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Assessment of the risk of introducing harmful marine organisms by shipping to Bantry Bay

Dan Minchin

Fisheries Research Centre,
The Marine Institute,
Abbotstown,
Dublin 15.

SUMMARY

The main shipping activity in Bantry Bay is centred at Leahill, a site where there is aggregate extraction with direct transmission to bulk carriers at a dedicated pier. The size of vessels ranges from 250 to 7,800mtNRT but with the majority of vessels being of 700 to 1,800mtNRT. Ballast water from these vessels is required to be deposited at sea before entering the Bay should these vessels be coming from outside of Ireland. If this is done the risk of introducing dinoflagellate species present in those ports in Atlantic France and Spain will be reduced. Vessels from Irish ports are not required to discharge ballast before entering the Bay. The main risk to Bantry Bay, albeit small - because the amount of ballast discharged is small, is from inoculations of the toxic dinoflagellate *Alexandrium tamarense* from ships that have ballasted in Cork Harbour or Belfast Lough. It would be prudent for vessels ballasting in these sea inlets not to do so in the region and during the time of the toxic algal bloom events. Although vegetative stages of *A. tamarense* have been identified from the plankton of Bantry Bay and *Alexandrium* sp. cysts have been found in fine sediments it is not known whether further innoculations of *A. tamarense* either in its vegetatitive or cyst state could result in a PSP event within the Bay. The development of a management plan for ships' ballasting in Cork Harbour and Belfast Lough based on cyst distributions and the distribution of algal bloom events could greatly reduce the risk of a transfer. In the meantime discoloured water in Cork Harbour and Belfast Lough should not be ballasted. The Cork Harbour Commissioners will be advised when algal bloom events take place so that basic precautions as suggested by the IMO guidelines can be carried out by ships masters.

INTRODUCTION

Ships as vectors of marine organisms

For more than a hundred years it has been recognised that shipping can unintentionally transfer organisms considerable distances leading to establishment of new populations beyond their natural range (Carlton, 1985). For many centuries wooden vessels provided habitats for sessile, crevace living and their associated organisms on ships' hulls. Fouling by modern shipping does not constitute the same risk as in earlier years because ships have steel hulls and use effective antifouling paint applications containing powerful biocides. These paints reduce fouling thereby decreasing drag and fuel consumption, increase ships speed with consequent economic benefits (Milne, 1996).

Some established exotic fouling species followed periods of vessel inactivity enabling development of a fouling community at the donor site or maturation and reproduction at the recipient site as happened in the establishment of *Styela clava* on warships following the Korean War to the south coast of Britain (Minchin and Duggan, 1987). Many fouling organisms occur at high densities and their close proximity may have promoted gamete fusion when spawning. The fate of the developing embryos and larvae would depend on the hydrodynamics of the associated water body and duration of the planktonic phase. In turn settlement and recruitment will depend on the suitability of the local conditions. It is notable that many of the areas where exotic species thrive are partially enclosed bays or estuaries, often with reduced tidal ranges.

The development of fast ships with rapid turnaround times and use of water in place of solid ballast creates a risk involving a wide range of taxa being transported beyond their natural range. In a recent study in Chesapeake Bay, USA, organisms identified in ballast water from 159 cargo vessels had 16 animal and 3 protist phyla and 3 plant divisions (367 taxonomic groups) and more than 70% of these ships contained copepods, polycheates, barnacles, bivalves and flatworms, and over 40% crabs and shrimp and chaetognaths (Anon., 1995). Ballast water organisms are being discharged in large quantities in many European ports (Gollasch, 1996). The extent to which these species cause problems is often not known until some time afterwards. The transportation and release of ballast water is a standard practice by shipping and is the main means of transfer of aquatic species worldwide (Carlton, 1985). Some species once transferred can become harmful and result in unexpected ecological, social and economic impacts. For example the introduction of the zebra mussels (*Dreissina polymorpha* and *D. bugensis*) in the 1980's, to the Great Lakes of North America from the Black Sea, and because of their abundance, have caused changes in trophic flow within ecosytems and blockages to freshwater supply pipes to cities and industry. The rapid expansion of their range east of the Rocky Mountains is expected to cost $3 billion US dollars before the end of this century (**REFERENCE**).

