles below 10°C 1991
C. okamurai	E+S Korea	temperatures *ca* 8°C in winter	Kang 1966
	Japan	temperatures *ca* 11°C in winter	Kajimura 1968a
C. scalpelliformis	Japan	11-25°C, max growth in cold season	Kajimura 1968b, 1969
	W+S Australia, Tasmania	0-36 m	Womersley 1984
C. remotifolia	S Australia, E Tasmania	to 10 m	Womersley 1984
C. ellistoniae	W+S Australia	(7) 25-68 m	Womersley 1984
C. alternans	S Australia	13-40 m	Womersley 1984
C. longifolia	S Australia, Tasmania	to 40 m	Womersley 1984
C. trifaria	W+S Australia, Tasmania	to 31 m	Womersley 1984
C. brownii	W+S Australia, Tasmania	to 42 m	
	New Zealand		Womersley 1984
C. cliftonii	W+S Australia	to 50 m	Womersley 1984
C. obscura	W+S Australia, Tasmania	to 35 m	Womersley 1984
C. flexilis	W+S Australia, Tasmania	to 40 m	
	New Zealand (North Island)		Womersley 1984
C. hedleyi	W+S Australia	to 38 m	Womersley 1984
C. geminata	W+S Australia, Tasmania	to 25 m	
	New Zealand		Womersley 1984
C. annulata	S Australia, Tasmania	deep water	Womersley 1984
C. cactoides	W+S Australia, Tasmania	to 38 m	Womersley 1984
C. papillosa	W+S Australia, N Tasmania	to 12 m	Womersley 1984
C. vesiculifera	W+S Australia, N Tasmania	to 25 m	Womersley 1984
C. simpliciuscula	W+S Australia, Tasmania	to 38 m	Womersley 1984

Table 2.2 Species of Caulerpa in the Mediterranean Sea, and distribution in adjacent waters.

Species	Area	Comments
C. prolifera	Most Mediterranean coasts, Black Sea	Not in cold areas e.g., N Aegean Sea,
	Canary Island, Madeira, S Portugal, SW Spain	Adriatic Sea (Lüning, 1990)
C. ollivieri	S France, Spain, Turkey; Canary Islands	
C. racemosa	Turkey, Israel, Syria, Lebanon, Egypt	Lessepsian immigrant (Lipkin, 1972)
	Tunisia	Harbour in Sousse (Hamel, 1930)
	Egypt; Red Sea	New areas in 1991 (Aleem, 1992)
C. scalpelliformis	Israel, Syria, Lebanon; Red Sea	Lessepsian immigrant (Lipkin, 1972)
C. mexicana	Israel, Lebanon, Syria, Ethiopia	Lessepsian immigrant (Lipkin, 1972)
	Gulf of Eilat	down to 100 m, Lipkin (1975)
	Canary Islands	
C. taxifolia	France 1984	Meinesz and Hesse (1991)
	Sinai peninsula (Red Sea)	Lipkin 1975

Table 2.3 Toxicity tests of selected Caulerpa species.

Species	Effects	Area	Reference
C. prolifera	Mortality of fish to water extracts, no erythrocyte haemolysis	Florida	Targett and Mitsui (1979)
C. mexicana	No mortality of fish to water extracts, no erythrocyte haemolysis		
C. mexicana	Low food preference and mortality of fish when only diet	Caribbean	Lobel and Ogden (1981)
C. prolifera	High avoidance of gastropod to crude diethylether extracts	Florida	Targett and McConell (1982)
C. racemosa	Little avoidance of gastropod to crude diethylether extracts		
C. mexicana	No avoidance of gastropod to crude diethylether extracts		
caulerpenyne	High avoidance of gastropod		
C. prolifera	*ca* 50% inhibition on sea-urchin feeding (diethylether extract)	Florida	McConell *et al.* (1982)
C. mexicana	No significant effect on sea-urchin feeding (diethylether extract)		
C. racemosa	No significant effect on sea-urchin feeding (diethylether extract)		
C. ashmeadii	No significant effect on sea-urchin feeding (diethylether extract)		
caulerpenyne	*ca* 50% inhibition on sea-urchin feeding (diethylether extract)		
caulerpin	No significant effect on sea-urchin feeding (diethylether extract)		
C. cypressoides	18-30% eaten by herbivorous fish in field study	Caribbean Sea	Hay (1984)
C. mexicana	28% eaten by herbivorous fish in field study		
C. prolifera	42-66% eaten by herbivorous fish in field study		
C. ashmeadii	76% eaten by herbivorous fish in field study		
C. sertularioides	100% eaten by herbivorous fish in field study	Seychelles	
caulerpenyne	Stops division of fertilised sea-urchin eggs		
C. sertularioides	65% eaten by herbivorous fish in field study, only found in sea-urchin free areas	Caribbean Sea	Taylor *et al.* (1984)
C. racemosa	82-100% eaten by herbivorous fish in field study, also found in area with sea-urchins		
C. mexicana	87% eaten by herbivorous fish in field study, only found in sea-urchin free areas		
C.prolifera	8-70% eaten by herbivorous fish in field study, caulerpenyne >40-20% of organic extract, respectively	Florida	Paul and Hay (1986)
C. racemosa	45-48% eaten by herbivorous fish in field study, caulerpenyne *ca* 20% of organic extract		
C. mexicana	63% eaten by herbivorous fish in field study, caulerpenyne *ca* 10% of organic extract		
C. sertularioides	60-90% eaten by herbivorous fish in field study, caulerpenyne 0% of organic extract	Florida	Paul and Hay (1986)
Caulerpenyne	Deterrent to parrotfish	Caribbean	Targett *et al.* (1986) in Paul *et al.* (1990)
C. ashmeadii	25-58% eaten by herbivorous fish in field study	Florida	Paul *et al.* (1987)
C. sertularioides	54-95% eaten by herbivorous fish in field study		
C. mexicana	78-99% eaten by herbivorous fish in field study		
C. racemosa	92-94% eaten by herbivorous fish in field study		
C. prolifera	94-100% eaten by herbivorous fish in field study		

Table 2.3 (continued)

Species	Effects	Area	Reference
Caulerpenyne	Ichthyotoxic and antimicrobial (also 4 other metabolites in *C. ashmeadii*)		
Caulerpin	Non-toxic to fish		
*C. racemosa**	No significant effect on fish feeding (diethylether extract)	Guam	Paul (1987)
*C. serrulatula**	No significant effect on fish feeding (diethylether extract)		
C. sertularioides	No significant effect on sea-urchin feeding (diethylether extract)		
	(*caulerpenyne present, all species much grazed in the reef)		
C. racemosa	*ca* 100% eaten by rabbitfish in tank experiment	Guam	Paul *et al.* (1990)
C. racemosa	Nondeterrent to adult or juvenile rabbitfish in tank experiment and higly preferred species		
Caulerpenyne	Nondeterrent to adult or juvenile rabbitfish		
Caulerpin	Nondeterrent to adult rabbitfish		

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3 Summary of Invertebrate Introductions and Transfers

3.1 Introduction

This section is a review of marine invertebrate introductions made into each ICES country from 1980 to 1991. In addition to introductions, transfers of indigenous species occurred within and between countries often on a regular basis. Tables are attached in which details of the dates, origins and fates of introductions and transfers in each country are given. These tables contain information that was available in the ICES annual reports and should be read in conjunction with this text. The legislation that controls the introduction and transfer of invertebrates is also described briefly although this legislation is often under review. For example, a Directive (No R(84)14) adopted in 1984 by the Council of Europe Committee of ministers will necessitate changes to the current legislation concerning the introduction of non-native species to member states of the European Union.

Most of the deliberate introductions of live animals were for aquaculture, for consumption or for recreation purposes. For aquaculture, introductions of molluscs were the most common although introductions of crustaceans, notably penaeid prawns, were important in some European countries (Spain, Portugal, France) and in the USA. Of the molluscs the Pacific oyster, *Crassostrea gigas*, continued to be of prime importance as a commercial species, with annual production increasing in many ICES countries. The introduction and culture of the Manila clam, *Tapes* (= *Ruditapes*) *philippinarum* has mirrored that of the Pacific oyster. Since its accidental introduction to Canada from Japan in shipments of *C. gigas* seed, it has been introduced to Europe. The Manila clam was in France in the late 1970s but during the 1980's it was introduced to many other European countries. There was increased interest in scallop culture during the 1980s. Introductions of *Patinopecten yessoensis* were made from Japan to the USA, Canada, France, Denmark and Ireland to assess the culture potential of this species against that of local species.

Information from ICES countries on the annual import and export of live invertebrates for commercial and recreational purposes was incomplete because data were often not available or not easy to differentiate. Also some countries import only to immediately re-export. In some European countries (Netherlands, UK and Denmark) some concern was expressed over the increase in the import of bait-worms for angling. As stocks in local countries became exhausted, countries of origin included Korea (via France or direct), Africa and the USA. It is extremely likely that many are released into open waters. There is also potential for the introduction of exotic species of macroalgae (e.g., from Korea), which are used as packing material for worms during transit.

In addition to deliberate introductions for commercial purposes, others were made for research. Most of these introductions involved only one importation of the species concerned, animals were usually held in quarantine during the study period and then destroyed when the research was completed. There was some concern, however, that not all research institutes were aware of the controls and guidelines for the introduction and holding of exotic species.

The 1980s were exceptional owing to the spread in Europe of two parasites, *Bonamia ostreae* which infected *Ostrea edulis*, and *Anguillicola crassa* which caused swim-bladder disease in *Anguilla anguilla*. Both were introduced accidentally with deliberate introductions of their hosts but the result was major economic losses in the oyster and eel fisheries. *B. ostreae* occurred on the Pacific coast of the US in Washington State and California. It is believed to have spread from Elkhorn Slough on Monterey Bay, California to Washington State in shipments of oysters. It is likely that oysters from California, sent to France in the 1970s, were the source of introduction into Europe.

Many other accidental introductions are thought to have been associated with the transport and discharge of ballast from shipping. Ballast, taken on board in one port, is often transported many miles before it is finally discharged. Some organisms, transported in ballast and introduced into alien environments, have successfully colonised their new habitat. A prime example is the devastating impact made by *Dreissena polymorpha* (the European freshwater zebra mussel) in the Great Lakes of North America in the late 1980s. Millions of dollars had to be spent annually to eliminate the mussel from municipal and industrial intake pipes. As countries became increasingly aware of the potential problem of introductions through ballast, legislation or guidelines were formulated (in Australia, Canada and the USA) to control ballast discharge.

3.2 Introduced Species in the Different Countries

3.2.1 Belgium

There are no laws on the control of introductions but shellfish imports have to be certified free of human health pathogens, toxins and parasites. Some control over live imports is taken to protect native shellfish from the introduction of disease.

There was limited information available on introductions of invertebrates compared to other ICES countries, but from the early 1980s *C. gigas* and *T. philippinarum* seed were being imported for on-growing in onshore nursery facilities.

3.2.2 Canada

Introductions and transfers into all regions and between administrative regions are controlled and managed on advice from Regional Introduction and Transfer Committees and scientific advisory groups. In British Columbia, Provincial Fisheries Regulations under the Fisheries Act prohibit some movements of shellfish and of *C. gigas*, including boats and equipment used by the industry, in order to restrict the spread of the Japanese oyster drill, *Ocenebra japonica* (= *Ceratostoma inornatum*, the newer but less well known name). Policies and legislation to control introductions and transfers of aquatic organisms are under development or review nationally and in some provinces. For example, a Federal-Provincial Introductions and Transfers Committee was established in Prince Edward Island to review all requests for introductions and transfers of fish, shellfish and plants in the Province.

Canada is one of the countries that has taken positive steps to prevent the inadvertent introduction of exotic species in ballast. The Canadian Coastguard issued ‘Voluntary Guidelines for the Control of Ballast Water Discharges from Ships Proceeding via the St Lawrence Seaway to the Great Lakes’ and an 11-page research document was prepared on ‘The Risk to Atlantic Canadian Waters of Unwanted Species Introduction Carried in Ships' Ballast’. In April 1991, The Department of Fisheries and Oceans held a one day workshop to address the problem of introductions via ballast water.

There is a well-established mariculture industry in Canada, particularly on the western Pacific coast and in the Maritime provinces on the eastern seaboard. The culture of *C. gigas* (and *Ostrea edulis*) and *T. philippinarum* in British Columbia involved the import of substantial numbers of seed from hatcheries in California, Oregon and Washington. The technique of remote setting of ‘eyed’-larvae, where settlement is carried out in tanks at the on-growing site, was used more extensively for the farming of *C. gigas*, and large numbers of animals were transferred from the hatcheries at this stage of their life cycle.

P. yessoensis was introduced to the Pacific Biological Station in British Columbia in 1984-1985 and assessments on the culture potential of other scallop species were continued. The F_1 and F_2 generations of the bay scallop *Argopecten irradians*, reared from two introductions of broodstock from the east coast of the United States in 1979 and 1980, were not released until a 'purple' parasite was shown to be present in other local stock species. Approximately 700 adults of later generations (F_{3-5}) were transferred from the Ellerslie, Prince Edward Island, hatchery to the Pleasant Point, Nova Scotia, hatchery as breeding stock to produce seed for commercial trials. Genetic 'bottle-necking' and poor survival rates created demand for another USA shipment of bay scallops in 1989 which passed through the quarantine facility at the Halifax Laboratory, Nova Scotia, producing additional broodstock of a different genetic composition for the aquaculture industry.

In 1986 *Argopecten purpuratus* were imported from Chile to British Columbia. Seventy adults were spawned, about 50,000 juveniles were produced, then broodstock were destroyed. Most of the juveniles were still held in enclosed nursery systems in 1988, but a few were released in open water in Departure Bay, British Columbia. Fifty *Placopecten magellanicus* (source not specified) were imported to British Columbia and were held in quarantine at the Pacific Biological station.

3.2.3 Denmark

The Order of 7 September 1971, on the import of live oysters, was replaced by the 'Order on Control of Oysters' (Ministry of Fisheries, Order No 104 of 22 March 1984). It is primarily concerned with human health aspects but Section 104.5.4 requires that oysters which are intended for release or rearing should be free from parasites and disease which could harm the local fauna. A health certificate may also be required. Under the 1986 Danish Salt Water Fisheries Act (Article 32), any introduction or transfer of fishes, crustaceans and molluscs, and eggs or juveniles thereof, requires a special permit granted by the Secretary for Fisheries after consultation with the fishermen's organisations and the Danish Institute for Fisheries and Marine Research.

In May 1991, a law on 'The Environment and Genetic Engineering' was passed. Any releases of genetically modified organisms into the territorial seas and the Danish fishery zone requires a permit issued by the Ministry of the Environment.

The bivalve culture industry imported *C. gigas* seed regularly from hatcheries in the UK, and on occasions from Germany, the Netherlands and France. This species was grown in cage culture in areas such as the Waddensea and in basins with cooling water from power stations. There was concern that in warm summers it might breed successfully and compete with *O. edulis*. The fishery for *O. edulis* was affected by *B. ostreae* which was introduced in 1980 with imports of oysters from France. Diseased oysters were found in Linnfjord in 1982 and steps were taken to clear beds in an attempt to prevent further spread of the disease. By 1983 *Bonamia* was no longer evident.

There was also interest in clam and scallop culture. *T. philippinarum* seed were imported from the UK for on-growing and a commercial firm imported 5,000 adult *P. yessoensis* from wild stocks in Japan. Within hours of arrival the scallops were placed in trays in the Kattegat but within a few days all, except 400, were dead. At the 1989 ICES meeting in Dublin, Ireland, it was stated that these animals could not be traced. It was assumed that the trays and animals were lost.

