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The significance of ballast water in the introduction of exotic marine organisms to Cork Harbour, Ireland.

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ABSTRACT

This paper reviews the occurrence of exotic species within one Irish port and examines the growing importance of ballast water discharges. Twenty-four exotic organisms known from Cork Harbour have been assigned according to their method of introduction. Six clam and oyster species have been used in aquaculture and unwanted species have been associated with these. Presently aquaculture introductions and transfers are governed by a code of practice and this will reduce the risk posed by unwanted biota in the future. Eight of these introductions took place prior to 1972 and four of these are likely to have been introduced as fouling on ships. Antifouling applications on ships generally included TBT from 1972 and subsequently its use will have considerably reduced the risk of introductions by fouling organisms. There has been an overall increase in ballast water discharges with estimates of less than 20,000 tonnes in 1955 to almost 200,000 tonnes or more in each year since 1970. The origin of ballast water in 1993 was principally from Northern Europe and the U.K., Australia, Egypt, the French and Spanish Mediterranean. There is a significant threat of establishment of non-native species, that survive in ballast water and are established elsewhere in Europe, becoming introduced to Cork Harbour.

INTRODUCTION

Introductions can have serious social and economic consequences. For example, the western Atlantic ctenophore, *Mnemiopsis leidyi*, introduced to the Black Sea from the western Atlantic in ballast water became so abundant that it has resulted in the collapse of some otherwise profitable fisheries by its predation of fish larvae (Harbison, 1993). The zebra mussels, *Dreissena polymorpha* and *D. bugensis*, introduced to the Great Lakes of North America in ballast water from the Black Sea, caused trophic competition and fouling and blockages of pipes (Kershner, 1993). Hallegraeff and Bolch (1992) demonstrated transportation of viable dinoflagellate cysts of toxic species in ships' ballast tanks. Some blooms in port areas may result

from cyst inoculations from ballast discharges and may spread to compromise inshore fisheries and aquaculture activities.

Over the 20th century marine transportation has expanded rapidly, with shorter transit times between ports. The risk of unintended introductions has increased with faster travel. Boudouresque (1994) has indicated that most exotic species in southern Europe have become established since the 1950s, with the principal sites of establishment being in lagoons (23 to 24 species) and ports (13 to 14 species).

Some species considered to be exotics may be previously unknown natives or have arrived as part of a natural range expansion. Others have been deliberately introduced for aquaculture and in certain cases have been the vectors of unwanted species. A third group are those species introduced by shipping. The increasing use of water as ships' ballast is thought to be the most important vector of exotic organisms in the future.

Cork Harbour, a large natural sheltered bay on the south coast of Ireland, has some features not unlike a coastal lagoon and is also an important port. This area contains a significant number of exotic species. This paper examines the historical information on aquaculture, shipping movements, estimates of ballast water and the literature on the exotic species to ascribe the likely means by which these exotics arrived. This paper explains why ballast water poses the most significant means for the introduction of exotic species in the future.

MATERIALS AND METHODS

Cork Harbour is a large natural sheltered bay and the principal port on the south Irish coast (Fig. 1). It has a cool temperate climate with sea temperatures ranging from 5-19°C and with estuarine to coastal marine conditions. The Harbour is regularly dredged to provide ship access to Cork city. There are deepwater berths at Cobh and at industrial centres. Oyster culture has also been developed (Fig. 1).

The occurence of exotic species in the harbour was sourced from the literature and unpublished observations. The accumulated net registered tonnage (NRT - a volumetric measurement calculated from the capacity in cubic feet of spaces within the hull, and of enclosed spaces above the deck available for cargo stores and fuel, divided by 100 (Anon, 1991)) and number of vessels were obtained for the period 1928-1993. The NRT does not provide a direct measurement and does not relate to weight of exports because it is a capacity measurement. Dead or gross weight tonnage (DWT) was not recorded because this was not available for the period 1928-1993. A regression of changes in NRT and exports since 1955 gave a high correlation of 0.916 (using MINITAB), demonstrating that a reasonable estimate of exports over that period could be calculated based on NRT values.

By using back extrapolations of numbers of vessels both import/exporting or just importing, the proportion of vessels exporting could be calculated, based on the records of shipping activities for 1993. It has been assumed that the relative proportions in 1993 were the same to 1955 and that all exporting vessels were of the same size. The tonnage exported was calculated as follows:

Total pure exports = (Total exports/Total number of exporting vessels) x Total number of pure exporting vessels.

Pure exports refer to those products which were exported from Cork Harbour in ships that arrived carrying ballast water. To calculate annual ballast water discharge volume a conversion factor from NRT to dead weight tonnage of approximately 2.0 was obtained from a random selection of ships from the maritime directory. This figure was then was multiplied by 0.35 to obtain the total ballast capacity (mean value of 0.32 to 0.38 for various vessels including tankers) and then by 0.24 to calculate ballast water on arrival (a mean value based on volumes carried in tankers 0.13, and container vessels 0.35) (Carlton *et al.*, 1995). Estimates of ballast discharges may be compromised because vessel ballast volumes depend on ship design, weather conditions and planned cruise track. The origin of ships arriving with ballast to Cork Harbour were examined for 1993. In this exercise the estimates of ballast water discharges from all sources have been combined.