A futher example is the introduction of the ctenophore *Mneniopsis leidyi* from the eastern coast of North America to the Black Sea region. This species is an avid predator of the larval stages of fishes, copepods and other zooplankton. Its abundance has resulted in the decline of important pelagic fisheries in the Sea of Azov and Black Sea causing serious economic hardship to local communities (Harbison & Volovik, 1994).

The majority of successful introductions will have been donated by regions with a similar climate. Thus temperate/Mediterranean organisms are more likely to become established in Irish waters than semi-tropical or tropical species. It is recognised that there are many organisms from different phyla capable of existing in ballast water for long voyages, although the numbers of species and individuals decline in tandem with the length of the voyage. Some organisms have resting stages and these may have prolonged periods over which they may remain viable. Studies of vessels travelling from Japan to Australia have shown that dinoflagellate cysts can be transported considerable distances in a viable state. These accumulate in the sediment settled out from the ballast water. This sediment forms a mud in the bottom of ballast tanks and may remain here for some time. Because dinoflagellate cysts can remain viable for some years there is great concern that these cysts may result in viable innoculations to new regions where there are ports. Indeed the recent blooms noted in Tasmania in all probablitity result from such an event. Ballast muds when disturbed following a rough passage may be suspended and when deballasted the cysts present in the mud can become broadcast.

Toxic dinoflagellates when present in sufficient numbers can result in illness if local shellfish are consumed. The toxins present in the dinoflagellates are accumulated in the tissues of the shellfish that feed on them. There are a number of different toxins associated with different phytoplankton species producing a wide range of symptoms. One serious toxin causes paralytic shellfish poisoning (PSP). The increase of PSP events since 1950 in the southern hemisphere and near port regions strongly implicates ballast water transfers in recent years. These toxin producing species have localised distributions within Europe and normal shipping could transfer these to new localities. Dinoflagellate cysts of species that can cause PSP are readily transported in ballast, and have been cultured from ballast sediments (Hallegraeff & Bolch, 1992).

Transfers of micro-organisms in ballast water and sediment may also have implications for human health. The Central American strain of the bacterium *Vibrio cholerae,* which causes cholera, was found within ships ballast tanks in Mobile, Alabama, USA in 1991 (McCarthy & Khambaty, 1994). The same strain had previously been found within shellfish near the port and sales on shellfish for human consumption were closed for a period (Eichold *et al.*, 1993). It has also been suggested that algal blooms may act as a carrier to extend and expand the populations of cholera (Epstein, 1995).

It can often be difficult to distinquish between native and non-native species, because the distributions of many marine organisms are incompletely known. Species whose native range remains unknown are referred to as cryptogenic species (Carlton, 1985). New species continue to be described in Irish waters and it can not be said with certainty these are native unless there is some means of verification. Nevertheless some forms are distinctive such as the barnacle *Elminius modestus*, the sea-squirt *Styela clava* and the slipper limpet *Crepidula fornicata* and their native ranges are well known.

The International Maritime Organisation has provided a set of guidelines for the management of ballast water to control the spread of harmful marine organisms (IMO, 1996). These are updated from time to time as the knowledge for handling this problem improves. Several methods to treat the contained ballast water have included filtering, altering salinity, uv treatments and ultrasound during ballasting. Disinfection of water while the ship is in passage using biocides, ozone, heat treatments, electrical methods, elimination of oxygen, uv, salinity changes and ultrasound or by ballast exchange all have limitations of efficacy, economics or practicality (Carlton *et al.*, 1995). This means that there is no presently recognised treatment for ballast water that will result in the elimination of all living organisms. The current IMO guidelines, if followed, reduce the risk of a ballast water introduction by observing the times of ballasting in relation to known events in port areas and to exchange ballast while underway over deep water. By releasing only small quantities of the original ballast water which may remain, following reballasting at sea over deep water, a smaller population of species from the original ballasting will be released. The size of the population innoculum is thought to be of importance as many species require a critical number of individuals before their establishment is possible.

Ballast water is carried in special compartments capable of being drained separately or together. Access to these tanks is difficult and the accumulated ballast sediment may only be practical to sample while vessels are in dry-dock. Because the sediment accumulates on the floor of these tanks and little is discharged during deballasting, the sediment will consist of particulate matter from a wide range of ports and will also reflect the conditions under which ballasting was done.