3.2.4 Finland

The import of animals is regulated mainly by the Animal Disease Law (No 55/80), the Animal Disease Statute (No 884/75), and the Decision of the Ministry of Agriculture and Forestry Veterinary Department (No 59/90) to prevent the spread of animal diseases. The import of fish and crustaceans, is also regulated by the Fishery Law (No 286/82).

The cold brackish waters of Finland make the import of molluscs and crustaceans for mariculture impractical. Aquarium shops and some restaurants and stores imported live animals such as oysters, lobsters and crabs for sale or consumption and this was permitted without the authorisation of the Veterinary

Department because the animals would not survive in Finnish waters.

3.2.5 France

Legislation on introductions exists within the Code Rural Francais. Shellfish, from countries with health regulations acceptable to French law, may be imported for direct consumption but importations can be suspended if animals are found to be diseased, parasitised or toxic. Adult shellfish (oysters excepted) can be imported and held in quarantine basins before sale. Seed can be imported into quarantine and, if found to be free of pests and diseases, they can be relaid in parcs.

France remained the most important producer of *C. gigas* in Europe with commercial production increasing up to 150,000 mt yr^{-1}. The industry relied on hatchery-produced seed, home produced and imported, and on spat collection from areas such as Marennes-Oleron where natural recruitment occurred. Importations of seed from Japan were banned in 1980 after seed, certified as disease-free, were found to contain a haplosporidian.

B. ostrea was identified in Brittany in 1979, even though importations of seed *O. edulis* from the USA were forbidden. Therefore, it is presumed that an illegal introduction of seed was made. In 1980 a regulation was introduced to forbid the transfer of oysters from areas with *B. ostrea*. As a result of the decline in the *O. edulis* fishery due to *B. ostreae*, broodstock of other *Ostrea* species were introduced into quarantine, from which spat were reared to assess their resistance to this disease organism. The species tested, *O. chilensis*, *O. densallamelosa*, *O. angasi* and *O. puelchana* were not resistant.

France was the first country in Europe to introduce *T. philippinarum* (from British Columbia in the late 1970s).

By the early 1980s cultivation in France was approaching commercial scales and by 1989 annual production was 450 mt. Breeding populations had also become established in the wild as far north as Brittany. A series of trials to assess the culture potential of *P. yessoensis* were started after broodstock were introduced into hatchery quarantine in 1986. Field trials in the Mediterranean and off the coast of Brittany were reported to have been disappointing and by 1992 the experiments had been terminated.

3.2.6 Germany

No national laws specifically regulate marine introductions although some local regulations cover resources in coastal waters, including introductions.

There was limited interest in mariculture but small numbers of *C. gigas* seed and 'eyed'-larvae were imported from Scotland.

3.2.7 Iceland

No information available.

3.2.8 Ireland

The import of live fish and shellfish is prohibited except under licence through the Live Fish (Restriction on Import) Order 1972 (SI No 4 of 1972) and the Fish Diseases (Control of Imports) Order 1973 (SI No 18 of 1973). A permit is necessary to move fish from one farm to another and for shellfish from one geographical area to another. The Molluscan Shellfish (Conservation of Stocks) Order 1987 (SI No 118 of 1987) prohibits the transfer of molluscs for relaying except under licence to avoid the spread of molluscan disease organisms, in particular *B. ostrea* which was found in oysters in Cork Harbour in 1987. By then it was well established and many adult oysters were found dead and dying. In 1988 and 1989, *B. ostreae* was found in oysters growing in Clew Bay and Galway Bay respectively.

During the 1980s interest in aquaculture increased. Several million *C. gigas* seed were imported annually to sustain the commercial culture of this species. A thriving industry developed particularly in Carlingford Lough where oysters were grown in bags and on trestles. Annual production in 1980 was 5 mt but this had increased to 170 mt in 1988, representing more than 50% of total landings.

The first introduction of *T. philippinarum* was made from the UK in 1982 and several million seed were subsequently imported annually from the same source. The species became widely cultured and many small hatcheries and farms, sited on all coasts, expanded rapidly. In 1989, 40 mt were produced, the majority of which were exported to Spain as too were surplus hatchery-produced seed.

There was also interest in the Pacific abalone and the Japanese scallop. Fifty *Haliotis discus hannai* were introduced from Japan in 1985 and successful spawnings were achieved in 1989. By1991, F_1 progeny had been distributed to commercial hatcheries and transferred also for on-growing in barrels in open waters on the south, east and west coasts. Those on the east coast were unable to survive the winter temperatures (2.8°C) of 1991. *P. yessoensis* seed, reared from imports of broodstock made in 1990, were being grown on in pearl nets in open waters on the SE coast. Initial results, assessing their peformance in relation to native scallop species, were disappointing but the on-growing site was thought to have been too exposed for the culture of *P. yessoensis*. Further assessments were to be made and more broodstock were imported into quarantine from Japan in 1991.

3.2.9 Netherlands

The Dutch Fishery Law (Visserijwet) 1963 forbids the import of fish and shellfish species except under licence granted by the Ministry of Agriculture and Fisheries. Once a species has been introduced from one country it is then theoretically possible to introduce it from other sources.

The Dutch oyster industry was severely affected by *B. ostreae* which was introduced in 1980 with imports of oysters from France. Oysters suffered 60% mortalities before steps could be taken to clear beds of infected stock. *C. gigas* is reported to have bred in the wild in very warm summers and to prevent it becoming a pest on *O. edulis* beds, Pacific oysters were removed from the beds and destroyed.

3.2.10 Norway

Laws on diseases in marine organisms, which also covered introductions and transfers, were implemented in 1990. Introductions and transfers are under the control of the Ministries of Agriculture, Environment and Fisheries.

C. gigas seed were imported from England and Scotland until 1983 and from Scotland in 1984 and 1985. Subsequently the Norwegian industry was self-sustaining for seed of this species and had itself started to export surplus seed. Like many other European countries, Norway became interested in the culture of *T. philippinarum* and in 1988 broodstock were introduced from the UK.

3.2.11 Poland

The Ministry of Agriculture Veterinary Department and the National League of Nature Protection have to approve any introduction of non-native species. Any transfer of indigenous species has to be approved by the local (regional) Nature Protection office.

All imports are disinfected on arrival.

3.2.12 Portugal

The only legislation concerns animal and public health control and the transfer of animals within interior waters. Animals intended for introduction must carry a certificate, defining the health status, from the country of origin. The National Institute for Fisheries Research inspects a sample of the animals and can, under Law 980-A/89, prevent the introduction.

Aquaculture has increased during the 1980s. Seed *T. phillipinarum* were introduced, it is believed illegally from Spain, sometime before 1986 and the culture of *C. gigas* is important. The semi-intensive farming of *P. japonicus* was taking place in several estuaries and lagoons after broodstock prawns were introduced from Spain in 1985.

3.2.13 Spain

New national regulations were in force in 1984 after changes in the Spanish Administration. Importations are regulated by Article 22 of Law 3/84 of Marine Cultures, they must be approved by the Ministry of Agriculture, Fisheries and Food (Oceanographic Institution), they must have a health certificate from the country of origin and they must be supervised by the competent Fisheries Organisation. For transfer of species between different zones of the coast, only a permit from the competent Fisheries Organisation, where the transfer is to be made, is required.

Shellfish culture is an important industry in Spain. Introduced species included *C. gigas* and *T. philippinarum* (both imported as seed from the UK and France) and the crustaceans *Penaeus monodon* and *P. japonicus*. *B. ostreae* was identified in Galicia in the early 1980s.

3.2.14 Sweden

Introduction and stocking of live fish and shellfish is allowed only under licence. The National Agriculture Board is responsible for any imports while the introduction and stocking is with the National Board of Fisheries and always in consultation with the State Veterinary Institute (Agriculture Board Ordinances, Veterinary Regulations (LSFS 1983:30/Vb10/ paragraph 6); Swedish National Ordinances (SFS 1982:126, paragraph 34)). Delivery of animals must be accompanied by certificates of health and origin. Introductions of exotic species into the Baltic (including the Kattegat) are prohibited by the International Baltic Sea Fisheries Commission (Rule 5) unless all surrounding states agree to it.

The cool waters of Sweden make the introduction of exotic species unattractive. Experiments on the culture of *C. gigas* in the 1970s led to the introduction of seed from the UK but they were not able to survive the local conditions.

3.2.15 United Kingdom

Several changes occurred in the 1980s to keep pace with the increase in aquaculture. The importation of live or dead fish and shellfish is controlled by the Animal Health Act 1981 (Section 10) and the main disease controls in the Diseases of Fish Act 1937 (Section 1) were updated by the Diseases of Fish Act 1983. Under the 1983 Act, movements of fish and shellfish into and out of farms, including the origin of the stock, is monitored under the Registration of Fish Farming and Shellfish Farming Business Order 1985. The Molluscan Shellfish (Control of Deposit) Order 1974 was amended by the Molluscan Shellfish (Control of Deposit) Order 1983 to prevent the spread of *B. ostrea* (see below). The Lobsters (Control of Deposit) Order 1981 prohibits the deposit of *Homarus americanus* and *H. gammarus* in all tidal areas of territorial waters unless a licence is granted. The Lobsters (Control of Importation) Order 1981 prohibits the importation of lobsters into these areas unless under licence. The Wildlife and Countryside Act 1981 also prevents the release of non-indigenous species except under licence.

Production of *C. gigas* was around 600 mt in 1989 and was expected to increase by 30% per year. The increase in production resulted from improved growth and survival of this species after the use of anti-foulant paints containing TBT was restricted in 1987. Commercial culture relied exclusively on seed produced in UK hatcheries and hatchery seed, which were surplus to UK requirements, were exported worldwide.

T. philippinarum broodstock were imported into quarantine from Oregon in 1980. In 1981 some of the F1 progeny were sent to two commercial hatcheries, one in England and one in Scotland, to establish hatchery broodstocks. Since 1982 *T. philippinarum* seed have been transferred regularly within and between countries of the UK and also to Eire. Although the hatchery production of commercial quantities of seed was well-established by the mid-1980s, few growers in the UK were interested in growing this species to market size. By 1990 the annual production was less than 20 mt and much of the seed was exported worldwide.

The *O. edulis* industry was affected by *B. ostreae* which was identified in oysters from Cornwall, England in 1982. The disease soon spread further, with shipments of oysters, to Essex on the east coast. Further spread of the disease was prevented by improvements in the legislation on movements of oysters in 1983. However, *Bonamia* was identified in oysters in the Beaulieu River, Poole Harbour and Emsworth Harbour on the south coast but this was thought to have been the result of movements of oysters from Cornwall before 1982.

Two other oysters, *Crassostrea rhizophorae* from Brazil and *Crassostrea virginica* from Chesapeake Bay, USA were introduced in 1980 and 1984 respectively and assessed for their aquaculture potential. Some of the F_1 generation of *C. rhizophorae* were planted in the sea in 1981 but they all died and no further work was done with this species. The shellfish industry's interest in *C. virginica* has been minimal because the production of *C. gigas* increased after the restriction on the use of TBT in 1987.

3.2.16 United States

The Lacey Act as amended in 1981 controls the import, export and transfer of fish and wildlife in violation of State, Federal or foreign laws or regulations. Individual states regulate fish and shellfish movements. Alaska declared that only ornamental fish and oysters could be imported into the state, and that oysters originating from Korea, the Gulf of Mexico and the Atlantic coast of the USA could not be imported unless they had passed through at least three generations on the Pacific coast of North America. The Atlantic States Marine Fisheries Commission issued a policy statement in 1989 regulating shellfish transfers and introductions on the east coast of North America with respect to concerns over disease, and ecological and genetic issues. Legislation to prevent and control infestations of coastal inland waters by the zebra mussel and other non-indigenous aquatic nuisance species was passed (the 'Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990). This had resulted from the explosive invasion of *Dreissena polymorpha* in the Great Lakes. From

1988 when the mussel was first found in Lake Erie, it had soon colonised Lake Ontario and Lake Michigan and was in all the Great Lakes by the end of 1990. The financial cost to the country of this invasive species was enormous. During the 1980s there was a further decline in the stocks of *C. virginica* on the eastern seaboard through over-fishing and disease outbreaks. As a result, there were requests to introduce *C. gigas* to open waters of the mid-Atlantic states (New Jersey, Delaware, Maryland and Virginia) but owing to conflicting opinions on the likely impact of the introduction, the requests had not been approved by 1990. An alternative proposal (reported in 1989) was to try and produce a hybrid between *C. gigas* and *C. virginica* which, it was hoped, would be more resistant to disease. Within the USA, *C. gigas* was transferred with consignments of *C. virginica*, to Massachussetts and maybe to Maine and New York as a result of aquaculture operations.

Growing interest in the culture of *Penaeus vanamei* led to importations of prawns from Panama and Texas into South Carolina. The importation of *P. stylirostris* into Atlantic waters was discontinued when infection of this species by IHHN virus was reported in Hawaii and Mexico. The disease, which was traced to importations of prawns from Costa Rica, affects *P. stylirostris* and *P. monodon*. *P. vannamei* carries and transmits the virus without itself being affected. *Macrobrachium rosenbergii* is not known to be affected.

Table 3.1 Analyses by country of introductions of invertebrates. Keys to ICES code of classification are given in Appendix 1 and the key to species abbreviations in Table 3.12

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
				BELGIUM			
3.2.2	Early 1980s	*Cg Oe, Tp*	-	juveniles	-	-	Under culture in onshore nurseries
3.2.5	-	*Oe*	-	-	Netherlands	Belgium	-
				CANADA			
3.2.1	May 1985	*Cv*	100 bushels	-	-	Port au Port Bay, Newfoundland	Poor growth
	1982	*Ha*	2000	adult	Notre Dam Bay, Newfoundland	St Michaels Bay, Labrador	-
	1983	*Ha*	1000	adult			
3.2.2	-	*Cg, Oe, Me, Tp*	substantial	seed	California, Oregon and Washington (hatcheries)	British Columbia	Regular trade
	-	*Cg*	substantial	'eyed' larvae	California, Oregon and Washington (hatcheries)	British Columbia	Regular trade
	-	*Hr*	20	adult	California	British Columbia	Hatchery broodstock
	-	*Oe*	-	adult	Scotland and Nova Scotia	British Columbia	Hatchery broodstock
	1980	*Plm*	-	seed	-	Quebec	
	1989	*Plm*	-	seed	Newfoundland	Nova Scotia	
	-	*Ai*	-	-	Nova Scotia	New Brunswick and Prince Edward Island	-
	-	*Oe*	-	-	Nova Scotia	New Brunswick	-
3.2.3	-	*Me, Cv, Cg, Oe, Mv, Mm, Ari, Ma, Sp, Ss, Ll, Bu, Ha*	-	adult	various	various	Regular trade See also 6.3
3.2.5	1981	*Pg*	-	juvenile	Washington (hatchery)	British Columbia	
	1987	*Me*	-	-	California, Nova Scotia and Spain	British Columbia	
	-	*Hr*	-	2 cm	California	British Columbia	
	-	*Pl sp.*	-	-	Alaska	British Columbia	
3.2.5	-	*Pem & Mr*	-	-	Hawaii	British Columbia	
	1987	*Cg*	-	adult	Washington and California	University of Victoria	
	1984	*Ps*	100	-	Vancouver	Dalhousie University	
	1989	*Aw*	250	-	Israel	-	