RESULTS

Exotic species were classified as either deliberate or unintended introductions (Table 1a & 1b) Some species are known to have been present over a short time and may not have become established. The distribution of those species considered to have become established are recorded for three regions of Cork Harbour(Fig. 2).

Intended introductions

With the exception of the ricegrass, *Spartina x townsendii*, introduced from Poole in Britain to stabilise mud flats near Lough Mahon in 1925 (Cummins, 1930), all intentional introductions were for aquaculture.

Oyster cultivation began following a decline of production on public beds, from 1860 in Lough Mahon (47 hectares), the Middleton River (10 hectares), Owenboy Estuary (31 hectares) and elsewhere in the Harbour from 1873 (48 hectares) (Wilkins, 1989). Beds were restocked using half grown flat oysters, *Ostrea edulis* regularly imported from France. From 1882 half-grown American oysters, *Crassostrea virginica*, were introduced, approximately 600,000 were laid on the Middleton bed in 1895. Half-grown Portugese oysters, *Crassostrea angulata*, were laid from 1892 to 1898, 5,000 at Lough Mahon, and later >8,000 within the Owenboy Estuary. The extent of the oyster fisheries at the turn of the century was recorded by Brown (1900) who refers to young native oysters, *O. edulis*, from the natural settlement area of Arcachon being relaid at the Middleton and Owenboy layings (Fig. 1). With up to 300,000 transferred in any one year from elsewhere in France and from the Netherlands, American oysters continued to be imported until the 1920s but overall numbers imported are unknown. Oyster culture in the harbour then declined and ceased although licensed areas were in existance.

Oyster cultivation did not again take place until 1969 when *O. edulis* settled as spat in ponds beside the North Channel, were laid on the seabed, or ongrown in bags on trestles. The broodstock was sourced from public oyster fisheries in Ireland, principally Tralee Bay. Pacific oysters, *Crassostrea gigas*, previously quarantined in Conwy, were cultured on trestles in the same area from 1976, and their production

rapidly expanded and new oyster growing areas evolved. Because this species rarely spawns in Irish waters, spat for culture are produced in hatcheries and most are imported from Britain and Guernsey. In 1993, as a result of EU legislation to promote free trade (Anon., 1991), half grown Pacific oysters were transferred to Ireland from France.

Other exotic molluscs were used in aquaculture trials; the hard shell clam, *Mercenaria mercenaria*, not currently in culture, and the Pacific clam, *Tapes philippinarum*, are cultivated in small quantities. Both were quarantined in Conwy. The soft shell clam, *Mya arenaria*, has been established in some European ports for some centuries, and is established in Cork Harbour. It is not clear whether this species was intended as food when introduced to Europe.

Unintended introductions

Introduced species associated with aquaculture

Uncontrolled movements of molluscs may result in the establishment of undesirable species, for example the sporozoan *Bonamia ostreae*, which infects the blood of *O. edulis*, may have been introduced with contaminated oysters in 1986 (McArdle *et al.*, 1991). In 1980, an eroded gill condition was found in up to 6% of *O. edulis* in the North Channel, similar to that produced by an elusive poecilostome copepod, *Herrmannella duggani*, (Holmes & Minchin, 1991) known from Ireland and Brittany. Its status as an exotic species is not certain but may have become established in Ireland following earlier oyster transfers from continental Europe.

A consignment of half-grown Pacific oysters from France in 1993 were laid in the harbour and were removed some weeks later. They contained two copepods, *Myicola ostreae*, attached to gills, and *Mytilicola orientalis*, a gut parasite of molluscs. These species are not known to have become established in Cork Harbour.

Introduced species associated with shipping

It is not clear whether many of the exotic marine algae, such as *Bonnemaisonia hamifera* found at Camden (Cullinane, 1973) were introduced by shipping but they may have been transported as attached plants on ships' hulls. The first Irish specimens of *B. hamifera* were washed ashore in Achill Sound in 1911 (in the National Herbarium, Dublin, DBN) and so the species is likely to have been present before this date elsewhere, at a time when little or no ballast water was used by ships for stability. Similarly *Codium fragile tomentosoides*, found at Corkbeg by Cullinane (1973), has been known from Ireland since 1833 (DBN). A further species, *Colpomenia peregrina*, had become established in France by 1905 and was first found in Lough Hyne, Ireland in 1939. This species may have reached Ireland as drift because it has a light thallus which when filled with air or gasses can float proud of the water and so become easily dispersed by wind. It may also have been transported in well boats involved with exports of lobsters from the Irish south coast. In 1971 a foliose red alga, *Cryptonemia hibernica*, was described for the first time from Cork Harbour (Guiry *et al.*, 1973); it has since been recorded from nearby Oysterhaven (Cullinane & Whelan, 1980). It is not known elsewhere in Europe, but its abundance and highly localised distribution and affinities with Pacific species strongly suggest that it is an introduction.