De-ballasting takes place either in port or on approach to port. The ballast tanks are interconnected by piping and exit via an aperture of 30-45cm diameter, depending on vessel size. Discharges normally are completed from the fully ballasted state within hours. The discharge of all ballast is unlikely. This is because water distribution within the tanks can be affected by the inclination of the ship and sea state. Once pumps cavitate, as the water level lowers, the pumps are switched off to avoid their damage. The filling of double bottom tanks can result in changes to ships behaviour due to a stiffning of the vessel, for this reason they are not always used. Ballast tanks would normally be filled to capacity because partially filled tanks can have surging water in heavy seas which can cause structural damage and changes of ships behaviour.

The management of ballast water on ships is an important part fo the management of a planned voyage and because of this changes to the routine of this management must not compromise the safety of the vessel or of its crew.

When turbid water, such as from the Shannon or Humber (Anon., 1995) estuaries is ballasted the suspended sediments will accumulate on the floor of the ballast tanks. These accumulations are derived from many ports and unless they result in large volumes of mud are not normally removed following dry dock inspections every two to three years. There are however, chemicals which can aid in its removal but large accumulations may require a number of treatments. Removal of sediment is difficult and costly because these must be removed from confined spaces which are difficult to work within. Sediment accumulates in all ships ballast tanks but this is normally unevenly distributed, being deposited in the less dynamic regions of the tank cell spaces. An oxidised layer often covers the deoxygenated mud, indicating a poor sediment turnover. However during storm conditions this may become overturned with sediments which have accumulated from many ports becoming mixed.

Historical account of shipping activities in Bantry Bay

Bear Haven Naval Base

Prior to this century the small numbers of vessels visiting Bantry Bay would have carried little or no ballast water. Should exotic species have arrived during these times it would most probably have been as a fouling organism or as range expansions along coastal fronts. It was not until the times of regular transatlantic passage that vessels will have taken shelter here. (CARROLL) Leading up to the First World War the British developed a naval base in Bere Haven Sound, still these warships will have carried comparatively small amounts of ballast. But may have carried significant amounts of fouling on their hulls and some may have become established in the bay at that time. As many as fifteen of the Dreadnought classs could be anchored within Bera Haven Sound over prolonged periods. The sea-squirt *Phallusia mammilata* has an unusual distribution being found in Bantry Bay and Portland Harbour, Dorset, both naval bases at this time. These populations are a considerable distance north of the next known populations in NW Spain.

Flying boat terminal

Following the First World War flying boats used the shelter of Bantry Harbour behind the fortified Whiddy Island. Although these do not carry ballast it has been suggested that the appearance of the alga XXXXXXX in Britain may have been due to fragments being carried attached to the bouyage lines (Eno, 1996).

Whiddy Oil Terminal

The first oil tankers came to the Whiddy Island terminal in 196 . Large vessels imported oil and smaller local tankers carried this to smaller ports about the Irish coast, principally to Whitegate in Cork Harbour. The main risk of an introduction at this time was from fouling organisms, although ballast water from Cork Harbour will have been released at this time. However, the voulmes will have been small and much of the ballast will have been treated to remove oily wastes. Large oil tankers managed hull fouling by regular cleaning. In the 1970's this was achieved by using a robot designed by Wynne Industries Ltd. near Kinsale. The robot clamped to the ships hull and had contra-rotating scubbers which scoured the hull surface along defined tracks. Either wire or nylon scrubbers were used depending on the texture of the fouling. It is thought that the detatched debris will have fallen to the sea floor. The cleaning of vessels took place either while they were at anchor, in the centre of the bay between Bear Island and Whiddy Island, or while berthed at the oil terminal. In all cases the detatched materials, should they have fallen directly to the sea floor, will have fallen onto mud. Organisms falling onto this substrate are unlikely to survive. The vessels were cleaned when possible on a regular basis on their return from Kuwait, approximately every 35 days. The majority of the fouling according to Mr T. Balfe, who supervised these claening operations, was made up of filamentous green algae. Hull cleaning continued up until about 1976/77. Following the explosion of the *Betelgeuse* in January 1979 activities at this terminal were considerably reduced.