Table 3.1. (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
	1989	*Stp*	50	-	California	New Brunswick	
	1989	*Stp*	-	-	British Columbia	Newfoundland	
6.1	1980	*Ai*	-	Adult	Connecticut	Ellerslie, Prince Edward Island	Hatchery broodstock
	-	*Ai*	700	adult	Ellerslie	Pleasant Point, Nova Scotia	Hatchery broodstock
	1986	*Ap*	>70	adult	Coquimbo, Chile	British Columbia	Hatchery broodstock
		Plm	50	adult	-	British Columbia	Hatchery broodstock
		Py	50	adult	Japan		
	1989–1990	*Me*	-	-	Washington	British Columbia	
	1989–1990	*Cc*	few	adult	Magdalen Islands	Nova Scotia	
6.2	1981–1982	*Ai*	-	-	Ellerslie (hatchery)	Bideford river and 13 locations around Prince Edward Island	F3 & F4 stock
	1987	*Ai*	1 million	juvenile	Pleasant Point (hatchery) Nova Scotia	Tracadie Bay	
	1988	*Ap*	< 50,000	juvenile	British Columbia	Departure Bay, BC	See 6.1
	-	*Oe*	-	seed	Pleasant Point (hatchery), Nova Scotia	-	Grow-out probably local
6.3	1982	*Cg, Tp*	-	seed	California (hatchery)	British Columbia	
8.1	-	*Sg, Ps, Tp, Cg, Pa, Hk, Sip*	-	seed	British Columbia	Include Europe and USA	Regular trade
		Cv, Me, Ma, Oe, Bu, Mm, Ai, Sp, Ss, Ll	-	seed	Nova Scotia and other Atlantic states	-	Regular trade
DENMARK							
3.2.2	-	*Cg*	-	seed	UK (hatcheries) Germany, France, Netherlands	e.g., Waddensea	-
	-	*Oe*	-	seed	UK (hatcheries)	-	-
	-	*Tp*	-	seed	UK (hatcheries)	Saeby, N Jutland	-
	1985	*Py*	5000	adult	Japan	Laeso, Kattegat	Trays and animals lost
3.2.3	-	*Cg*	13,7 kg	adult	England, Netherlands	-	-
	-	*Oe*	2.7 kg		France		

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
	-	oysters	50–100	adult	Yugoslavia (Istria)	-	-
	-	oysters	-	seed	Yugoslavia	-	-
3.2.5	-	oysters	760 kg	juvenile	Ireland, Norway	-	-
4.0	1980	*Bo*	-	-	France	-	With oyster imports
	-	*Ac*	-	-	-	-	-
	-	*Ac*	-	-	-	-	-
5.0	1985	*Ed*	-	-	-	Kattegat coast	-
	-	*Eriocheir sinensis*	-	-	-	-	-
6.1	-	*Cg, Cv*	-	-	-		Into quarantine
8.1	-	*Me*	-	adult	-	France	Regular trade
	1985 or 1986	*Cg*	-	adult	-	Sweden	-
FINLAND							
5.0	Pre-20th century	*Cordylophora caspia*	-	-	Ponto-Caspian	-	Common from S Baltic to N Bothnia Bay (on bottoms of ships)
	1963	*Polydora redeki*	-	-	W Europe	SW area of Finland	Found from Aland Islands in west to Porvoo/Borga in east (on ships)
	-	*Mya arenaria*	-	-	N America	-	Extends up to northern Bothnian Sea (in ballast or as bait)
	1926	*Potamopyrgus jenkinsi*	-	-	New Zealand	Aland Islands	In Gulfs of Bothnia and Finland by 1945 (ballast species)

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
	1930s	*Eriocheir sinensis*	-	-	SE Asia	Baltic Sea	To Bothnia Bay within 20 years (ballast species)
	1844	*Balanus improvis*	-	-	-	-	Very common today in all sea areas
		Victorella pavida	-	-	-	-	Common in waters off southern coast (on bottoms of ships)
FRANCE							
3.2.1	-	*Cg, Tp*	-	adult	-	-	Breeding in wild
3.2.2	-	*Cg, Oe*	-	seed	UK and Guernsey (hatcheries)	-	-
	-	*Td*	-	seed	Guernsey (hatchery)	-	-
	-	*Tp*	-	seed	Senegal	Atlantic coast areas	Sent to Senegal from France
	-	*Pm*	500,000	juveniles	Ireland (Mulroy Bay)	St Brieuc Bay and Brest Harbour	-
	-	*Pej*	-	post-larvae	-	Languedoc-Roussillon	Pond culture
3.2.3	-	*Oe, Cg*	-	-	Italy, Netherlands, UK, Ireland, Spain	-	Regular consumer trade
	-	*Cg*	-	seed	Italy, Netherlands, UK, Ireland, Spain and Senegal	-	-
	-	*Me*	-	adult	Belgium-Luxembourg, Netherlands, Ireland, UK, Spain, Germany, Italy, Turkey, Canada, Denmark, S Korea, Sweden	-	Regular consumer trade
	-	oysters	-	seed	Tunisia	-	-
	-	other shellfish, e.g., *Pm, Chlamys*	-	-	Ireland, UK, Canada, Spain	-	Regular consumer trade
		Plm			Netherlands, Italy, Belgium-Luxembourg		Trade
3.2.5	-	*Pev*	-	-	Tahiti	-	-
4.0	1980	*Bo*	-	-	? California	Brittany	With oyster imports
		Mytilicola intestinalis	-	-	-	-	Still present

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
6.1	1987–1988	*Py*	-	adult	Japan	La Tremblade (hatchery)	Into quarantine
	pre-1982	*Ostrea chilensis*	80 kg	various	Chile	Cherbourg (hatchery)	Into quarantine
	1982	*Ostrea densalamellosa*	-	adult	Korea		Into quarantine
	pre-1985	*Ostrea angasi*	-	adult	New Zealand		Into quarantine
	late 1980s	*Ostrea puelchana*	400	adult	Argentina	IFREMER	Into quarantine
5.0	late 1980s	*Ostrea puelchana*	800,000	seed	IFREMER	Brittany and Marennes-Oleron	Testing for resistance to *Bonamia ostreae*
8.1	-	*Oe*	-	adult	-	Denmark	Regular trade
	-	*Cg*	-	adult	-	Denmark, UK, Portugal	Regular trade
	-	*Hg*	-	adult	-	Spain	Regular trade
GERMANY							
3.2.2	-	*Cg*	80,000	seed	Scotland	North Sea sites	Quarantine on arrival
		Cg	200,000	‘eyed’ larvae	Scotland	North Sea sites	Quarantine on arrival
3.2.5	-	Sea urchins	-	-	Israel (Red Sea)	-	Bioassay studies
4.0	1984	*Mytilicola intestinalis*	-	-	-	Wadden Sea	In relaid mussels (?)
	1983	*Ac*	-	-	-	Ems river	-
5.0	-	*Eriocheir sinensis*	-	-	-	-	Declining numbers due to exploitation
	-	Amphipods	-	-	-	Extended range	
8.1	-	*Me*	-	adult	-	France	Regular trade
IRELAND							
3.2.2	1982	*Tp*	25,000	Seed (2-20 mm)	UK (Conwy)	-	First introduction
	1980–1990	*Cg*	substantial	seed (2-20 mm)	UK and Guernsey (hatcheries)	-	Regular trade

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
	1989–1990	*Tp*					
3.2.4	-	*Artemia salina*	-	eggs	Worldwide	-	Dried and vacuum packed
4.0	1987	*Bo*	-	-	-	Cork harbour	With oyster imports
	1988	*Bo*	-	-	-	Clew Bay	With oyster imports
	1989	*Bo*	-	-	-	Galway Bay	With oyster imports
	-	*Herminella duggani*	-	-	-	West and south coasts	*Oe* with wavy gill margins
	-	*Calyptraea chinensis*	-	-	? France	Clew Bay and Ballinakill Bay	? Introduced in 1950s and 1960s with oyster imports
5.0	1986	*Styela clava*	-	-	-	Cork Harbour	First seen 1972
	-	*Corophium sextonae*	-	-	-	South coast (3 sites)	Introduced by shipping
5.0	1986	*Ficopomatus enigmaticus*	-	-	Cork Harbour (1972)	Lee Estuary	-
	1989	*Elminius modestus*	-	-	-	Galway Bay	-
6.1	1987	*Haliotis discus hannai*	30	adult	Japan (Iwate Prefecture)	Carna	Into quarantine
	1990	*Py*	177	adult	Japan (Miyagi Prefecture)	Wexford	Into quarantine
			1,250,000	D-larvae			larvae died
6.2	-	*Haliotis tuberculata*	-	-	Guernsey (1975-broodstock)	South-west and west coast	On-growing trials
7.0	-	*Py*	-	adult	Japan	Wexford	Hatchery broodstock
8.1	-	*Oe*	-	adult	Clew Bay and Tralee Bay	France, Netherlands, Denmark	Regular trade
	-	*Ll*	-	adult	-	France, Netherlands	Regular trade
	1989–190	*Tp*	-	adult	-	Spain	Regular trade
8.2	-	*Palinurus elephas*	-	adult	-	France, Spain, UK	Regular trade
	-	*Liocarcinus depurator*	-	adult	-	Spain	Regular trade
	-	*Hg*	-	adult	-	Spain	Regular trade

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
	-	*Pl*	-	adult	-	France	Regular trade
9.1	1981/2	*Pm*	2,000,000	juveniles	-	France (Rade de Brest and Baie de St Brieuc)	For restocking experiments
9.1	1981/2	*Pm*	2,000,000	juveniles	-	France (Rade de Brest and Baie de St Brieuc)	For restocking experiments
	-	*Pm, Tp*	-	juveniles	-	Spain	-
	-	*Ll*	-	-	-	France	To graze algae in oyster parcs
NETHERLANDS							
3.2.1	-	*Mm, C. angulata*	-	adult	-	-	Some individuals remain from 1970s (*C. angulata* and 1965 (*Mm*) introductions
3.2.2	1988	*Oe*	-	-	USA (Maine)	-	From Zeeland strain to US in 1950s and 1960s
3.2.3	-	bait worms	significant	adult	Korea, Africa, USA	-	Regular trade for angling purposes (direct sale or rearing)
4.0	early 1980s	*Bo*	-	-	France	-	-
	1985	*Ac*	-	-	-	throughout country	-
5.0	1980	*Rhithropanopeus harrisii*	-	adult	-	IJmuiden	
	1981	*Callinectes sapidus*	1	adult	-	IJmuiden Harbour	Associated with shipping lanes
5.0	1983	*Callinectes sapidus*	3	adult	-	Eemhaven (Rotterdam) and Nordzeecanal	
	-	*Hydroides eleganis*	-	-	-	Zeeland	In canal warmed by cooling water from power station
		Ficopomatus enigmaticus	-	-	-	Zeeland	
	1984	*Ed*	-	adult	German Bight	Texel Island	Empty shells found in 1982; soon spread to Wadden Sea
8.1	-	*Me*	-	adult	-	France	Regular trade
	-	*Oe*	-	adult	-	Belgium, Denmark	Regular trade
	-	*Cg*	-	adult	-	Denmark	Regular trade

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
NORWAY							
	1980–1985	*Cg, Oe*	-	seed	UK	-	Norwegian industry self-sustaining from 1985
	1986	*Tp*	-	broodstock	Scotland	-	Introduced into quarantine
	1986	*Tp*	-	broodstock	Scotland	-	Introduced into quarantine
	1986	*Tp*	-	broodstock	Scotland	-	Introduced into quarantine
	1985	*Pm*	-	-	Scotland	-	-
	1980s	*Hg*	-	adult	Scotland	re-export to continental Europe	Import licences for *Ha* refused
8.1	-	*Oe*	-	adult	-	Sweden, Denmark	-
	-	*Oe*	-	seed	-	Sweden	-
PORTUGAL							
3.2.2	Pre-1986	*Tp*	-	-	France or Spain	-	? Illegal introduction
	1987–1990	*Pm*	-	seed	Scotland	-	-
	1985	*Pej*	-	post-larvae	Spain	-	To establish disease-free broodstock
	1985	*Pej*	-	broodstock	-	Ria de Aveiro	? Illegal introduction
3.2.3	-	*Cg*	-	adult	France	for consumption	Regular trade; stored in ponds before sale for consumption
	-	*Cancer pagurus, Maia squinado, Palinurus guttatus, Jasus lalandii, Hg, Ha*	-	adult	UK, France	for consumption	Regular trade; stored in ponds before sale for consumption
	-	*Ll*	-	adult	Netherlands	for consumption	-
8.1	-	*Td*	-	adult	-	France, Spain	Regular trade

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
8.2	1987-1990	*Pl*	-	adult	-	France	Regular trade
				SPAIN			
3.2.2	-	*Tp*	-	seed	France, England (hatcheries)	-	-
	-	*Pm*	-	seed	Ireland (Mulroy Bay)	Ria de Arosa and Ria de Betanoz	-
	-	*Cg*	-	seed	-	N Spain	-
3.2.3	-	*Hg*	-	adult	Ireland	-	Regular trade
	-	Spiny lobsters	-	adult	N Africa	-	Regular trade
	-	*Palinurus sp., Maia squinado*	-	adult	France, Morocco and other N African countries	-	Regular trade
	-	*Oe*	-	adult	Greece, Turkey	-	Regular trade
4.0	-	*Bonamia ostreae*	-	-	-	Galicia	-
8.1	-	*Me*	-	adult	-	France	Regular trade
	-	Clam species	-	adult	-	France	Regular trade
				SWEDEN			
3.2.2	-	*Oe*	Limited	seed	Norway	-	-
	-	*Cg*	-	-	England (1970s)	-	All from this introduction have disappeared
3.2.3	-	Oysters	-	adult	France	for consumption	Regular trade
	-	*Ha*	-	adult	Canada, USA	for consumption	Regular trade
4.0	-	*Ac*	-	-	-	Baltic Sea (east coast south of Stockholm and on west coast to Goteborg)	-
	1981/82	*Ed*	-	-	-	Bohuslan and East Skaggerak	-
				UK			
3.2.1	-	*Tiostrea lutaria*	-	adult	New Zealand (1960s)	N Wales	Local breeding population
	-	*Cg, Oe, Me, Td, Tp*	significant	seed	Regular transfers within and between UK countries; also to and from Ireland		
3.2.3	-	*Ha*	-	adult	Canada	Consumption in UK or export to continental Europe	Regular trade
	-	Crawfish	-	adult	New Zealand, Nigeria	-	-

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
3.2.3	-	*Nereis virens, Arenicola marina*	significant	adult	Netherlands	-	Regular trade for angling purposes
	-	Bait worms	-	adult	Korea	-	Regular trade for angling purposes
3.2.5	1982	*Mytilus californianus, Hr*	-	-	California	Research Institutes	Into quarantine
	1984	*Cv*	-	-	Virginia		
	-	*Pinctada spp*	-	-	Bahrain		
	1988	*Nassarius obsoletus*	200	-	Chesapeake Bay		
	1988	*Nacella concinna*	80	2 cm	S Georgia and Antarctica		
	1988	*Anadara senilis, Crassostrea tulipa*	1 kg	5–8 cm	Ghana		
	1988	*Saccostrea cucullata, Crassostrea iredalei*	1 kg	5 cm	West Java		
	1988	*Ll, Cerastoderma edule, Mytilus gallo-provincialis, Td*	50–100	-	Portugal		
		Nucella lapillus	500	adult	Brittany		
	-	*Perna perna, Brachidontes emarginatus, Barbatia obliquata, Saccostrea spp., Meretrix casta, Meretrix lusoria*	-	adult	Sri Lanka		-
	-	*Mytilus galloprovincialis*	-	adult	French Mediterranean coast		-
	-	*Me*	-	adult	Netherlands		-
	1987	*Pem, Pej, Mr*	-	adult and nauplii	Asia, Australia		Into quarantine
4.0	-	*Ac*	-	-		S England	-
	1982	*Bo*	-	-	-	England	-
5.0	1988	*Ha*	1	adult	-	S England	-
	1989 and 1990	*Pej*	2	adult	? France	S England	-