The New Zealand barnacle, *Elminius modestus*, and the Korean sea-squirt, *Styela clava*, were probably introduced as fouling. *E. modestus* is the most frequent barnacle in Lough Mahon and North Channel and is common at the Harbour entrance. The first Irish record was from Lough Hyne (Beard, 1957); it was probably established in Cork Harbour before then, and was first seen in the Owenboy Estuary in 1968. Crisp (1958) records its expansion on the south coast of Britain from 1946 (Fig. 4), where it is thought to have been established since 1939.

Styela clava became established on the south coast of Britain and is thought to have been introduced by returning warships following the Korean War. It was already established in Cork Harbour in 1972 (Kilty & Guiry, 1972). In 1987 it was widely distributed within the upper Harbour and was also found to be common on the hull of a moored vessel (Minchin & Duggan, 1988).

Mytilicola intestinalis, a gut parasite of mussels, was first found in Ireland in 1947 from Fountainstown and Church Bay in Cork Harbour (Grainger, 1951); it is now well established. It is likely that it was introduced from larval releases from its host *Mytilus edulis*, a known fouling organism of ships. The first record outside of the Mediterranean was from the North Sea (Caspers, 1939). More recently its status as an exotic species has been questioned, but it sporadic occurence, principally within Irish bays with ports and earlier absences, provide evidence that it is an introduction close to its northern range (Grainger, pers. comm.).

The serpulid *Ficopomatus enigmaticus*, which may form extensive intertwining masses in estuarine areas, is considered to have been introduced to Europe from the Indo-Pacific (Fauchild, 1977) as ships' fouling during the first world War (Zibrowius, 1994). It was first recorded from Cork Harbour by Kilty & Guiry (1973) near Cork city, further specimens were seen in Lough Mahon in 1986 and 1993. This species may have been introduced directly from Swansea where there is a local population (Kilty & Guiry, 1973) by the regular ferry service between Cork and Swansea.

The species *Gyrodinium aureolum* described from the western North Atlantic by Hulbert was first recorded in the eastern Atlantic by Braarud and Heimdal (1966) on the SW coast of Norway and may have been introduced to Europe as ballast water. Since then it has been observed at a number of other localities and probably arrived by spreading at coastal fronts. There is, however, some taxonomic confusion with a form from the Pacific. Its initial appearance in Europe may have been due to ballast water. It was first noticed on the south Irish coast in 1976, when it formed blooms. Although it has appeared in water samples since 1981 in Cork Harbour, it is not known to have bloomed there.

Alexandrium tamarense forms blooms in coastal areas and may cause paralytic shellfish poisoning. A bloom, of low toxicity, of this species was first recorded in Cork Harbour in the spring of 1985 in the North Channel, Owenboy Estuary and near Spike Island. No cysts of this genus were found in a 1993 study. It is not clear whether this species is native to Cork Harbour or was transferred or introduced in ballast water at some former time.

Quantifying the relative risk from shipping

Estimated annual discharges of ballast water into Cork Harbour rose from 1955 to 1971, during the 1970's much of the ballast water entering the harbour will have been as a result of the extensive dredging taking place as a result of harbour developments over that time: these vessels will have taken on ballast on return to the harbour following disposal of spoil at the nearby dumping ground. The ballast discharges again rose consistantly from 1982 (Fig. 4). Increases of ballast discharge relate to periods in the development of and export of specialised products such as oil, steel, chemicals and livestock (Table 2). In 1993 the majority of vessels carrying ballast were associated with oil products and consequently the opening of the Whitegate oil terminal in 1959 is a significant factor in the volumes of ballast discharged.

Patterns of shipping entering the port of Cork show an obvious decline in the gross tonnage of liners to 1972 (Fig. 3). Liners, which are unlikely to hold significant quantities of ballast, when entering Cork Harbour were principally in transit to and from North America, but when disembarkation took place liners either anchored south of the Harbour entrance or when conditions were suitable smaller liners anchored off Spike Island or berthed at Cobh for short periods of time. The large volume of liners until the 1960s may have been significant for innoculations of fouling organisms to have taken place. Although the shorter time spent by liners may have meant that the risks were reduced. Nevertheless, changes in temperature and salinity on entering the harbour may have promoted spawnings which could have led to recruitment. The greatest changes in temperature and salinity would have been at the berths in Cork city where in the earlier years, and before the development of the Tivoli and Ringaskiddy dock sites were developed, most of the non passenger shipping traffic would have gone.

The net rate tonnage (NRT) of merchant vessels trading with the U.K. has been 500,000 tonnes or less from 1928, declining during the Second World War. Following the war tonnage increased to 2,500,000 tonnes in 1974 and then generally declined. There has been a continual trend of increased NRT with continental Europe and elsewhere to 4,000,000+ tonnes in 1992. With the increase in NRT, from a wider range of ports, the potential of an exotic innoculation has increased. Pre and post war port facilities were not as efficient as in present times and the turnaround time of trading vessels, then principally centred at Cork city, was some days. The efficient biocidal antifoulant TBT paints, widely available to shipping since 1972, may have significantly reduced the potential for dispersal of fouling organisms, by reduction of fouling biomass. Although the International Maritime Organisation have recommended further controls on its general use by shipping, whatever replaces it will need to be as effective.