There is presently a single mooring bouy put in place in 1995 from which vessels will discharge or load oil at the Whiddy Island Terminal. No exotics are known to have become established in Bantry Bay as a result of activities at this terminal.

Export of stone aggregates from Leahill

Bulk carriers arriving in Bantry Bay to tranship aggrigates from Leahill will have ballast water on board to act as trim. Some arriving from continental Europe will have been obliqued to undergo ballast water exchange at sea before entering the bay and must make a declaration that this has been done. No exceptions to this rule have been recorded since exports began in 1992. Ships from the UK or elsewhere within Ireland are not requested to make such an exchange. In most cases some ballast water will be released within Bantry Bay, a portion of this will be discharged before berthing and it is possible during fine weather some may have discharged all ballast water before entering the bay.

Because the main shipping activities are associated with Leahill Quarry in Bantry Bay this area was examined in some detail in order to elucidate the relative risks posed by the introduction of unwanted species to Bantry Bay.

Living marine resources

Bantry Bay is a drowned river valley, 35km in length and 10km at its widest point. Soft sediments, often burrowed by *Nephrops norwegicus*, predominate in the central region of the bay. A number of ecological studied have been conducted by Guiry *et al.* (1973), Myers *et al.* (1997) and Baker *et al.* (1981). Populations within the bay have been regularly influenced by algal blooms (Cross & Southgate, 1980) and by some oil pollution events. Sublittoral investigations in the Bay include those by Willis (1975) on sea urchins and on the marine alga *Laminaria hyperborea* (Edwards, 1980). General studies within the bay were conducted by Grainger *et al.* (1980) following the explosion of the Betelgeuse which sank at Whiddy Island. The main studies on scallops were conducted by Gibson (1953; 1956), Baird and Gibson (1956) and Minchin (1992).

The introduction of exotic or other unwanted species to Bantry Bay have implications for the living resources within the bay. The species most likely to result in negative effects are dinoflagellates and diatoms. Already blooms of *Gyrodinium mikimotoi* (*Gyrodinium aureolum, G. nagasakiense*) have appeared on the south-west coast and have been recorded there since 1978. The first European record of this species was from Norway (Tangen, 1977) where they were found responsible for fish kills. Blooms of this species appeared for the first time in Ireland in July 1976 on the south-east coast (Ottway et al., 1979), there were fish kills at a farm in Dunmanus Bay in August and September 1978 (Leahy, 1980) and first appeared in Bantry Bay during the same summer (Cross & Southgate, 1980) the water can become viscous with gas bubbled trapped within it and visibility can be considerably reduced. During these blooms events sea urchins *Echinus esculentis* have been noted to drop their spines and small scallops *Pecten maximus* died. The appearance of this species in Bantry Bay has probably been as a result of population extension along coastal fronts. Although the species was first discovered in Atlantic North America in the 1950's (Hulburt, 1957) the species is generally recognised as being a Pacific species and it may have extended its range to the eastern North Atlantic in ballast water.

Presently the main aquaculture activity is mussel cultivation, made up of *Mytilus edulis* and probably *Mytilus galloprovincialis* and it is possible that hybrids of these two species exist. These are cultivated in the sheltered bays: Bantry Harbour, Glengarriff Harbour, Seal Bay and Bear Haven Sound (Fig.). The development of this industry followed the decline of activities at the Whiddy Island oil terminal and presently large expanses are under cultivation. This industry is compromised by diahorritic shellfish toxins caused by two dinoflagellates *Dinophycis acuminata* and *Dinophycis acuta*. Low levels of these species in the plankton can cause the mussels to become toxic causing acute diahorrea if eaten. The symptoms usually go away after some days. The occurrence of these species is monitored so that the marketing of the mussels can be regulated.

Some scallop sowing studies have taken place about Whiddy Island and in Bere Haven Sound, and scallops are held in suspension culture in Bantry Harbour. The earliest exploitation known is from about 1910, scallops were dredged from with Bantry Harbour. In the 1940's scallops were dredged by using a capstain and long anchor rope which was gradually wound in, following this the outboard motor was used and this lead to greater fishing pressures and by the 1960's most boats dreding had inboard motors. During the 1970's and 1980's progressively more beds were found and exploited. In the 1980's trials ranching scallops were performed with the intention of restocking the major beds where scallops grow rapidly and survive well. Young scallops for sowing are in short supply but when these become available this resource could expand.