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
6.1	1980	*Crassostrea rhizophorae*	-	adult	Brazil	Conwy	Into quarantine hatchery broodstock - later destroyed
	1984	*Cv*	160	adult	USA (Chesapeake Bay)	Conwy	-
	1980	*Tp*	50	adult	USA (Oregon)		-
	-	*Pem*	-	-	Tahiti and Thailand	-	-
	-	*Ha*	-	-	USA	-	-
6.2	1981	*Crassostrea rhizophorae*	-	F1 seed	Conwy (hatchery)	N Wales	100% mortality
	1986	*Cv*	-	F1 seed	Conwy (hatchery)	N Wales	Experimental work
6.3	1981	*Tp*	-	seed	Conwy (hatchery)	Several sites and commercial hatcheries	-
8.1	-	*Oe*	-	adult	-	Ireland, Denmark, France	Regular trade
	-	*Cg*	-	adult	-	Ireland, Denmark, France, Norway	Regular trade
	-	*Td*	-	adult	-	Ireland	Regular trade
	-	*Me*	-	adult	-	Netherlands, France	Regular trade
	-	*Cerastoderme edule, Ll, Ensis sinensis, Pm Chlamys opercularis*	-	adult	-	France, Spain	Regular trade
	-	squid, cuttlefish, octopus	several tonnes	adult	-	-	Regular trade
8.2	-	*Hg, Liocarcinus puber, Cancer pagurus, Carcinus maenas, Maia squinado*	5,000 mt in 1986	adult	-	Spain and other continental European countries	Regular trade
	-	*Nephrops nephrops*	-	adult	-	France, Spain, Netherlands, Belgium, Italy, Germany	Regular trade
	-	*Hg*	-	adult	-	US and Spain	Regular trade
9.1	-	*Tp*	significant	seed	hatcheries	France, Spain, Italy, Ireland, Germany, Falkland Islands, US, South Africa	-
9.2	-	*Hg*	-	-	-	Norway	-
	-	*Penaeid* prawns	few	juvenile	hatcheries	Europe and tropics (research units)	-

Table 3.1 (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
				USA			
3.2.1	late 1980s	*Tridacna gigas*	-	adult	(Palau) Micronesia	(Bonaire) Guadeloupe and S Florida	No health certification
3.2.2	1983	*Tp*	1	adult	? Pacific coast	Cape Cod	? From unauthorised plantings
4.0	-	*Haplosporidium nelsoni*	-	-	-	Maine, S Carolina and Georgia	Extension of range
	-	*Cg*	-	-	-	Massachusetts and ? Maine and ? New York	With consignments of *Cv*
	-	*IHHN*	-	-	Costa Rica	Hawaii	In imported penaeid prawns
	1985	Status of introduced species on Atlantic coast – see Appendix					
	1988	*Styela clava*	-	-	-	Southern New Jersey	-
	-	*Corbicula manilensis* = *Corbicula fluminea*	-	-	-	Chesapeake Bay, Central New Jersey, Lake Erie	-
*	1988	*Dreissena polymorpha*	significant	-	Europe	Great Lakes	In ships ballast
*	1984	*Bythotrephes cederstroemi*	-	-	Europe	Great Lakes	In ships ballast
5.0	-	3 species Asian copepods	-	-	Asia	San Francisco Bay	? In ships ballast
	1987	*Callinectes sapidus*	-	adult	US Atlantic coast	San Francisco Bay	Not established
	1988	*Hemigrapsus sanguineus*	-	adult	Japan	Southern New Jersey	Via ship ballast
	1988	*Pem*	-	post-larvae	Hawaii	S Atlantic coast	5000 recaptured, July-October 1988, largest 220 mm, between South Carolina and northern Florida
6.1	1983	*Py*	200 + 200	seed and adult	Japan	Washington State	Quarantine, in hatchery
	-	*Pev*	-	-	Panama and Texas	South Carolina	Disease free animals
7.0	-	*Cg*	-	-	Pacific coast of N America	New Jersey, Delaware, Maryland, Virginia	-

*Fresh water species.

Table 3.1 1991 Addendum (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
				CANADA			
3.2.2	1990	*Cg, Tp*	-	seed	-	British Columbia	On-growing and for bioassay
	1990	*Plm*	5000	juveniles	Port au Port Bay, Newfoundland	Lameque Bay, New Brunswick	After bimonthly histopathology and thioglycollate culture analyses
3.2.3	1990	several	-	adult	-	British Columbia	Lobster, geoduck clam, Dungeness crab, oysters, green mussel, sea urchin, crawfish
	1990	*Ha, Me*	-	adult	-	Ontario	Food and restaurant trade
	1990	*Hirudinea*	-	adult	USA	Ontario	For fish bait
	1990	*Me*	-	adult	Magdalen Islands, Quebec	Prince Edward Island	For processing and sale
3.2.5	1990	*Cv*	25	-		Newfoundland	
	1990	*Plm*	-	spat	Nova Scotia hatchery	Newfoundland	For research and culture in sea
	1990	*Ai*	1000	juvenile	Halifax (Department Fisheries and Oceans)	Havre Boucher, Nova Scotia	In pearl nets, in open sea, to be removed at end of year
	1990	*Oe*	750	adult	Nova Scotia	Prince Edward Island	In quarantine, only for research
4.0	1990	*Oe*	-	seed	Nova Scotia (private hatchery)	New Brunswick	With shipment of *Mm* seed
	1990	*Oe*	-	seed	Nova Scotia (hatchery)	Prince Edward Island	With shipment of *Cv* seed
6.0	1990	*Py, Pa, Patinopecten caurinus*	-	adult	-	British Columbia	-
6.2	1990	*Hr*	-	adult	-	British Columbia	-
8.1	1990	*Pa, Cg, Tp, Pollicipes sp., Chlamys hastata, Chlamys hericia, Me, Sip, Ps, Sg*	-	adult	British Columbia	-	Regular trade
8.2	1990	*Cancer magister, Pandalus sp., Strongylocentrotus franciscanus*	-	adult	British Columbia	-	Regular trade
				DENMARK			
3.1.2	1990	*Artemia salina*	small quantities	eggs	Several, worldwide	-	Live food in aquaculture and research systems
3.2.2	1990	*Cg*	few thousand	seed	Norway (hatchery)	-	Extensive on-growing systems

Table 3.1 1991 Addendum (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
					IRELAND		
3.2.2	1990	*Haliotis discus hannai*	-	F1 seed	Carna (hatchery)	Hatcheries and SW coasts	On-growing in barrels (6 of original broodstock remain in quarantine)
	1991	*Haliotis discus hannai*	-	F1 seed	Carna (hatchery)	Carlingford Lough	Died, water temperature too low
3.2.3	1990	*Oe*	-	adult	Solent (UK)	Cork Harbour	Brine dipped, exposed to air and held in ponds overnight. Effluent chlorinated
3.2.4	1990	*Artemia salina*	-	eggs	-	-	As food in aquariums
5.0	1990	*Cg and Oe*	-	spat (2% of *Oe*)	Arcachon, France	Galway Bay	Illegal import
6.0	1991	*Py*	71	adult	Japan	Wexford	Hatchery, quarantine. F1 (up to 1.5 mm) remain in quarantine
6.2	1991	*Py*	6000	seed (F1) 4.5 mm	Carna (hatchery quarantine)	SE coast	In pearl nets, mortalities after six months was 90%, grew to 15 mm
6.3	1991	*Oe*	700,000	seed	Norway	Oysterhaven (S coast)	Commercial on- growing
6.3	1991	*Oe*	700,000	seed	Norway	Oysterhaven (S coast)	Commercial on-growing
	1991 1991	*Cg* *Tp*	39,546,000 250,000	seed seed	UK (hatcheries) England (hatchery)	- -	Commercial on-growing Commercial on-growing
6.3	1991	*Haliotis tuberculata*	30,000	seed	UK	Co Mayo	Commercial on-growing
	1991	*Me*	1000 mt	adult	N Ireland	-	For processing
7.0	1991	*Cv*	-	-	-	-	Request for transfer refused
8.1	1991	*Cg*	110 mt	adult	S Ireland	N Ireland	
	1991	*Cg and Oe*	108 mt 150 mt	adult	S Ireland	Great Britain Netherlands	
	1991	*Me*	6000 mt 1600 mt	adult	S Ireland	France UK	
8.1	1991	*Pm*	72 mt 12 mt 1 mt <1 mt	adult adult adult adult	S Ireland S Ireland S Ireland S Ireland	France Spain Netherlands Germany, Belgium, Great Britain	
	1991	Other spp	233 mt 117 mt	adult adult	S Ireland S Ireland	France -	Live, fresh or chilled Live, fresh or chilled

Table 3.1 1991 Addendum (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
8.2	1991	*Hg*	335 mt	adult	S Ireland	France	
			65 mt	adult	S Ireland	Spain	
			20 mt	adult	S Ireland	Italy	
			40 mt	adult	S Ireland	UK	
	1991	Crabs (mostly *Liocarcinus puber*)	400 mt	adult	S Ireland	Spain	
9.1	1991	*Haliotis tuberculata*	-	seed	S. Ireland	Guernsey (UK)	Restocking
	NORWAY						
3.2.1	1990–1991	*Hg*	55000	juveniles	Norway	Rogaland Co	Restocking
			10000			Vest Agder Co	
			10000			Hordaland	
3.2.3	1990–1991	*Hg*	-	adult	Scotland	-	-
3.2.4	1990–1991	*Artemia salina*	large quantities	eggs	several	-	Live food for fish and lobster in aquaculture
8.0	1990–1991	*Hg*	-	adult	Norway	-	Regular trade
9.0	1990–1991	*Tp, Cg, Oe*	-	seed	Norway	-	Produced for export
UK							
3.2.2	1991	*Cg*	-	seed	Guernsey	Scotland and England	
	1991	*Pm*	1 kg	seed	Guernsey	Scotland	
3.2.3	1990	Lobsters	775 mt	adult	-	-	
		Me	597 mt	adult	-	-	
		Squid and cuttlefish	281 mt	adult	-	-	
		Bait worms	-	adult	-	-	
3.2.4	1990	*Artemia salina*	-	eggs	many	-	
3.2.5	1990	*Pinctada radiata*	150	50–100 mm	Bahrain	N Wales	In quarantine
	1990	*Me*	300	1–6 mm	Netherlands	N Wales	In quarantine
	1990	*Nucella lapillus*	300	10 g	Norway	Plymouth	In quarantine
	1990	*Haliotis tuberculata*	300	12–14 mm	Channel Islands	Plymouth	In quarantine

Table 3.1 1991 Addendum (continued).

ICES code	Date	Species	Number	Age	Source	Destination	Remarks
6.3	1990	*Tp*	2.4 million	seed	UK hatcheries	within UK	On-growing
	1990	*Cg*	-	seed	UK hatcheries	within UK	On-growing
8.1	1990	*Me*	3587 mt	adult	-	-	Regular trade
		Squid and cuttlefish	3152 mt	adult	-	-	Regular trade
8.2	1990	Lobsters	1032 mt	adult	-	-	Regular trade
	1991	Crabs	14018 mt	adult	-	-	Regular vivier trade
9.1	1991	*Cg*	23.5 million	seed	hatcheries	S Africa, Cyprus, Ireland, Germany, Channel Islands	For on-growing
		Oe	30000	seed	hatcheries	Spain	For on-growing
		Tp	3.3 million	seed	hatcheries	Spain and Ireland	For on-growing
		Td	1 million	seed	hatcheries	Spain	For on-growing

Refer to keys.

Table 3.2. Key to Species.

Molluscs	
Ari	*Arctica islandica*
Ai	*Argopecten irradians*
Ap	*Argopecten purpuratus*
Bu	*Buccinum undatum*
Cc	*Clinocardium ciliatum*
Cg	*Crassostrea gigas*
Cv	*Crassostrea virginica*
Ed	*Ensis directus*
Hk	*Haliotis kamtschatkana*
Hr	*Haliotis rufescens*
Ll	*Littorina littorea*
Ma	*Mya arenaria*
Me	*Mytilus edulis*
Mv	*Mytilus viridis*
Mm	*Mercenaria mercenaria*
Oe	*Ostrea edulis*
Pa	*Panope abrupta*
Pg	*Panope generosa*
Py	*Patinopecten yessoensis*
Pm	*Pecten maximus*
Plm	*Placopecten magellanicus*
Ps	*Protothaca staminea*
Sg	*Saxidomus giganteus*
Sip	*Siliqua patula*
Sp	*Spisula polynyma*
Ss	*Spisula solidissima*
Tp	*Tapes philippinarum*
Crustaceans	
Ha	*Homarus americanus*
Hg	*Homarus gammarus*
Pem	*Penaeus monodon*
Pej	*Penaeus japonicus*
Pev	*Penaeus vanamei*
Mr	*Macrobrachium rosenbergii*
Echinoderms (sea urchins, sea stars)	
Aw	*Asterina wega*
Pl	*Paracentrotus lividus*
Stp	*Stronglyocentrotus purpuratus*
Miscellaneous	
Bo	*Bonamia ostreae*
Ac	*Anguillicola crassa*

Table 3.3. Status (1985) of some common introduced (non-native) shellfish species on the US Atlantic coast.

Species	Common name	Date entered community (locality)	Native to (mechanism)	Notes
Littorina littorea	Common periwinkle	1860-1870s north of Cape Cod, Massachusetts; 1875-1880s south of Cape Cod	Western Europe (introduced for food?)	North to Labrador; populations now south to at least Delaware
Hapliplanella lineata	Lined sea anemone	1892; New Haven, Connecticut	Asia (ship fouling)	Spread north to Salem,Massachusetts, by 1901; now along much of coast
Ficopomatus enigmaticus (=*Mercierella)*	Tube worm	1976; Barnegat Bay, New Jersey	Australasia (but via ship fouling from western Europe?)	Associated with thermal effluent of power station
Teredo furcifera and T. bartschi	Ship worms	1974; Barnegat Bay, New Jersey	Subtropics (via wooden pleasure boats)	Associated with thermal effluent of power station
T. bartschi	Ship worms	1975; Waterford Connecticut (Long Island Sound)	Subtropics (via wooden pleasure boats)	Associated with thermal effluent of power station; very localized
Carcinus maenas	Green crab	South of Cape Cod; presumably an 18th or 19th century introduction into Long Island Sound; north of Cape Cod: 1872, Provincetown	Western Europe (in ship fouling?)	Spread north to Eastern Canada possibly still expanding range along Nova Scotia coast
Praunus flexuosus	Mysid 'shrimp'	1960; Barnstaple Harbour, Cape Cod, Massachusetts	Western Europe (ballast water of ships)	Spread north to Nova Scotia; but not south of Cape Cod?
Botryllus schlosseri	Sea squirt (colonial tunicate)	19th century (?); 'It is.......very probably an introduced species brought here on the bottoms of ships'-Van Name, 1945:222	Western Europe (ship fouling?)	Now along much of coast
Botrylloides diegensis	Sea squirt (colonial tunicate)	Early 1970s: Eel Pond, Woods Hole, Massachusetts	California (released by experimental biologist)	Spreading along Cape Cod coastline; expected to expand in range
Styela clava	Sea squirt (solitary tunicate)	1976; Rhode Island	Asia (but probably via Western Europe in ship fouling)	In 1985 found north to Boston, Massachusetts (probably via Cape Cod Canal); southernmost record: September 1984, Long Island Sound (Mystic River Estuary, Mystic, Connecticut)

Prepared by J T Carlton, May 1985.