In Ireland there are presently no general controls on segregated ballast water or procedures for managing discharges with the exception of controls on oily ballast. Ballast water was first regularly used in the 1880's (Carlton & Geller, 1993). This was a more economic method of ballasting as it was rapidly done and required less labour than stone ballast. The sites where deballasting takes place and the volume discharged depends on ship design, sea state and the nature of the cargo. Vessels normally discharge at the first available opportunity so as to reduce time spent in port. Oil tankers, in particular, can discharge ballast near their destination while under way and most usually before berthing, because oil products are rapidly loaded, providing

insufficient time to enable deballasting, while berthed in port. On older ships ballast water would be taken on in empty oil tanks. However, there are facilities at Whitegate to pump dirty ballast water to tanks ashore, where oil can be removed before the water is discharged. The greater proportion of trading vessels in Cork Harbour are associated with oil products and since the terminal is near the Harbour entrance some deballasting may commence while at sea and so may reduce the efficacy of a potential innoculum.

Since the 1970s, the usage of TBT antifouling paints, has had a major impact on transfers of fouling organisms on ships. This biocide may modify the viability of innocula from ships' ballast water. Discharges of fine sediment from ballast tanks may become deposited along with fine sediments known to act as a sink for TBT in port areas. Polychaetes and other soft sediment fauna and possibly some algal cysts, settling in these areas, may consequently become constrained from establishment. It may also influence previously established populations.

The last port of call (LPC, being the port at which the ballast water was loaded), by region, of vessels visiting Cork Harbour in 1993 containing ballast water is shown in Table 3. The risk of introductions may be greater where there is much traffic throughout the year from the same LPC, particularly for those species which have seasonal cycles of abundance. Future introductions to Cork Harbour, will as a consequence, be likely to evolve following their establishment in northern European port areas, for example Glasgow, Liverpool, ports along the Bristol Channel and Rotterdam. It should be noted that the LPC does not always provide an accurate account of the ballast water transported, because deballasting and ballasting may take place while in transit or may have been contained from earlier visits. Sediments will accumulate from several ports in ballast tanks.

In 1993, vessels arrived from elsewhere in Ireland and Britain, continental Europe, north Africa, the Middle East and Australia. It is clear from Table 3 that vessels distributing oil products discharge the largest volume of ballast water into the Harbour. This is followed by ships exporting chemicals and steel. Almost all the vessels arriving in ballast, that load ammonia, are from Belfast. This route could result in the introduction of species to Cork Harbour previously introduced to Belfast Lough. Forty-two ships arrived carrying ballast water from north African ports (33 from Alexandria and 7 from Tripoli) to export livestock. This route may permit access of Mediterranean biota to Cork Harbour.

DISCUSSION

High exploitation of oysters during the mid-nineteenth century resulted from a rapid and reliable steam transportation by rail and sea, and improved marketing. Depletion of oysters lead to several introductions to Ireland of half-grown *O. edulis*, often in large numbers, from France, Britain and the Netherlands into the 1950s in order to enhance stocks and maintain oyster production. There were also extensive and sustained introductions of American oysters to Ireland and Britain during 1880-1920, from Long Island Sound, which were laid in several areas including Cork Harbour. Importations from the same source resulted in the establishment of slipper limpets, *Crepidula fornicata* and the American tingles *Urosalphinx cinerea* to the south-east

coast of Britain (Utting & Spencer, 1992). *C. fornicata* spread throughout much of northern continental Europe in the following hundred years, principally with oyster transfers. As its range expanded within Europe the risk of it becoming introduced with relayed oysters from the continent increased (Minchin, *et al.*, 1995).

Several organisms have been moved unintentionally with introductions and transfers of oysters. These risks are greatest with movements of half-grown oysters. Parasites and diseases, intimately associated with molluscs, are likely to be transferred. Three (*B. ostreae, M. intestinalis and H. duggani*) are thought to be established in Cork Harbour.

It is likely that associated biota arrived in Cork Harbour with the large volumes of American oysters introduced and may include species that have now become established within natural communities, possibly including planktonic species. Asian coastal copepods have appeared in California, USA and in Chile, all in areas of Pacific oyster cultivation (Omori *et al.*, 1994). The implication is that Pacific oyster cultivation has resulted in the introduction of Asian coastal copepods to these areas. Such planktonic species may survive being transferred in the liquor within the mantle cavity, as is known for *Myicola ostreae*.

Prior to 1993, shellfish and fish importations to Ireland were refused from unrecognised or uncleared areas, because being an island there was some freedom from pests, parasites and diseases. However, under EU Directive 91/67/EEC designed to improve trade within Europe, free movement of Pacific oysters not subjected to listed diseases, in Europe was allowed. The subsequent importations resulted in additional species being introduced to Ireland (Minchin *et al.*, 1993), including a short appearance of *M. ostreae* and *M. orientalis* not previously known to have appeared in Cork Harbour.