During the 1960's the large populations of sea-urchin (*Paracentrotus lividus*) were exploited by diving and exported. The high quality and consequently high market price led to a significant decline of this resource. Recruitment of these urchins may be dependant on warm summers. Redevelopment of this resource by means of cultivation and ranching is under study.

Several species are fished using traps within the bay, these include lobsters, Nephrops, shrimp *Palaemon serratus*, velvet crab *Necora puber*, brown crab *Cancer pagurus*. These are fished about the periphery of the bay where there is broken rock in case of brown crab and lobsters, over soft mud for *Nephrops norwegicus* and in shallow water for shrimp and velvet crabs.

Salmon cultivation has taken place near Roancarrig, near Bear Island, since the early 1990's and smolts are reared on the south side of Bere Island during the summer period. Salmon are also cultivated near Gearies, south west of Whiddy Island. Other species likely to evolve culture practices include the turbot, presently grown in an onshore facility at Gearies.

Although Bantry was founded on a pilchard *(Sardina pilchardus)* fishery with several pilchard pallaces surrounding the main square. The pilchards do not presently make up landings because there are not sufficient numbers present. The changing abundance of pilchard on the south coast of Ireland probably relates to small changes in climate, there having been cycles of their abundance in former years (Minchin, 1993). Herring, however, do spawn over the gravels off Gearies and the returning herring have in past years formed a small drift net fishery.

In the region of Bear Haven Sound, near Lonehort Point, are deposits of the marine coralline algae *Phymatolithon calcareum* and *Lithothamnion corallioides*. There are other smaller deposits about the bay which are uneconomic to exploit. The Lonehort Point deposit was exploited for neuralising soils and as a fertilizer by a sailing dredger earlier this century. The neutralsing capability depended on the amount of carbonates present in the dredged samples. and for coralline sands these values were generally higher than for shell sands. The extracted deposits were heaped up beside the road to wash and dry out and some was distributed by rail inland from Bantry. The landings in 1947-48 were 71,000 tons and in 1959-60 50,000 tons (Anon, 1963). The extractions were subsidised at the time at three shillings and sixpence (£0.18) per ton with a maximum subsidy of 16 tons per person. The demise of the coralline extraction activities co-incided with the more widespread use of ground limestone which had a higher neutralising value. Until 1990 no further extractions took place. Extractions have taken place each year since then and special dried and milled products have been produced.

METHODS

Examination of records

Port records were provided by Shipman Ltd., Bantry, following discussions with Mr John Fleming of Wimpey-Fleming Quarries Ltd. Ships were listed according to net rate tonnage (NRT), dead weight cubic capacity (DWT), estimated ballast on arrival, last port of call, last location of ballasting, next destination, whether reballasting at sea took place and the duration in hours to deballast. Records were examined by year from 1992 to the end of June 1996.

The ports of vessels prior to their arrival in Bantry were grouped according to region, normally this was a bay or an estuary or group of closely associated ports. Ports were tabled according to Irish, British and other ports.

Estimation of ballast discharges

Ballast discharges were based on the mean volume of ballast water reported as ballast on arrival for all vessels for which data was available. From this the total volumes of water were scaled according to the size and number of vessels arriving at Leahill Quay by donor region. The time taken to deballast at Leahill was also examined as a possible means of identifying the amounts of ballast water discharged. Relationships between Net Rate Tonnage (NRT) and Dead Weight Cubic Capacity (DWCC) were derived.

RESULTS

Profile of vessels trading in Bantry Bay 1992-96

The last destination of ships entering Bantry from ports other than Ireland has been classified by region according to Figure 2 and those from Irish ports have been classified according to Figure 3. The main traffic patterns are from other Irish ports (Table 1), the majority of vessels coming from the Shannon (138), Cork Harbour (100) and Waterford (90) over the approximately four year period. The main ports in Britain are the Severn (31) and the Mersey (11) (Figure) and from overseas South Biscay (31), Brittany (8) and Marennes/Gironde (5) (Figure) although vessels range from Morocco (3) in the south to The Schelde (1) in the east. The most northerly port was on the Solway Firth (1). Vessels ranged from 250 to 7,800 mtNRT but the majority of these were 700 to 1,800mtNRT. The majority of ships visiting have done so only on one occasion over the four year period.