4 Summary of Fish Introductions and Transfers

Introduction

In this report the fish data are presented as a country by country summary and an account given as seen through the discussions of the Working Group in its annual deliberations. Most interest in fish has centred on salmonid movements, in particular on introductions of Pacific salmon to the North Atlantic and transfers of Atlantic salmon within their natural range in the North Atlantic. Particular concerns were expressed about: a) the introduction for various reasons of Pacific salmon which might establish spawning populations to the detriment of native salmonids, especially Atlantic salmon; and b) the transfer of Atlantic salmon for commercial aquaculture causing the dilution of native gene pools with a feared presumption of population decline. It is noticeable that records of successful fish introductions especially to 'open' systems are few. Discussion of this conclusion and the greater success of fish introductions to more 'closed' systems is given by Baltz (1991) in the list of ancillary references. The following refer to Pacific species:

Latin name	Common name
Oncorhynchus gorbuscha	pink, humpback
Oncorhynchus kisutch	coho, silver
Oncorhynchus nerka	sockeye, red, kokanee
Oncorhynchus tshawytscha	chinook, king
Oncorhynchus keta	chum, dog
Oncorhynchus mykiss	rainbow trout

4.1 Belgium

Belgium has not been represented but the Working Group has learned of some consequences in Belgian waters of the actions of neighbouring countries.

It was learned in 1984 that four coho salmon (*O. kisutch*) were caught at Nieuwpoort, probably as a result of release 100 km distant in the Somme estuary in France. Possibly as a consequence, private sources in the same year released 6,000 coho smolts from France in the Yser estuary but most died soon after release owing to environmental problems. There is no account of their subsequent return.

4.2 Canada

Canada has attended all meetings and provided much data on both deliberate introductions and transfers (especially interprovincial transfers) and the finding of exotic species in her waters introduced by various anthropogenic sources.

<u>Pacific Salmon - Coho</u>

Coho have been caught regularly in the Bay of Fundy watersheds despite no known Canadian stockings, e.g., in 1982 nine coho were caught in the Cornwallis River and five more the following spring. They are considered to originate from deliberate releases of cultured juveniles in the US states of Maine, New Hampshire and Massachusetts which occurred throughout the 1980s (qv under USA).
Successful spawning had been observed on at least three occasions by 1984 but a subsequent electrofishing survey of 28 New Brunswick streams in the Bay of Fundy area failed to find any coho parr. However, in 1985 there was a report of juvenile populations in the Cornwallis River and sighting of cohos in two other rivers. A study of the coho population in Cornwallis River continued until 1988 after which the population apparently died out.

<u>Pinks</u>

In 1978 and 1979 the provinces of New Brunswick and Newfoundland had introduced pink salmon ova from British Columbia to study the feasibility of ocean ranching and intensive cage culture. These experiments were discontinued in Newfoundland in 1981 and in New Brunswick in 1982 because of unsuitability of the species for commercial culture, low returns from releases and opposition from Atlantic salmon interests.
Occasional pink salmon have been caught and recorded in subsequent years, e.g., in 1985 in a New Brunswick river. These pinks are thought to originate from US releases in Maine.

<u>Chinook</u>

There is a record of three chinook salmon identified in spawning condition in a Nova Scotia river. Again these are likely to have originated from USA releases.

<u>Rainbow Trout</u>

The reports from Canada consistently show that significant numbers of rainbow trout ova are imported from USA and other Canadian provinces into the Maritimes Region and also traded between provinces within the region. These ova are principally used for commercial aquaculture but there was a report in 1984 of a fishery on the west coast of Newfoundland for these trout but it is unclear whether they originated from escapes or deliberate releases. In 1986 there was a report of many thousands of escapes from a culture system.

Atlantic Salmon

Interest in this species is strong in the Maritimes because it has been traditionally the source of an estuary and sea-based commercial fishery and a recreational river-based rod fishery. In recent years stocks have been in decline, causing interest both in the causes of (and attempts to reverse) the decline and in the prospect of enhancing other existing species or introducing new species. In the last five years commercial net pen culture of Atlantic salmon has grown and an industry producing 5,000 tonnes existed in 1990. Strict national laws prevail to control disease and minimise introduction of stocks deemed to have significantly different gene pools. Nevertheless, shortages of ova have resulted in several interprovincial transfers being recorded, e.g., in 1989 several tens of thousands of ova from the Gulf of St Lawrence were introduced to the Maritimes. Landlocked strains of Atlantic salmon in Maine have also been introduced to evaluate their potential for commercial culture in 1990. However, ova from outside the eastern seaboard of Canada have not been allowed entry although the Pacific province of British Columbia, where another salmon sea pen industry has been established, has introduced Atlantic salmon ova from Scotland and Norway over several years although the stated current intention of BC authorities is to allow future imports only to establish broodstocks.

Other Species

Many transfers of Arctic charr (*Salvelinus alpinus*) within the east coast and Gulf of St Lawrence provinces are recorded and occasionally from further afield, e.g., Iceland in 1989. There are also reports of transfer of various trout and charr hybrids for sport fishing. Species of whitefish (*Coregonus lavaretus* and *C. clupeaformis*) have been imported to Quebec from Finland and Ontario respectively for research purposes connected with the decline of related species in the Great Lakes.

4.3 Introductions to the Great Lakes

This great water resource shared by the USA and Canada drains via the Gulf of St Lawrence. It is now clear that several species of Pacific salmon have become established in the Great Lakes, pink salmon by human accident, and coho, chinook and sockeye by deliberate introduction and sustained stocking. These species continue to expand their territory in the Great Lakes system and reports show that straying into the St Lawrence occurs as far as Montreal.

The lakes have also experienced the successful introduction of other fish species probably from anthropogenic causes, e.g., as baitfish or carried in ballast water. The European river ruffe (*Gymnocephalus cernua*) has apparently reached unacceptable population levels and is regarded as a pest in Lake Superior. The European rudd (*Scardinius erythrophthalamus*) and the tube-nosed goby (*Proterorhinus marmoratus*) are two others although it is doubtful that these three can be called marine species.

4.4 Denmark

Denmark has a large and long established commercial rainbow trout culture industry. Although long established in fresh water, in recent years it has developed a cage culture industry in its Baltic waters. This industry is a major source of ova which are exported to many of the major rainbow trout industries throughout the world. In latter years (1984, 1985 and 1986) small numbers of tagged rainbow trout have been released in coastal estuaries. Recoveries have been reported from local sources and from Sweden and Norway. Escapes of significant numbers of trout from sea cage operations are reported periodically. Rainbow trout from Polish releases in the Baltic are regularly reported from Danish waters.

There is continuing interest in developing other species for aquaculture in Denmark. In consequence Danish reports show that eggs, larvae and juveniles of several marine species were imported for research and commercial trials. Turbot (*Scophthalmus maximus*) were imported from UK between 1980–1982 for these purposes. Similarly, elvers have been imported from several countries, e.g., UK, France and Portugal, virtually in every year throughout the 1980s for both commercial culture and to support extensive restocking programmes in Danish fresh waters. The reasons for restocking were associated with a serious decline in local eel fishery stocks. The introduced Asian eel pathogen *Anguillicola* sp. was first reported in Denmark in 1987. A recent feature of eel imports has been the requirement for a period of quarantine before release to test for unwanted pathogens.

Periodic reports of Atlantic salmon releases of smolts of Swedish origin into Danish Baltic waters (Bornholm) are made (1980 and 1985). The monogenean skin parasite *Gyrodactylus salaris* has been reported as occurring in rainbow trout in a Danish fish farm.

Finally, an interesting Danish German cooperative project to conserve the rare houting (*Coregonus oxyrhynchus*) was reported in 1985. Smolts of the houting were reared in Denmark, transferred to cages in the Kiel Canal and then returned to enhance stocks in the Vidaa River Lake system.

4.5 Finland

Since 1980 Finland has operated strict control policies on introductions and transfers which means that it is not possible to introduce live fish or ova into the country without permission of the veterinary authorities. Finland does have significant fishery and aquaculture resources and the controls are aimed at protecting these resources.

Eel

The eel (*Anguilla anguilla*) is one of Finland's native fish species, but without stocking it will disappear because of dams at the river mouths. In 1980, the import of eels was prohibited because of the risk of introducing fish virus diseases via the eels. From 1989 onwards, the veterinary authorities have allowed the import of a small number of eels annually from Swedish quarantine facilities for experimental stocking of some small lakes in southern Finland. The eels have been kept in quarantine for some weeks in Finland as well. It is planned to import eel fry annually from quarantine in Sweden.

Rainbow Trout

During the 1970s and 1980s, the rainbow trout has become the most important food fish species. In 1990, about 13,000 t of rainbow trout were reared in net cages in brackish water. In fresh water the amount was about 5,300 t. The value of the rainbow trout produced for human consumption was about 350 million Finnish markka in 1990. Until the end of 1987 the import of live rainbow trout fingerlings was allowed from Sweden for food fish rearing. After that the only import of this species permitted from Sweden has been batches of fertilised eggs for breeding purposes during the years 1989–90. The rainbow trout is not able to reproduce in natural waters in Finland.

Atlantic Salmon

Until the end of 1987 the import of live Atlantic salmon fingerlings was allowed from Sweden to Åland Islands for food fish rearing, but after that no import has been permitted.

Arctic Charr

In 1988 a small number of fertilised eggs of Arctic charr was imported from Sweden for breeding purposes.

Sea Trout

Sea trout smolts (*Salmo trutta m. trutta*) from the Vistula Bay (Poland) were imported in 1980 for research purposes and the fish were released off the Finnish coast in the Gulf of Finland. According to tagging results, the fish probably died soon after release.

Atlantic Cod

An experiment was carried out in 1991 in which Atlantic cod fry (*Gadus morhua*) from the island of Gotland (Sweden) were transferred to the Bothnian Sea.

Fish species captured accidentally in Finnish coastal waters are chum salmon in the beginning of the 1980s, pink salmon since 1975, coho salmon in 1983–87 and longnose sucker (*Catostomus catostomus* (Forster)) in the 1970s and 1980s, all of which had been released into the Gulf of Finland by the Soviet Union.

4.6 France

France has a very large aquaculture industry dominated by molluscan culture. However, it has a significant fresh water rainbow trout industry and traditionally it has been the largest European importer of Pacific salmon. Throughout the 1980s it has developed very active programmes of research aimed at the development of the commercial culture of several species of fish in both Atlantic and Mediterranean waters. Atlantic salmon are native to French Atlantic waters but commercial culture of this species has proved difficult owing to high sea summer temperatures and lack of suitable sea areas for cage culture. As a consequence, attention was directed to the commercial culture of coho salmon in the late 1970s. Since that period France has regularly imported annually from USA several million ova of wild coho salmon (Table 4.1) and has

established an industry based both on fresh and sea water culture.
Concern was expressed about transfers of coho as potential competitors of the seriously reduced populations of Atlantic salmon in France, southern England and Ireland. These concerns arose from two aspects, namely that significant numbers would escape and from proposals to experimentally ranch the species involving release of many more juveniles. As a consequence CNEXO proposed and conducted a series of experiments to study fresh water interactions between coho and native salmonids which are documented in the Working Group reports.
France reported in 1983 the recovery of coho from estuaries of North Brittany and Cherbourg (close to the areas where sea cage culture was practised). Unofficial reports of imports and releases of coho and chinook salmon were not uncommon during this period, e.g., in 1981 and 1983, and some fish were recaptured in French, Belgian and Dutch estuarine waters. There have been no reports of recaptures in recent years and none ever from England and Ireland.
In 1987 France reported the presence of IHN virus in a rainbow trout farm presumed to have been introduced from North America with imports of salmonid ova. Since then this virus has spread to other farms in France and has been reported in Italy, Belgium and Switzerland.
France also reports importing rainbow trout ova from various sources including Denmark, USA and Australia.
France has established the commercial culture of turbot, bass and bream. As a consequence, movements of ova, fry and juveniles of all three species between Brittany, Spain, UK and the French Mediterranean coast are commonplace in most years. IPN virus has been reported as a cause of mortality in juvenile bass and bream.
Recently, renewed interest in Atlantic salmon culture has resulted in imports of ova from Scotland and Norway in 1989 and 1990.

4.7 Germany

Germany has limited potential for deliberate commercial introductions of marine species and trade in transfers is limited to rainbow trout, both ova and fish, almost exclusively from and to fresh waters. Owing to the active interest of researchers, especially in the early 1980s, there were many introductions of small numbers of species of interest for aquaculture, e.g., *Dicentrarchus*, *Siganus*, *Sparus* and *Mugil* spp. Much of this interest centred on use of thermal waste water of which Germany has considerable quantities both fresh and salt. Currently no significant developments are known to be in progress.
Germany has a significant rainbow trout industry based on fresh water resources but nevertheless is a major importer of farmed trout and salmon. Several small scale developments in sea cage culture and experimental sea releases of trout have occurred in the Kiel area.
Germany has significant eel fisheries and reported the occurrence of the introduced Asian eel parasite *Anguillicola* sp. in 1985. Since then the parasite has been recognised as widely distributed.

4.8 Iceland

No information available.

4.9 Ireland

Ireland has strict laws controlling introductions and transfers and its relatively isolated island position supports this attitude to preserve its native fauna and flora. Freshwater aquaculture of rainbow trout developed in the 1970s and of Atlantic salmon sea pen culture in the 1980s. To sustain rainbow trout culture, Ireland regularly imports ova only mainly from Denmark, Northern Ireland, UK, Tasmania and occasionally from other sources, eg Iceland and Finland. Normally Ireland imports only ova but due to extreme shortages of salmon smolts small numbers (approximately 30,000 annually) were imported from Norway from 1982 to 1984. Increasingly, Ireland has imported Atlantic salmon ova to sustain her salmon farming industry, e.g., in 1988 imports were recorded as 4.7 million from Norway, 5.3 million from Scotland, 0.5 million from Iceland and 0.1 million from Northern Ireland. In 1990 approximately nine million were imported from Scotland.

4.10 Netherlands

The Netherlands has limited potential for deliberate commercial fish introductions owing to competition for resource from other industries. It has no significant trade in transfers other than a large trade in live eels which, depending on market conditions, may not only be the native eel, *A. anguilla*, from many

European sources, but other species of eel from Asian, US and Australian sources. The widespread occurrence of the introduced Asian eel parasite *Anguillicola crassa* was first reported in 1986.
The Netherlands also reported the capture of two coho salmon near Rotterdam in 1983 and of a third coho in 1984 near IJmuiden.

4.11 Norway

During the period of review Norway has developed Atlantic salmon farming into a very large industry which now produces >150,000 tonnes per annum. In order to expand the industry significant numbers of smolts have been imported over all years in the 1980s. Table 4.2 shows the numbers imported in the years 1983 and 1988. However, as a proportion of the production of smolts produced locally (>75 million in 1990) these imports have become proportionately very small (<2% in 1990).
In view of reports that very large numbers of farm escapes now make up 10% of the wild fish catch, concern has been expressed about the genetic contribution these escaped fish make to wild populations. Some are of Baltic and Icelandic origin as noted in Table 4.2, and others, the result of intensive breeding programmes.
Various diseases affect this large industry some of which an endemic, e.g., vibriosis, cold water vibriosis and IPN virus, some of unknown origin, e.g., infectious salmon anaemia, and pancreas disease, while others are considered to be introduced, e.g., furunculosis caused by *Aeromonas salmonicida salmonicida* and the fresh water monogenean skin parasite, *Gyrodactylus salaris*. Some are considered to pose a threat to wild salmonids and possibly to marine stocks, e.g., IPN virus. Whilst most of these threats are perceived rather than proven there is a good case for considering that *G. salaris* is the cause of the death of most wild parr and in more than 30 Norwegian rivers. The introduction of parr and smolts of Baltic origin is blamed for this catastrophe. Since 1987, smolts from Sweden and Finland are introduced directly to sea water to ensure death of any *G. salaris* carried by the fish. The introduction of smolts from Scotland in 1986 is blamed for introducing furunculosis which has spread rapidly to many sea cage farms and is being reported to cause some mortality in wild salmon as well.
The most northerly region of Norway, Finmark, is adjacent to the Kola peninsula where large numbers of pink salmon ova from the Russian Pacific region were planted throughout the 1970s. Pink salmon were caught in Norwegian commercial nets and were also observed spawning in some rivers in Finmark in the late 1970s and 1980s. However, Russian introductions were stopped around 1980 and Norwegian catches declined, e.g., in 1982 only 10 pinks were recorded. Norway reported in 1990 that pink salmon were no longer found in Finmark. Pinks were kept in net pen systems in Norway until at least 1981 to evaluate their potential for commercial culture but the superiority of Atlantic salmon led to the abandonment of this project and none now exist.
In 1981 Norway sought advice from ICES on the possible introduction of coho salmon for commercial evaluation and this advice is recorded in the Working Group reports. No introductions were subsequently made.
In 1982 elver imports from UK were found to contain IPN virus. Such transfers were subsequently banned. Turbot juvenile (*Scophthalmus maximus*) introductions started in 1985 from UK and further periodic introductions have been made.
In 1990 Norway reported that juveniles of bass (*Dicentrarchus labrax*) from Denmark were imported for commercial trials in a heated recirculation sea water system.
In recent years Norwegian research to develop alternative species for aquaculture has concentrated on three native species, namely cod, halibut and wolffish.