It has been an aim of the International Council for the Exploration of the Sea to reduce risks associated with aquaculture introductions and with trade, and a code of practice has recently been updated (Anon, 1995) to take account of such shellfish movements, and to address the planned development of new species for aquaculture within ICES member countries. This code covers not only the consequences of the introduced species but outlines measures for prevention of release of associated species, by recommended procedures in quarantine. Intended molluscan introductions themselves seldom result in negative effects and correct implementation of the ICES code considerably reduces the risk of unwanted effects.

Tenacious species and associated biota may become widely distributed on ships hulls. The ascidian *S. clava*, a frequent fouling organism in the north-west Pacific, has spread within northern Europe since 1952. It had become established in Cork Harbour by 1972 and can only have colonised Cork Harbour between these dates (Fig. 3). Similarly, *E. modestus*, introduced during the second world war to Britain from New Zealand, rapidly expanded its range in Europe and had become established in Cork Harbour before 1968, when it was first recorded (Fig. 3). The serpulid *F. enigmatica* may have been introduced to Ireland between the end of the First World War to 1972. Although trade with Britain was relatively low prior to the Second World War, there may have been a better opportunity for its establishment due to the

slower turnabout times in port. The introduction of *M. intestinalis* clearly occured before 1947, and as the shipping traffic at this time was very low, due to the Second World War, it is likely that it became established prior to 1941.

The estimated volumes of ships' ballast discharges into Cork Harbour will merely reflect a general trend, which demonstrates that there is indeed an increase in annual ballast water discharges from a low level in 1955. The estimates have not included ballast discharges from vessels other than those with a net export from the harbour. Many other ships will have discharged ballast water and consequently the figures are under-represtented. In addition the ballast discharges of tankers following the opening of the Whitegate Refinary are likely to provide lower figure than shown in Figure 4 if these were known, this is because, the ballast water on arrival will be less than the ballast capacity of the ship, and this can vary widely from 0.13 of the gross tonnage of tankers and is lower than the mean value of 0.24 used in all annual calculations. Since the expansion of the port facilities (Table 2) the container vessel traffic has increased and the ballast water on arrival of such vessels approximates to 0.35.

Cork Harbour has acquired marine biota from aquaculture, ships' fouling and possibly ships' ballast. The ICES Code of practice first adopted in the 1970's has resulted in much tighter controls on species introductions associated with aquaculture, and so the risks of undesirable species' introductions are considerably reduced.. The use of TBT antifouling paints on ships' hulls since the 1970s is also likely to significantly reduce the risk of introductions via ships' fouling. Ballast water, however, has increased in importance since the 1960's and may act as the main source of future introductions. The question of the control of ballast is under discussion by ICES and the International Maritime Organisation (IMO) with a view to finding adaquate control methods, using either continuous exchange of ballast at sea, biocidal methods or contained ballast transfers.

In this exercise it has not been possible to quantify accurately the volumes of ballast discharged and the development of a register of source, volumes, times and dates of taking on ballast by compartment by port authories would greatly aid management. Technological developments and data bases of nuisance species distributions and algal bloom events may aid in the treatment of ballast once effective and practical methods of controlling nuisance species in ballast have been developed.

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Table 1a. Species introduced intentionally to Cork Harbour. * *M. arenaria* may have been introduced as ships fouling.

SPECIES	ABUNDANCE	VECTOR	COMMENT
Spartina x townsendii	Abundant	Ship transfer	Arrived in Cork Harbour 1925
Mya arenaria *	Generally distibuted	Unknown	Widely distributed about Ireland
Crassostrea virginica	Abundant in years 1880-1920.	Aquaculture	Never became established. Relaid and sold
Crassostrea angulata	1890s	Aquaculture	Never became established. Relaid and sold
Crassostrea gigas	Abundant	Aquaculture, introduced in 1970's	Part of current large scale aquaculture
Mercenaria mercenaria	rare or no longer present.	Aquaculture trials in 1960's and 1980's	Not established
Tapes phillippinarum	Frequent	Aquaculture, introduced in 1980's	Small scale aquaculture activities

Table 1b. Species unintentionally introduced to Cork Harbour. Most likely vectors of introduction to Cork Harbour are shown in bold print.

	SPECIES	ABUNDANCE	VECTOR	COMMENT
1	*Bonamia ostreae*	Frequent Established	**Oyster transfers** Ship transfer	Identified 1987, oyster disease organism
2	*Gyrodinium aureolum*	Common Established	**Range extention** Unknown	Forms algal blooms
3	*Cryptonemia hibernica*	Abundant Established	**Ships fouling** **Ships ballast**	New species, now spread to Oysterhaven, first record 1971
4	*Bonnemaisonia hamifera*	Present Established	**Ships fouling** Unknown	Cullinane, 1973 generally distributed
5	*Colpomenia peregrina*	Frequent Established	**Drift** **Oyster transfers** Ships fouling	Cullinane, 1973 generally distributed
6	*Cladophora sericea*	May be common	**Ships fouling** **Ballast water** Oyster transfers	Cullinane, 1973
7	*Codium fragile* subsp. *tomentosoides*	Occasional Established	Unknown	Parkes, 1975 generally distributed
8	*Ficopomatus enigmaticus*	Occasional Established	**Ships fouling**	In Ireland only known in Cork Harbour. First record 1972
9	*Elminius modestus*	Abundant Established	**Ships fouling**	Causes extensive fouling in brackish areas, first record 1972
10	*Mytilicola intestinalis*	Frequent Established	**Ships fouling** in mussels	Gut parasite in mussels, recorded since 1947
11	*Mytilicola orientalis*	Rare	**Oyster transfers**	Briefly introduced on oysters in 1993
12	*Herrmannella duggani*	Occasional	**Native species?** **Oyster transfers**	New species, causes gill damage to oysters, 198
13	*Myicola ostreae*	Rare	**Oyster transfers**	Briefly introduced on oysters in 1993
14	*Corophium sextonae*	May be common	**Ships fouling**	First recorded by Costello in 19
15	*Styela clava*	Frequent Established	**Ships fouling**	First recorded in 1972.

Table 2. Development of Port of Cork facilities

Year	Port Area	Product	Development
1946	Haulbowline	Steel	Steel first made
1959	Whitegate	Oil, oil products	Oil refinary opens
1960	Haulbowline	Steel	Steel plant modernised
1969	Tivoli	Cars, passengers	Car ferry terminal opens
1970	Tivoli	Livestock	Livestock terminal opens
1970	Ringaskiddy	Containers	Container terminal opens
1972	Haulbowline	Steel	Modernisation of steel plant
1979	Marino Point	Ammonia, urea, fertilisers	First production of natural gas products
1981	Ringaskiddy	Timber, wood products	Berthing facilities open
1982	Ringaskiddy	Cars, passengers	Car ferry terminal opens
1986	Ringaskiddy	Containers	Deepwater berthing terminal opens

Table 3. Origin, by area of ships carrying ballast water to Cork Harbour for 1993.

Commodity	Origin of ships carrying ballast water								
	Ireland (+ N. Ireland)	U.K.	Northern Europe	Eastern Medi-terranean	Western Medi-terranean	Southern Medi-terranean	Eastern Atlantic	Other	Total
Oil	181	92	12	0	0	0	0	0	**285**
Chemicals	95	53	3	0	1	0	0	0	**152**
Steel	62	22	9	0	0	0	0	0	**93**
Wood	41	35	2	0	0	0	0	0	**78**
Livestock	0	1	0	2	1	42	2	2	**50**
Foodstuffs	9	4	7	0	2	0	1	1	**24**
Total	**388**	**207**	**33**	**2**	**4**	**42**	**3**	**3**	**682**