4.12 Portugal

Fish fin culture of marine fish is only just beginning in Portugal. Records of introductions are scarce but there is a report of concern to the Working Group in 1983 of the numbers of tropical fish species imported without checks on identity and health status.
In 1990 Portugal reported that sturgeon hybrids (*Acipenser ruthenus* x *A. baeri* triploids) were imported from the USSR for commercial evaluation.
Portugal exports live elvers to many European countries for restocking and culture.

4.13 Poland

Poland is active in several forms of aquaculture involving salmonids but reports of activities are few. A meeting of the Working Group in Gydinia in 1986 gave some indication of the scope of these activities.

In 1984 some 326,000 rainbow trout were released for ranching purposes to the Baltic. Reports from Denmark (qv) indicate some of these fish were caught in Danish Baltic waters. In 1985 Poland released a further 400,000 rainbow trout to the Baltic. Unfortunately no information on subsequent releases or the judged success of these projects is available.

In 1985, Poland imported 50,000 ova of *Salmo salar* from each of Latvia and Finland for net pen culture trials in the Baltic; also some 70,000 rainbow ova were imported from Finland and Czechoslovakia and 200 ova from Japan. Poland also reported in 1986 that an average of 14 tonnes of elvers are imported annually from France and UK for restocking of rivers and lakes.

4.14 Spain

Periodic reports from Spain are confined to introductions and transfers concerned with aquaculture. Spain has experienced an increase in aquaculture activity during the 1980s with small numbers of farms rearing coho and Atlantic salmon, turbot and sole species and the development of a large rainbow trout industry in fresh water.

Coho salmon have been continuously farmed in Galicia throughout the 1980s using imports of ova of wild fish from Washington and Oregon states in the USA. Bacterial kidney disease has been imported with some batches of ova and remains a problem for the industry.

Interest in the commercial culture of Atlantic salmon is more recent. Reports show 500,000 ova imported from Ireland in 1987 and 1988 with several million ova in 1989. UK also exported ova in 1990. Several batches of 100,000 smolts of Norwegian origin have been transferred in 1989 and 1990 by sea going wellboat. In 1990 Spain reported the occurrence of pancreas disease of farmed Atlantic salmon, a serious disease common in Ireland, Scotland and Norway.

Atlantic salmon ova from Scotland have been released as ova and fry into some of Spain's northern rivers. Genetic analyses by an isoenzyme technique has shown that the introduced strains differ from the native strains. It has been reported that *G. salaris* has been found in a Spanish rainbow trout farm. The significance of this finding for wild Atlantic salmon in Spain remains to be evaluated.

Turbot and sole juveniles have been imported since 1984 from the UK and latterly from France as well.

4.15 Sweden

Sweden operates strict regulations governing introductions and transfers and in addition has restrictive regulations on aquaculture. A large *Salmo salar* ranching programme for Baltic salmon has existed for many years. This programme must be operated by hydroelectric companies to compensate for restricting the access of fish to the headwaters of many rivers. Strict disease control of these smolt hatcheries is operated by the State and more recently programmes to try and keep the genetic integrity of river races intact have been practised. The monogenean skin parasite of salmonids, *Gyrodactylus salaris*, has been reported as widely distributed in Sweden.

There are reports of transfer of elvers to Baltic rivers from 1982 initially from Swedish west coast rivers, Denmark and France, but latterly from France and UK (1987) and UK and Portugal (1989). Intensive culture of eels has been practised more recently. Because a variety of disease agents was reported in 1987 (furunculosis, IPN virus and *Rhabdovirus anguilla*) elver imports must go through extensive quarantine procedures which have been described in the scientific literature.

In 1982 and 1984 sturgeon (*Acipenser gulderistedti*) were reported as being infrequently caught on the Baltic coast as a result of Soviet introductions to the Gulf of Riga.

In 1989 Sweden reported on a feasibility study to enhance Gulf of Bothnian cod stocks by rearing juveniles in high salinity water elsewhere and then releasing them when better able to tolerate the variable salinities of the Gulf of Bothnia.

In 1989 turbot fry and ova were imported from Denmark for commercial aquaculture trials.

4.16 UK

There were significant developments in salmon farming during this period, production rising from <1,000 tonnes to 32,000 tonnes in 1990. Rainbow trout culture, almost exclusively confined to fresh water increased perhaps by 50% to 16,000 tonnes. All eel, sole, turbot and bass farms growing fish for fattening went out of business but the rearing of turbot juveniles has remained profitable.

Atlantic salmon culture has regularly imported ova from Norway and much smaller numbers from Finland from 1980–1987 (shown in Table 4.3). Thereafter regulations excluded most supplies except ova of landlocked salmon from protected water supplies in Maine, USA, between 1987–1989 when approximately 20,000 were imported annually.

Rainbow trout ova are imported on a large scale (shown in Table 4.3).

During 1977 coho ova from British Columbia were introduced to the UK into a quarantine site. They were spawned and the F1 generation successfully hatched in 1980. The F1 generation was retained in a safe (from escape) situation, spawned and an F2 generation hatched in 1983. All coho were destroyed in 1984 because of restrictive legislation designed to prevent release or escape of 'species likely to prey upon, compete with or, otherwise harm native fish'.

In 1982 the UK informed the Working Group of a scheme to ranch pink salmon from the East Anglian coast using all female stocks. By 1984 no decision had been taken and subsequently the scheme placed in abeyance.

During the period 1980–1985 regular imports, exports and exchanges of turbot, bass and bream ova and juveniles occurred between France and UK.

In 1988 the Working Group was informed that the Asian eel parasite *Anguillicola crassa* was considered widespread in eel stocks of much of southern and middle England.

4.17 USA

The ICES report is principally concerned with the eastern seaboard of the USA from Maine to Florida and also the Great Lakes. At least four northeast Atlantic states, namely Maine, Massachusetts, New Hampshire and New Jersey, have had active programmes of introduction and release of Pacific species during the period under review.

<u>Maine</u>

The Maine authorities granted permission for a Federally funded private company, Sea Run, to release annually 1–2 million smolts of introduced chum and pink salmon; thereafter it was expected returns would keep the programme running. In 1981 the first releases were reported, namely 55,000 chum salmon. In 1983, pink salmon ova from Alaska and chum salmon from Japan were both released as feeding fry/smolts from net pens. The Working Group criticised this project and asked to be kept informed.

In 1984 Sea Run reported 400 pinks returned but few were caught. None was released in 1984 owing to a shortage of ova. In May 1985 Sea Run released one million pink fry of Japanese origin and half a million pink fry from Washington State. The Working Group again expressed concern. In 1986 Sea Run released half a million fry of chum salmon from Washington State. The company ceased operation around 1989 because the original concept, namely that returns would be sufficient to fuel all future releases, was never fulfilled.

<u>New Hampshire and Massachusetts</u>

Initial introductions (1971) and releases followed by releases of the progeny of returning fish were at the instigation of state fishery agencies trying to establish popular coastal recreational fisheries for coho. Chinooks were also released in much smaller numbers. In 1985 it was reported that 100,000 pen reared coho smolts of the F3 and F4 generation were released by Massachusetts and 118,000 smolts by New Hampshire. In 1986 both states reported all introductions from the Pacific were stopped owing to insufficient returns of brood fish from previous releases. Table 4.4 shows the releases in 1986–1989.

However, it was reported in 1990 that New Hampshire had stopped all coho releases owing to lack of supplies but that the chinook programme continued with the release of 631,000 parr from NY State hatcheries. Massachusetts reported that it had stopped its chinook programme owing to poor returns and budgetary constraints.

Great Lakes

As reported for Canada several species of Pacific salmon are now established in the Great Lakes as a consequence of accidental (pinks) or deliberate (coho, chinook, sockeye, chum) human actions. Several other species of what are normally regarded as fresh water fish species have also become accidentally established in the Great Lakes, namely the European ruffe, a species of goby and the European rudd.

Atlantic Florida Coast

Several species of tropical or semitropical fish have become established in coastal areas owing, it is believed, to escapes from ornamental collections. The most common are species of tilapia (*Tilapia aurea*, *T. massambica*, and *T. methanothdion*) reported in 1981, 1984 and 1985. A report in 1985 of an exotic Pacific serranid fish, *Chromiliptes altivelis*, recorded that this species had established itself also it is believed from accidental aquarium releases.

4.18 USSR

Information about introductions and transfers within the Soviet Union has been gained second hand. They concern the introduction of pink salmon to the Kola Peninsula from Soviet Pacific sources with the objective of trying to either establish the species or sustain it through hatchery releases in order to provide a commercial fishery. This work has been moderately reported by both Soviet scientists and others. The project is believed to have terminated in the early 1980s with little evidence of success.

The Soviets have also been involved in the introduction of some species of Pacific salmon and other fish species, e.g., sturgeon, to the Baltic. Little is known of the extent of these stockings carried out in the 1970s and possibly into the 1980s, but it is suspected they have been terminated for some years now.

Table 4.1. French imports of wild coho salmon and annual production from such imports in fresh and sea water.

Year	Numbers of ova imported (millions)	Tonnes	
		Fresh water	Sea water
1983	0.6	-	-
1984	2.2	-	60
1985	3.4	30	60
1986	4.5	150	70
1987	NA	250	80
1988	17.0	900	130
1990	7.0	NA	NA

NA = Not available.

Table 4.2. This shows the numbers of Atlantic salmon of Baltic stock origin and rainbow trout imported into Norway in 1983* and 1988.

	Denmark	**Finland**	**Iceland**	**Sweden**	**Total**
1983 salmon					
Ova	-	-	-	40,000	40,000
Fry	-	-	-	544,000	54,400
Smolts	-	5,000	-	340,000	345,000
Rainbow trout					
Ova	-	-	-	60,000	60,000
Fry	-	-	-	2,000	2,000
Fingerlings	60,000	-	-	100,000	100,000
Sea trout					
Ova	30,000	-	-	30,000	30,000
Gullspang trout					
Fingerlings	-	-	30,000	-	30,000
1988 salmon					
Smolts	-	124,000	92,400	236,000	1,284,000

*The only other imports to Norway in 1988 were of rainbow trout ova from Denmark.

Table 4.3. Shows scale of imports of salmonid ova to UK in some years between 1981–1990.

Year	Salmon (millions)			R trout (millions)					
	Norway	Finland	USA	Denmark	USA	Tasmania	Isle of Man	N Ireland	S Africa
1981	1.6								
1982	1.5								
1983	1.6								
1984	2.3	0.50							
1985	2.5	-							
1986	1.8	0.25							
1987	2.6	0.25	0.02						
1988	-	-	0.02	31.0	21.5	2.0	5		
1989	-	-	0.05	31.5	20.0	12.0	5	1.5	0.4
1990	-	-	-	13.8	16.6	5.0	-	1.5	2.4

Table 4.4. Releases of Pacific salmon by Massachusetts, New Hampshire and New Jersey, 1986–1989.

Year	Species	Stock from	Numbers	Released by	Agency
1986	Coho	F4 returns	30,000 smolts	Massachusetts	Division of Fisheries
	Coho	Prior returns	130,000 smolts	New Hampshire	State of NH
	Coho	Prior returns	30,000 fry	New Hampshire	State of NH
	Steelhead trout	L Ontario	47,000 smolts	New Hampshire	State of NH
1987	Coho	Prior releases	152,000 smolts	New Hampshire	State of NH
	Chinook	Gt Lakes	40,000 smolts	New Hampshire	State of NH
	R trout	Gt Lakes	37,000 smolts	New Hampshire	State of NH
	Chinook	NY State	55,000	New Hampshire	State of NH
1988	Coho	L Michigan	20,000	Massachusetts	Division of Fisheries
	Coho	L Michigan	151,000	New Hampshire	State of NH
	Chinook	NY State	88,000	New Jersey	State of NJ
1989	Chinook	L Michigan	77,000 smolts	Massachusetts	Division of Fisheries

APPENDIX 1 Key to ICES Working Group Code of Classification of Introductions

Laws	1.0 Relevant laws and regulations in ICES Member Countries 2.0 Other procedures concerning introduced species
Deliberate introductions	3.0 Delibe rately introduced animal or plant species 3.1 FISH 3.1.1 Fishery enhancement (establishment of new breeding populations) 3.1.2 Mariculture (growth and fattening) 3.1.3 Live storage prior to sale 3.1.4 Recreational purposes 3.1.5 Captures of introductions originally made in neighbouring countries 3.1.6 Research purposes (excluding use in hatcheries)
	3.2 INVERTEBRATES 3.2.1 Fishery enhancement (establishment of new breeding populations) 3.2.2 Mariculture (growth and fattening) 3.2.3 Live storage prior to sale 3.2.4 Improvements of food supplies for other species 3.2.5 Research purposes (excluding use in hatcheries)
Accidental Introductions	4.0 Species introduced accidentally with deliberate introductions 5.0 Completely accidental introductions
Hatchery Introductions	6.0 Species introduced for hatchery rearing 6.1 Stock not subsequently planted outside the hatchery 6.2 Stock relaid in small quantities under controlled experimental conditions 6.3 Stock supplied in larger quantities to the industry or some other organisation
Planned Intros	7.0 Planned Introductions
Live Exports	8.0 Live exports for consumption 8.1 Molluscs 8.2 Crustaceans and sea urchins 8.3 Fish
	9.0 Live exports for purposes other than direct consumption 9.1 Molluscs 9.2 Crustaceans and fish

APPENDIX 2 Selected Literature Concerning Introduced Species During the Period 1980–1991

The following brief list of references, although by no means exhaustive, illustrates many of the topics and issues of the decade under review.

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ANNEX 1 - ICES Code of Practice on the Introductions and Transfers of Marine Organisms 1994 (Code de Conduite du CIEM pour les Introductions et Transferts d'Organismes Marins 1994)

Preamble

Global interest in marine aquaculture (mari-culture) began to increase dramatically in the 1950s and 1960s. A natural complement to this interest was the search for fish, shellfish (molluscan and crustacean), and plant species whose biology was well known and which already had achieved or could achieve success in mass cultivation. Once identified, these species were thus potential candidates for movement to new locations in the world for the purpose of establishing new fisheries and new mariculture resources. Such animals and plants that are not native to these new locations are referred to as non-indigenous, introduced, exotic, or alien species. Organisms transported and released within their present range are referred to as transferred species.