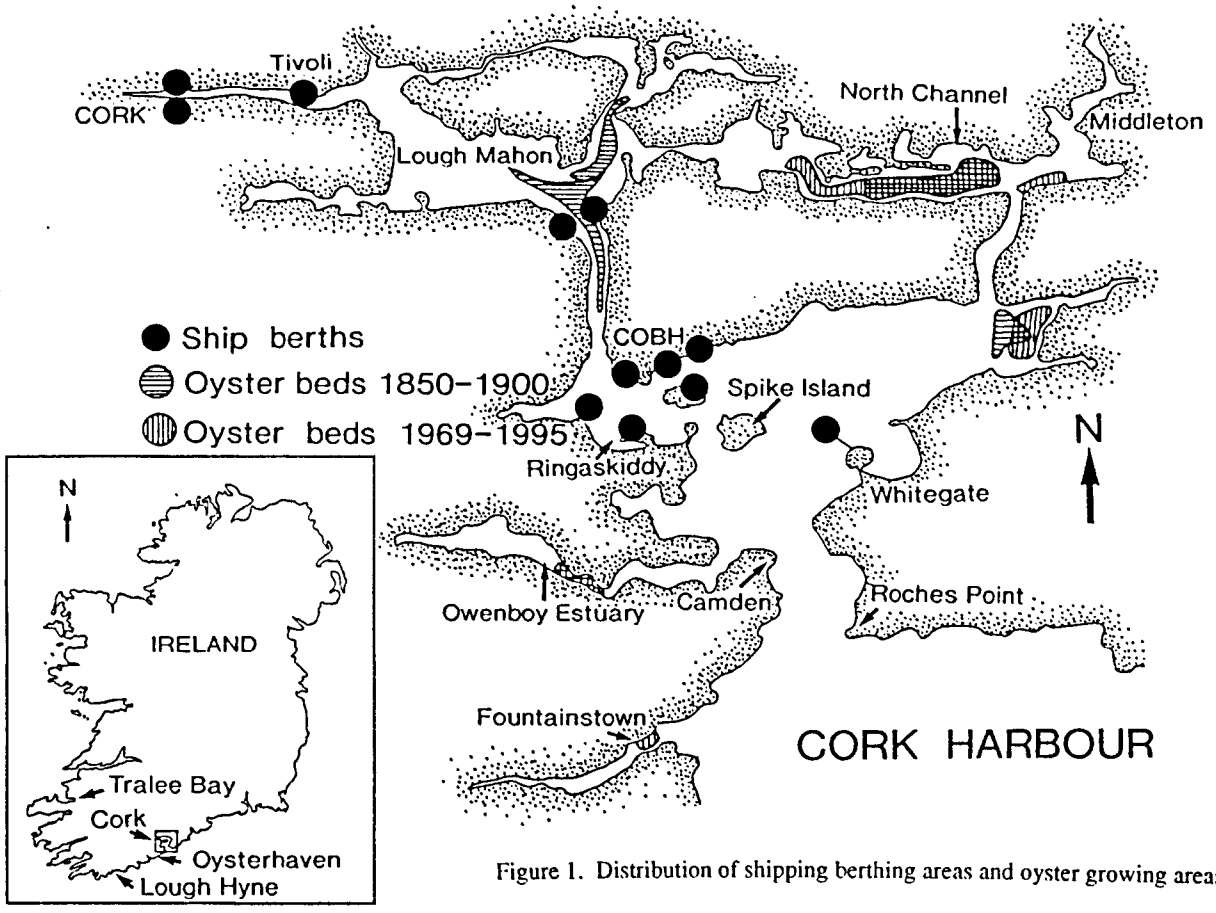

Figure 1. Distribution of shipping berthing areas and oyster growing areas.

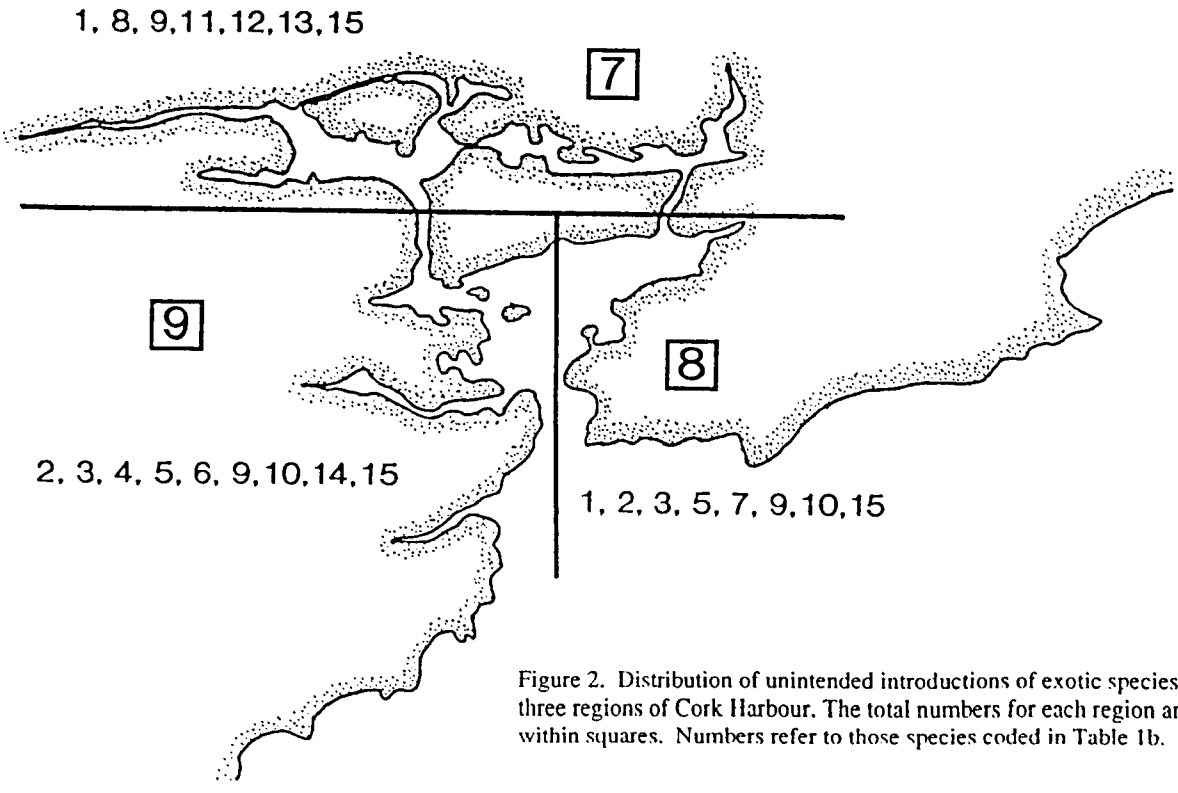

Figure 2. Distribution of unintended introductions of exotic species within three regions of Cork Harbour. The total numbers for each region are shown within squares. Numbers refer to those species coded in Table 1b.