While great successes have been achieved by these activities, leading to the creation of new and important fishery and mariculture resources, three challenges have surfaced over the past several decades relative to the global translocation of species to new regions.
The first challenge is posed by the inadvertent coincident movement of harmful organisms associated with the target (host) species. The mass transfer of large numbers of animals and plants without inspection, quarantine, or other management procedures has inevitably led to the simultaneous introduction of disease agents, causing harm to the development and growth of the new fishery resources and to native fisheries.

The second challenge lies in the ecological and environmental impacts of introduced and transferred species, especially those that may escape the confines of cultivation and become established as wild stocks. These new populations can have an impact on native species.

The third and most recent challenge to be addressed stems from the genetic impact of introduced and transferred species, relative to the mixing of farmed and wild stocks as well as to the release of genetically modified organisms.

Préambule

L'intérêt mondial pour l'aquaculture marine (mariculture) a grandit de façon spectaculaire depuis les années cinquante et soixante. Une conséquence naturelle de cet interêt croissant a été la recherche d'espèces de poissons, de mollusques, de crustacés, et de plantes dont on connaissait bien la biologie, et dont la culture à grande échelle était ou semblait possible. Une fois identifiées, ces espèces étaient alors prêtes à être transferrées dans de nouvelles régions du monde dans le but d'y établir de nouvelles ressources pour la pêche et l'aquaculture. On appelle espèces non-indigènes, introduites, exotiques ou étrangères, ces animaux et ces plantes qui ne sont pas originaires de ces nouvelles régions. Les organismes transportés et disséminés à l'intérieur de leur aire de répartition naturelle sont appelés espèces transférées.

Tandis que ces activités aboutissaient à des résultats très positifs, permettant la création d'importantes ressources pour la pêche et l'aquaculture, les transferts mondiaux d'espèces dans de nouvelles régions ont fait émerger trois grands défis au cours des dernières décennies.
Le premier défi est posé par le déplacement fortuit et simultané d'organismes nuisibles associés aux espèces cibles (espèces hôtes) à l'occasion du transport de ces dernières. Le transfert à grande échelle d'un nombre considérable d'animaux et de plantes a inévitablement conduit à l'introduction simultanée d'agents pathogènes portant préjudice au développement et à la croissance des nouvelles ressources de pêche et aux activités de pêche traditionnelles.

Le second défi repose sur l'impact écologique et environnemental des espèces introduites et transferées, en particulier pour celles risquant de ne pas rester confinés dans un système de culture, et de s'établir à l'état sauvage. Ces nouvelles populations peuvent avoir en effet un impact sur les espèces indigènes.

Le troisième défi, qui est aussi celui apparu le plus récemment, est l'impact génétique des espèces introduites et transferées, par le biais des croisements entre populations cultivées et sauvages et par la dissémination volontaire d'organismes génétiquement modifiés.

The International Council for the Exploration of the Sea, through its Working Group on Introductions and Transfers of Marine Organisms and its cooperation with other ICES Working Groups and with the European Inland Fisheries Advisory Commission (EIFAC) of the Food and Agriculture Organization of the United Nations (FAO), has addressed these three levels of concern since 1973.

On 10 October 1973, the Council adopted the first version of what was to become an internationally recognized "Code of Practice" on the movement and translocation of non-native species for fisheries enhancement and mariculture purposes. The Code was set forth "to reduce the risks of adverse effects arising from introduction by non-indigenous marine species". Subsequent modifications proposed by the ICES Working Group on the Pathology and Diseases of Marine Organisms in 1978 and by the then newly reconvened ICES Working Group on the Introduction of Non-Indigenous Marine Organisms in 1979, led to the publication of a "Revised Code" adopted by ICES in October 1979. The ''1979 Code" became the standard for international policy and the version of the Code most widely used, cited, and translated for the next 10 years. Minor revisions and additions over the decade resulted in the adoption in October 1990 of a "1990 Revised Code."

The "1994 Code" presented here was adopted by ICES in September 1994 (ICES, 1994). It incorporates further changes and adds critical new sections relative to genetic issues. The latter include consideration, under Section IV (c), of the need to assess the genetic impacts that releases—such as of farmed salmon or other fish—could have on the natural genetic diversity of native stocks and thus on the environment in general; and a new Section V on recommended procedures for the consideration of the release of genetically modified organisms.

Le Conseil International pour l'Exploration de la Mer, par l'intermédiaire de son Groupe de Travail sur les Introductions et les Transferts des Organismes Marins, en coopération avec d'autres Groupes de Travail du CIEM et avec la Commission Européenne Consultative pour les Pêches dans les Eaux Intérieures (EIFAC) de l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO), travaille sur ces trois grandes questions depuis 1973.

Le 10 octobre 1973, le Conseil a adopté la première version de ce qui allait devenir un "Code de Conduite" internationalement reconnu sur les mouvements et les transferts d'espèces non-indigènes, ayant pour but l'amélioration de la pêche et de la mariculture. Le Code a éte établi préalablement "pour réduire des risques d'effets négatifs pouvant résulter de l'introduction d'espèces marines non-indigènes". Par la suite, des modifications furent proposées. D'abord en 1978 par le Groupe de Travail du CIEM sur la Pathologie et les Maladies des Organismes Marins, puis en 1979 par un groupe de travail du CIEM nouvellement reformé, et formellement nommé "Groupe de Travail sur l'Introduction d'Organismes Marins Non-Indigènes". Ces modifications conduisirent à la publication d'un "Code Revisé" adopté par le CIEM en octobre 1979. Le Code 1979 devint une référence standard pour une politique internationale et la version du Code la plus largement utilisée, citée et traduite pendant les 10 années qui suivirent. Pendant cette période, des révisions mineures et des compléments aboutirent à l'adoption, en octobre 1990, du "Code Révisé 1990".

Le "Code de Conduite 1994" présenté ici a été adopté par le CIEM en septembre 1994 (ICES, 1994). Il prend en compte les modifications ultérieures et incorpore des nouvelles sections décisives concernant les questions génétiques. Ces dernières comportent des considérations sur la nécessité d'évaluer l'impact génétique eventuel des disséminations volontaires—comme par exemple de saumon ou d'autres poissons d'élevage—sur la diversité génétique naturelle des stocks indigènes et donc sur l'environnement en général (section IV (c)). Elles incluent aussi une nouvelle section V décrivant la procédure recommandée quand une dissémination volontaire d'organismes génétiquement modifiés est envisagée.

A brief outline of the
ICES Code of Practice 1994

The ICES Code of Practice 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 since it applies to both public (commercial and governmental) and private (including scientific) interests. In short, any persons engaged in activities that could lead to the intentional or accidental release of exotic species should be aware of the procedures covered by the Code of Practice.

The 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 content of Sections I, II, and IV has been referred to above and in ICES reports (ICES, 1984, 1988, and 1994). Section III, while brief, acknowledges the need to understand the vectors, other than intentional releases, that can bring exotic species to one's shores. In recent years, for example, the release of exotic organisms via a ship's ballast water has become a pressing issue, with profound implications for fisheries resources, mariculture, and other activities. Section V is the newer section noted earlier.

The Code is presented in a manner 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.

ICES Member Countries contemplating new introductions are requested to present to the Council a detailed prospectus on the rationale and plans for any new introduction; the contents of the prospectus are detailed in Section I of the Code. The Council may then request its Working Group on Introductions and Transfers of Marine Organisms to consider the prospectus and comment on it. The Working Group, in turn, may request more information before commenting on a proposal.

Les grandes lignes du
Code de Conduite du CIEM 1994

Le Code de Conduite du CIEM est établi préalablement pour recommander les procédures à suivre et les pratiques à appliquer pour diminuer les effets nuisibles potentiels d'introductions et de transferts volontaires d'organismes marins (y compris saumâtres). Le Code est destiné á un large public puisqu'il s'applique aux intérêts publics (commerciaux et gouvernementaux) et privés (y compris scientifiques). En somme, toute personne impliquée dans des activités qui pourraient conduire à la dissémination intentionnelle ou accidentelle d'espèces exotiques devrait avoir connaissance des procédures couvertes par ce Code de Conduite.

Le Code est divisé en cinq sections de recommandations concernant: (1) les démarches à suivre avant l'introduction d'une nouvelle espèce, (2) les démarches à suivre après que la décision de procéder à une introduction ait été prise, (3) la prévention des introductions non-autorisées par les Pays Membres, (4) les politiques à appliquer pour les introductions et les transferts en cours d'espèces faisant l'objet de pratiques commerciales courantes, et (5) les démarches à suivre avant la dissémination volontaire d'organismes génétiquement modifiés. Le Code inclut également une section de définitions.

Il est fait référence au contenu des sections I, II, IV ci-dessus et dans les rapports du CIEM (ICES, 1984, 1988 et 1994). La section III, bien que brève, fait le constat de la nécessité de comprendre par quels vecteurs, autres que les disséminations volontaires, les espèces exotiques arrivent sur les rivages. Ces dernières années, par exemple, la dissémination d'espèces exotiques via les eaux de lestage des navires (ballast) est devenu un problème très préoccupant, ayant de profondes implications pour la pêche, l'aquaculture, et pour d'autres activités. La section V est la section la plus récente, comme on l'a vu plus tôt.

Le Code est présenté de telle façon qu'il permet une application large et flexible à un champs étendu de circonstances et de demandes dans nombre de pays, tout en reposant sur une série d'indications et de principes scientifiques de base.

Les Etats Membres du CIEM envisageant toutes nouvelles introductions sont invités à présenter au Conseil une notification détaillée sur les objectifs et le déroulement prévu de la nouvelle introduction; le contenu de la notification est détaillé dans la section I du Code. Le Conseil aurait alors la possibilité de charger le Groupe de Travail sur les Introductions et les Transferts des Organismes Marins d'étudier la notification et de la commenter. Le Groupe de Travail, à son tour, pourrait demander des informations complémentaires avant d'émettre un avis sur la proposition.

If an introduction or transfer proceeds, ICES requests Member Countries to keep the Council informed about it, both through providing details of the brood stock established and the fate of the progeny, and through submitting progress reports after a species is released into the wild. The specifics of this stage are detailed in Section II of the Code.

ICES has published two extended guides to the Code, one in 1984 as *Cooperative Research Report* (*CRR*) No. 130, entitled "Guidelines for Implementing the ICES Code of Practice Concerning Introductions and Transfers of Marine Species", and one in 1988 as *Cooperative Research Report* No. 159, entitled "Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms". These reports are available in many libraries and from the ICES Secretariat. The Working Group on Introductions and Transfers of Marine Organisms is in the process (1995) of revising these documents, and inquiry regarding the date when the new *ICES Cooperative Research Report* will be available should be addressed to ICES.

ICES views the Code of Practice as a guide to recommendations and procedures. As with all Codes, the current one has evolved with experience and with changing technological developments. The latest (1994) version of the Code reflects the past 20 years of experience with its use and application and with the evolution of new fisheries and genetic technologies. While initially designed for the ICES Member Countries concerned with the North Atlantic and adjacent seas, the Code soon found use as far away as the Pacific islands.

We are pleased to present the ICES Code of Practice in this fashion for wide consideration, and we welcome advice and comments from both Member Countries and our colleagues throughout the world. Recommendations and suggestions should be directed to the General Secretary of ICES in Copenhagen, Denmark.

James T. Carlton
Chairman, ICES Working Group on Introductions and Transfers of Marine Organisms

Katherine Richardson
Chairman, ICES Advisory Committee on the Marine Environment

Si une introduction ou un transfert a lieu, le CIEM invite les Etats Membres à tenir le Conseil informé de l'opération, à la fois en fournissant des détails sur le stock des géniteurs mis en place et sur le devenir des descendants, et, une fois les espèces disséminées dans le milieu naturel, en réalisant des études de suivi donnant lieu à des rapports soumis au CIEM. La description précise de cette étape est détaillée dans la section II du Code.

Le CIEM a publié deux guides détaillés pour l'application du Code, l'un en 1984: *Cooperative Research Report (CRR)* No. 130, intitulé "Guidelines for Implementing the ICES Code of Practice Concerning Introductions and Transfers of Marine Species", et l'autre en 1988: *Cooperative Research Report* No. 159, intitulé "Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms". Ces rapports sont disponibles dans de nombreuses bibliothèques et au Secrétariat du CIEM. Ces documents sont actuellement (1995) en cours de révision par le Groupe de Travail sur les Introductions et les Transferts des Organismes Marins, et les demandes de renseignement concernant la date à laquelle le nouveau *ICES Cooperative Research Report* sera disponible peuvent être adressées au CIEM.

Le CIEM considère le Code de Conduite comme un guide de recommandations et de procédures. Comme tous les Codes, celui-ci a évolué avec la pratique et avec les nouveaux développements technologiques. La dernière version (1994) du Code reflète 20 années de pratique aussi bien dans l'utilisation et l'application du Code que dans l'évolution de nouvelles technologies dans les domaines de la pêche ou de la génétique. Alors qu'il était à l'origine destiné aux Etats Membres du CIEM concernés par l'Ocean Atlantique Nord et les mers adjacentes, le Code s'est vu rapidement trouvé utilisé dans des régions aussi éloignées que les îles du Pacifique.

Nous sommes heureux de présenter ce Code de Conduite du CIEM sous cette forme pour une large diffusion et nous accueillons avec intérêt les conseils et les commentaires des Etats Membres, mais aussi de nos collègues du monde entier. Les conseils et les suggestions sont à adresser au Secrétaire Général du CIEM à Copenhague, Danemark.

James T. Carlton
Président du Groupe de Travail du CIEM sur les Introductions et les Transferts des Organismes Marins

Katherine Richardson
Présidente du Comité d'Avis sur l'Environnement Marin du CIEM

ICES Code of Practice on the Introductions and Transfers of Marine Organisms 1994

The introduction and transfer of marine organisms, including genetically modified organisms, carry the risk of introducing not only pests and disease agents but also many other species. Both intentional and unintentional introductions may have undesirable ecological and genetic effects in the receiving ecosystem, as well as potential economic impacts. This Code of Practice provides recommendations for dealing with new intentional introductions, and also recommends procedures for species which are part of existing commercial practice, in order to reduce the risks of adverse effects that could arise from such movements.

I **Recommended procedure for all species prior to reaching a decision regarding new introductions.** (A recommended procedure for introduced or transferred species which are part of current commercial practice is given in Section IV; a recommended procedure for the consideration of the release of genetically modified organisms is given in Section V.)

(a) Member Countries contemplating any new introduction should be requested to present to the Council at an early stage a detailed prospectus on the proposed new introduction(s) for evaluation and comment.

(b) The prospectus should include the purpose and objectives of the introduction, the stage(s) in the life cycle proposed for introduction, the area of origin and the target area(s) of release, and a review of the biology and ecology of the species as these pertain to the introduction (such as the physical, chemical, and biological requirements for reproduction and growth, and natural and human-mediated dispersal mechanisms).

(c) The prospectus should also include a detailed analysis of the potential impacts on the aquatic ecosystem of the proposed introduction. This analysis should include a thorough review of:

Code de Conduite du CIEM pour les Introductions et les Transferts d'Organismes Marins 1994

L'introduction et le transfert d'organismes marins, y compris d'organismes génétiquement modifiés, comportent le risque d'une introduction, non seulement d'agents nuisibles et de pathogènes, mais aussi de beaucoup d'autres espèces. Qu'elles soient intentionnelles ou non, ces introductions peuvent avoir des effets écologiques et génétiques indésirables pour l'écosystème receveur, et un impact économique potentiel. Ce Code de Conduite fournit des recommandations à suivre lors de futures introductions intentionnelles, et indique les procédures pour les cas d'espèces faisant l'objet de pratiques commerciales courantes. Il vise à limiter les effets négatifs possibles pouvant être générés par ces mouvements.