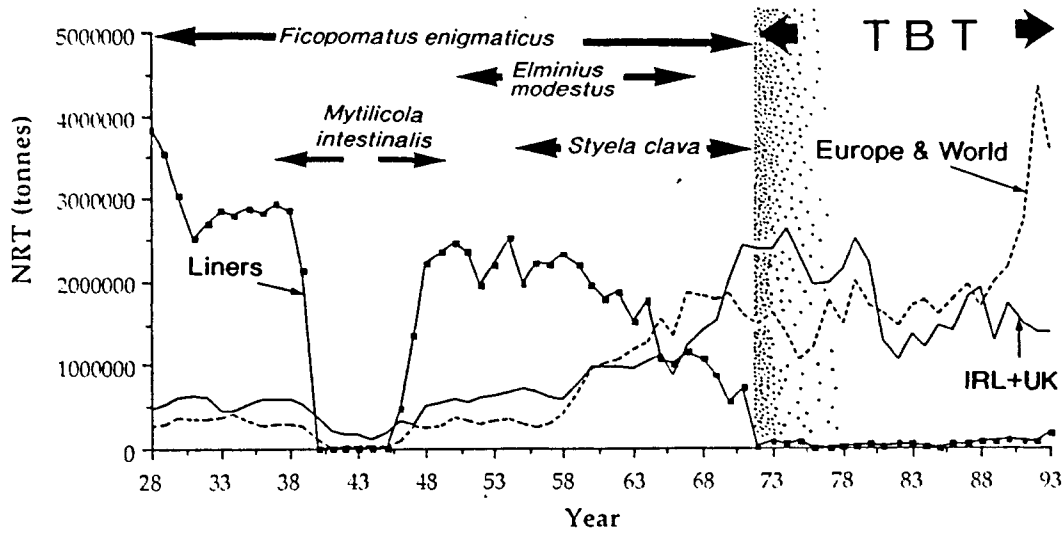

Figure 3. Trends in shipping volume 1928 to 1993 for Cork Harbour. The period over which four exotics became established are indicated with arrows. The use of TBT may have had an important effect on reducing the opportunity for exotic species to become established.

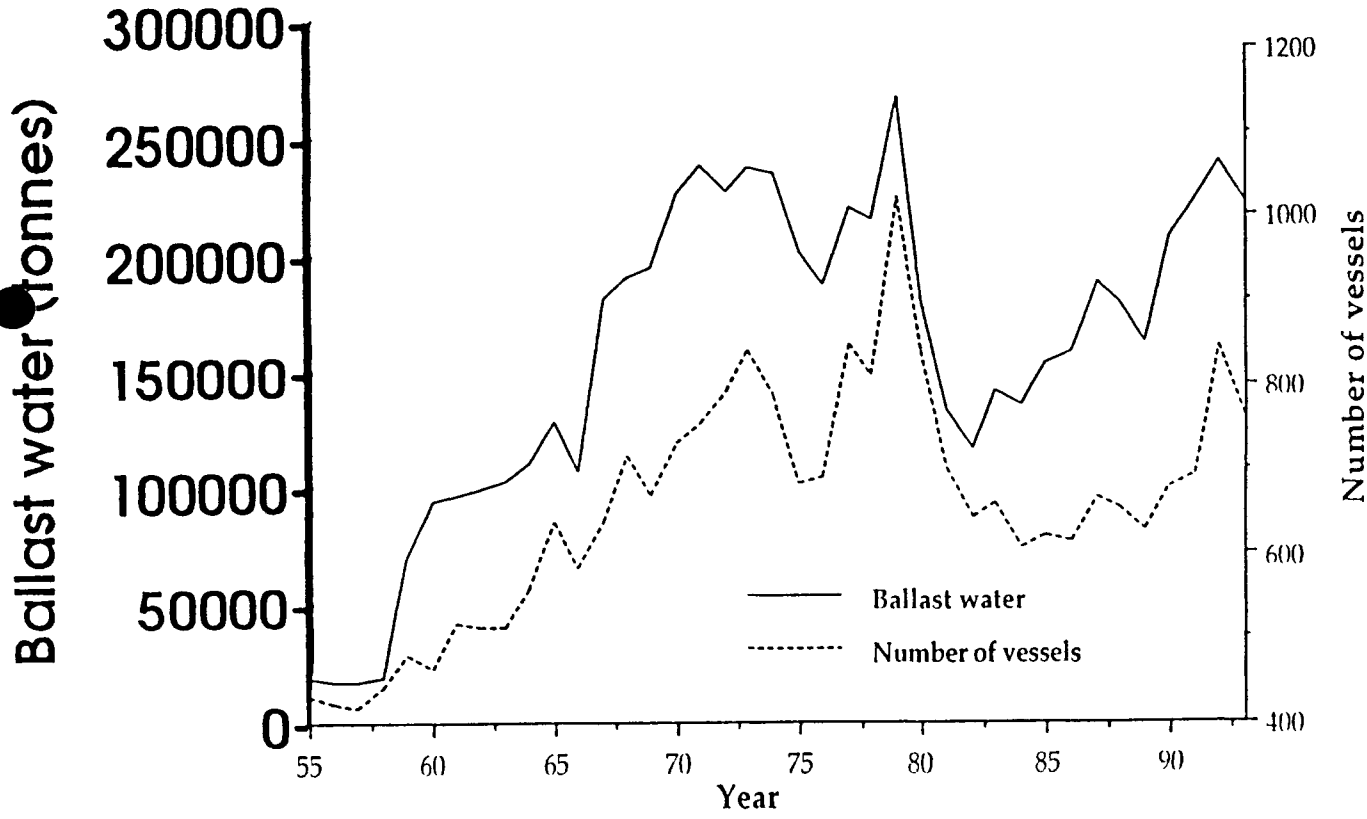

Figure 4. Number of vessels discharging ballast and estimated volume of ballast water discharged in Cork Harbour for 1955 to 1993.