I **Procédure recommandée avant toute prise de décision concernant les nouvelles introductions, quelque soit l'espèce.** (On trouvera en section IV la procédure conseillée en cas d'introduction ou de transfert d'espèces qui font l'objet de pratiques commerciales courantes; en section V la procédure conseillée en cas de dissémination volontaire d'organismes génétiquement modifiés.)

(a) Il conviendrait que les Etats Membres envisageant une nouvelle introduction soient invités à présenter le plus tôt possible au Conseil une notification détaillée sur la/les introduction(s) proposée(s) pour évaluation et commentaires.

(b) Cette notification devrait contenir le but poursuivi et les objectifs de l'introduction, le/les stade(s) du cycle biologique auquel/auxquels l'introduction est prévue, la région d'origine et la/les région(s) cible(s) de la dissémination volontaire, et une présentation de la biologie et de l'écologie de la/des espèce(s) concernée(s) par l'introduction (exigences physiques, chimiques et biologiques pour la reproduction et la croissance, mécanismes de dispersion naturels et humains, etc.).

(c) La notification devrait aussi comprendre une analyse détaillée des impacts potentiels de l'introduction proposée sur l'écosystème aquatique. Cette analyse devrait contenir une présentation précise:

(i) the ecological, genetic, and disease impacts and relationships of the proposed introduction in its natural range and environment;

(ii) the potential ecological, genetic, and disease impacts and relationships of the proposed introduction in the proposed release site and environment. These aspects should include but not necessarily be limited to:

- potential habitat breadth,
- prey (including the potential for altered diets and feeding strategies),
- predators,
- competitors,
- hybridization potential and changes in any other genetic attributes, and
- the role played by disease agents and associated organisms and epibiota.

Potential predation upon, competition with, disturbance of, and genetic impacts upon, native and previously introduced species should receive the utmost attention. The potential for the proposed introduction and associated disease agents and other organisms to spread beyond the release site and interact with species in other regions should be addressed. The effects of any previous intentional or accidental introductions of the same or similar species in other regions should be carefully evaluated.

(d) The prospectus should conclude with an overall assessment of the issues, problems, and benefits associated with the proposed introduction. Quantitative risk assessments, as far as reasonably practicable, could be included.

(e) The Council should then consider the possible outcome of the proposed introduction, and offer advice on the acceptability of the choice.

(i) des impacts écologiques, génétiques, et pathologiques et des inter-relations de l'introduction proposée dans sa région d'origine et son habitat naturel;

(ii) des impacts écologiques, génétiques, et pathologiques et des inter-relations potentiels de l'introduction proposée dans le site où a lieu la dissémination volontaire proposée et dans l'environnement plus étendu. Il serait souhaitable que ces aspects abordent, sans nécessairement s'y limiter:

- le potentiel à occuper de nouveaux habitats,
- les proies (y compris les modifications potentielles de régimes et de stratégies alimentaires),
- les prédateurs,
- les concurrents,
- le potentiel d'hybridation et toutes autres modifications génétiques,
- le rôle joué par les agents pathogènes, les organismes associés et les épibiotes.

Les phénomènes de prédation, de compétition et de perturbation ainsi que les impacts génétiques potentiels sur les espèces indigènes et sur les espèces antérieurement introduites devraient faire l'objet de la plus grande attention. Les risques de propagation de l'introduction proposée et des agents pathogènes et autres organismes associés au-delà du site de dissémination, ainsi que les interactions possibles avec les espèces d'autres régions devraient être abordés. Les effets de toute introduction antérieure d'espèces semblables ou similaires, intentionnelle ou accidentelle, dans d'autres régions devraient être evalués avec soin.

(d) La notification devrait conclure par une évaluation globale des questions, problèmes et avantages liés à l'introduction proposée. Dans la mesure du possible, cette partie pourrait inclure une évaluation quantitative des risques.

(e) Il conviendrait alors que le Conseil étudie les résultats prévus de l'introduction proposée et émette un avis quant à l'acceptabilité du choix des orientations proposées.

II If the decision is taken to proceed with the introduction, the following action is recommended:

(a) A brood stock should be established in a quarantine situation approved by the country of receipt, in sufficient time to allow adequate evaluation of the stock's health status.

The first generation progeny of the introduced species can be transplanted to the natural environment if no disease agents or parasites become evident in the first generation progeny, but not the original import. In the case of fish, brood stock should be developed from stocks imported as eggs or juveniles, to allow sufficient time for observation in quarantine.

(b) The first generation progeny should be placed on a limited scale into open waters to assess ecological interactions with native species.

(c) All effluents from hatcheries or establishments used for quarantine purposes in recipient countries should be sterilized in an approved manner (which should include the killing of all living organisms present in the effluents).

(d) A continuing study should be made of the introduced species in its new environment, and progress reports submitted to the International Council for the Exploration of the Sea.

II Si la décision de procéder à l'introduction est prise, le Conseil recommande les actions suivantes:

(a) Un stock de géniteurs devrait être mis en quarantaine, avec l'accord du pays receveur, pour durée suffisante pour permettre l'évaluation de l'état sanitaire des stocks.

La première génération de descendants de l'espèce introduite pourrait alors être transplantée dans le milieu naturel si aucun agent pathogène ou parasite n'est mis en évidence dans la première génération. Il conviendrait d'éviter l'introduction du stock importé à l'origine. Dans le cas du poisson, le stock des géniteurs devrait être développé à partir des stocks importés au stade oeuf ou au stade juvénile afin de permettre une observation en quarantaine d'une durée suffisante.

(b) La première génération de descendants devrait être introduite à petite échelle en milieu naturel afin d'évaluer les interactions écologiques avec les espèces indigènes.

(c) Tous les effluents des écloseries ou des bâtiments utilisés pendant les périodes de quarantaine dans le pays receveur devraient être stérilisés selon une méthode agréée (qui inclurait l'élimination de tous les organismes vivants présents dans les effluents).

(d) Un suivi de l'évolution de l'espèce introduite dans son nouvel environnement devrait être fait, et les rapports devraient être soumis au fur et à mesure au Conseil International pour l'Exploration de la Mer.

III Regulatory agencies of all Member Countries are encouraged to use the strongest possible measures to prevent unauthorized or unapproved introductions.

IV Recommended procedure for introduced or transferred species which are part of current commercial practice.

(a) Periodic inspection (including microscopic examination) of material prior to exportation to confirm freedom from introducible pests and disease agents. If inspection reveals any undesirable development, importation must be immediately discontinued. Findings and remedial actions should be reported to the International Council for the Exploration of the Sea.

and/or

(b) Quarantining, inspection, and control, whenever possible and where appropriate.

(c) Consider and/or monitor the genetic impact that introductions or transfers have on indigenous species, in order to reduce or prevent detrimental changes to genetic diversity.

It is appreciated that countries will have different requirements toward the selection of the place of inspection and control of the consignment, either in the country of origin or in the country of receipt.

III Les autorités de tous les Etats Membres sont invitées à utiliser les mesures les plus dissuasives pour prévenir les introductions non-autorisées ou non-approuvées.

IV Procédure recommandée pour les espèces introduites ou transferées faisant l'objet de pratiques commerciales courantes.

(a) Inspections périodiques (incluant examens au microscope) du matériel avant toute exportation pour confirmer l'absence de risque d'introduction d'agents nuisibles et pathogènes. Si une inspection révèle un quelconque développement d'agent indésirable, l'importation doit être arrêtée immédiatement. Il conviendrait de présenter les résultats de ces examens et les mesures mises en oeuvre pour y remédier en cas de problème au Conseil International pour l'Exploration de la Mer.

et/ou

(b) Mises en quarantaine, inspections et contrôles aussi souvent que possible sur les sites où ces actions semblent appropriées.

(c) Prise en compte et surveillance de l'impact génétique des introductions ou transferts sur les espèces indigènes afin de réduire ou de prévenir des modifications néfastes de la diversité génétique.

Le Conseil prend en compte le fait que les pays concernés par ces introductions et transferts aient des exigences différentes en ce qui concerne le choix du site d'inspection et de contrôle des lots expédiés, même s'il s'agit du pays d'origine ou du pays receveur.

V Recommended procedure for the consideration of the release of genetically modified organisms (GMOs).

(a) Recognizing that little information exists on the genetic, ecological, and other effects of the release of genetically modified organisms into the natural environment (where such releases may result in the mixing of altered and wild populations of the same species, and in changes to the environment), the Council urges Member Countries to establish strong legal measures* to regulate such releases, including the mandatory licensing of physical or juridical persons engaged in genetically modifying, or in importing, using, or releasing any genetically modified organism.

(b) Member Countries contemplating any release of genetically modified organisms into open marine and fresh water environments are requested at an early stage to notify the Council before such releases are made. This notification should include a risk assessment of the effects of this release on the environment and on natural populations.

(c) It is recommended that, whenever feasible, initial releases of GMOs be reproductively sterile in order to minimize impacts on the genetic structure of natural populations.

* Such as the European Economic Community "Council Directive of 23 April 1990 on the Deliberate Release into the Environment of Genetically Modified Organisms (90/220/EEC)", Official Journal of European Communities, No. L, 117: 15–27 (1990).

(d) Research should be undertaken to evaluate the ecological effects of the release of GMOs.

V Procédure recommandée dans le cas de la dissémination volontaire d'organismes génétiquement modifiés (OGM).

(a) Reconnaissant le peu d'information existant sur les effets génétiques, écologiques et autres de la dissémination volontaire d'organismes génétiquement modifiés dans le milieu naturel (dans lequel ces disséminations pourraient conduire à un croisement entre les populations modifiées et sauvages de la même espèce et à des modifications du milieu) le Conseil recommande vivement aux Etats Membres la mise en place de mesures légales strictes* régulant de telles disséminations, incluant l'obligation, pour les personnes physiques et juridiques engagées dans la modification génétique, l'importation, l'utilisation, ou la dissémination de tout organisme génétiquement modifié, de détenir une autorisation officielle.

b) Les Etats Membres envisageant une quelconque dissémination volontaire d'organismes génétiquement modifiés en milieu dulçaquicole ou marin devraient le déclarer au Conseil dès la phase préliminaire, et en tout cas avant que ces disséminations ne soient faites. Cette déclaration devrait comprendre une évaluation des risques d'impacts de ces disséminations sur le milieu receveur et les populations naturelles.

c)) Il serait souhaitable que, autant que faire se peut, les premiers essais de dissémination volontaire d'OGM soient constitués d'individus stériles afin de minimiser les impacts sur la structure génétique des populations naturelles.

(e) Il conviendrait d'entreprendre des recherches afin d'évaluer les

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* Telles que la "Directive du Conseil du 23 avril 1990 relative à la dissémination volontaire d'organismes génétiquement modifiés dans l'environnement (90/220/EEC)" de la Communauté Economique Européenne, Journal Officiel des Communautés Européennes, Nº L, 117: 15–27 (1990).

conséquences écologiques des disséminations volontaires d'OGM.

DEFINITIONS

For the application of this Code, the following definitions should be used.

Brood stock

Specimens of a species, either as eggs, juveniles, or adults, from which a first or subsequent generation may be produced for possible introduction to the environment.

Country of origin

The country where the species is native.

Current commercial practice

Established and ongoing cultivation, rearing, or placement of an introduced or transferred species in the environment for economic or recreational purposes, which has been ongoing for a number of years.

Disease agent

For the purpose of the Code, "disease agent" is understood to mean all organisms, including parasites, that cause disease. (A list of prescribed disease agents, parasites, and other harmful agents is made for each introduced or transferred species in order that adequate methods for inspection are available. The discovery of other agents, etc., during such inspection should always be recorded and reported.)

Genetic diversity

All of the genetic variation in an individual, population, or species (ICES, 1988).

Genetically modified organism (GMO)

An organism in which the genetic material has been altered anthropogenically.*

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* Such technologies include the isolation, characterization, and modification of genes and their introduction into living cells as well as techniques for the production of living cells with new combinations of genetic material by the fusion of two or more cells.

DEFINITIONS

Pour appliquer ce Code, les définitions suivantes devront être prises en compte.

Stock des géniteurs

Individus d'une même espèce (oeufs, juvéniles ou adultes), que l'on fait se reproduire afin d'introduire éventuellement la première génération ou les suivantes dans le milieu naturel.

Pays d'origine

Le pays dont l'espèce est originaire.

Pratiques commerciales courantes

Culture, élevage ou simple mise en place dans le milieu naturel d'une espèce introduite ou transférée selon une pratique établie et continue depuis plusieurs années, pour des raisons économiques ou de loisirs.

Agent pathogène
Dans ce Code, le terme "agent pathogène" recouvre tous les organismes, y compris les parasites, pouvant être la cause d'une maladie. (Une liste indicative des agents pathogènes, parasites, et autres agents nuisibles doit être établie pour chaque espèce introduite ou transférée afin que soient mises en place des méthodes d'inspection appropriées. La découverte d'autres agents pathogènes, etc., au cours de ces inspections devrait toujours être notée et signalée.)

Diversité génétique
L'ensemble des variations génétiques au sein des individus, des populations, ou des espèces (ICES, 1988).

Organisme génétiquement modifié (OGM)

Un organisme dont le matériel génétique a été modifié par l'homme.*

DEFINITIONS

Introduced species
(= non-indigenous species, = exotic species)
Any species intentionally or accidentally transported and released by humans into an environment outside its present range.

Marine species
Any aquatic species that does not spend its entire life cycle in fresh water.

Quarantined species
Any species held in a confined or enclosed system that is designed to prevent any possibility of the release of the species, or any of its disease agents or any other associated organisms into the environment.

Transferred species
(= transplanted species)
Any species intentionally or accidentally transported and released within its present range.

* Ces technologies incluent l'isolation, la caractérisation, et la modification de gènes, ainsi que l'introduction de gènes dans des cellules vivantes. Elles comprennent aussi les techniques de production de cellules vivantes comportant de nouvelles combinaisons de matériel génétique par fusion d'une ou plusieurs cellules.

DEFINITIONS

Espèce introduite
(= espèce non-indigène, = espèce exotique)
Toute espèce transportée et disséminée intentionnellement ou accidentellement par l'homme dans un milieu différent de son habitat naturel.

Espèce marine
Toute espèce aquatique ne passant pas tout son cycle biologique en eau douce.

Espèce mise en quarantaine
Toute espèce maintenue en système confiné ou clos dans le but de prévenir toute possibilité de dissémination de cette espèce ou d'un de ses agents pathogènes ou de tout autre organisme associé dans le milieu naturel.

Espèce transférée
(= espèce transplantée)
Toute espèce intentionnellement ou accidentellement transportée et disséminée à l'intérieur de son aire de répartition naturelle.

NOTES

(a) It is understood that an introduced species is what is also referred to as an introduction, and a transferred species as a transfer.

(b) Introduced species are understood to include exotic species, while transferred species include exotic individuals or populations of a species.

(c) It is understood for the purpose of the Code that introduced and transferred species may have the same potential to carry and transmit disease or any other associated organisms into a new locality where the disease or associated organism does not at present occur.

NOTES

(a) Il est sous-entendu ici qu'une espèce introduite fait référence à une introduction, et une espèce transférée à un transfert.

(b) Il est sous-entendu que les espèces introduites incluent les espèces exotiques, alors que les espèces transférées incluent les individus ou les populations exotiques d'une espèce.

(c) Il est sous-entendu, dans le cadre de ce Code, que les espèces introduites ou transférées peuvent avoir le même potentiel de transport et de transmission de maladie ou de tout autre organisme associé vers des régions où ces maladies ou organismes associés ne sont pas présents actuellement.

REFERENCES

ICES. 1984. Guidelines for Implementing the ICES Code of Practice Concerning Introductions and Transfers of Marine Species. Cooperative Research Report No. 130. 20 pp.

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