Records for the amount of ballast discharged by vessels into Bantry Bay are not routinely collected. However, there are some records of deballasting times and ballast volumes in arrival. Deballastings may take up to ten hours, the majority discharged ballast between two to eight hours. No clear relationship between the time taken to discharge ballast and the volume discharged was found (Figure). The amount of ballast declared on arrival for those vessels for which data was available also demonstrated high variability and did not appear to relate to vessel size. (Figure). A relationship between NRT and DWCC was derived from these values being available for the majority of vessels

Estimates of ballast released

The amount of traffic is about vessels per year. This represents based on estimates of ballast water discharges in the Bay a volume of cubic metres being discharged. The volume discharged from Cork Harbour is M3 and Belfast Lough is m3, both areas where PSP episodes have been recorded.

DISCUSSION

The vessels exporting aggrigates from Leahill in Bantry Bay are bulk-carriers. These are designed to carry large volumes of loose materials which can be rapidly loaded and unloaded. The low value of aggrigates will mean that the majority of ports for delivery will be in Britain and Ireland. Before loading in Bantry Bay these vessels will discharge ballast, from ballast tanks. The tanks used for ballast water on bulk carriers will include opposing pairs of upper and lower wing tanks, double bottom tanks, single fore and aft peak tanks and in addition cargo holds may also be used, normally hold 4 of larger vessels. The amount of ballast carried can range but usually approximates to about 20-25% in these vessels. When incorrectly ballasted vessels can have poor stability and develop bending stresses that could compromise the safety of the vessel particularly in large vessels. In all, the use of ballast water is an important feature of modern shipping. The volumes carried will be determined by the recommendations specified by the ships designers according to given weather conditions, sea states, season and ballast water density.

Relative volumes of ballast water discharged

The volumes of water discharged in Bantry Bay are small compared to some other European ports, being less than that for Sullom Voe, Scotland (, 19..). Should the records of ballast exchange at sea for those vessels from the continent be accurate the greatest risk of an introduction is that of free-living or cyst stages of *Alexandrium tamarense* in Cork Harbour. Introductions from Belfast Lough (est m3)also constitute a risk, but this is thought to be lower than for Cork Harbour (est m3)because the fewer arrivals from there.

Fate of discharged water in Bantry Bay

It is difficult to determine the fate of water discharged within Bantry Bay. However the recent understanding of water movements within the bay would suggest that the relative rsk of etbalishing new species is small because there is a residual flow passing through the bay, from the southern side into the bay and exiting on the northern side. This could mean that recruiment from introduced organisms is unlikely to take place in the same region and should it be succesful the developing adults would be well dispersed and perhaps out of range for successful synchony of gamete release and fusion. In addition to this there are large volume excahnges that take place during prolonged north-eatsterly winds. On these occasions shelf water displaces the residential water water within the bay.

Should cysts of dinoflagellates be released on ballast water discahrges it is likely that these will generally be dispersed over a wide area from the quay area over different depths. Recent information obtained on tri-butyl-tin contamination within the bay, based on the indicator organisms *Nucella lapillus* (Minchin & Minchin, 1997) also indicates a trend of a seaward dispersal of water from the Leahill site. The overall result is to have cysts widely distributed at different depths and conditions and unlikely to result in coinciding development from the cyst state. Nevertheless it is still not known what population size is required before a population can evolve.

The movement of *Alexandrium tamarense* cysts from distant ports forma threat to the mussel cultivation in Bantry Bay in particular. Nevertheless for the forgoing reasons such establishment is unlikely if the numbers of cysts that arrive are reduced in number.

Within Ireland *Alexandrium* species that may result in paralytic shellfish poisoning (PSP) exist in Cork Harbour and Connemara (Silke & Jackson, 1993) and Belfast Lough (Tylor *et al.*, 1995). Although blooms in thes eareas are not recorded every year there would appear to be coditions when these do bloom from time to time. It is not clear whether ballast uptake of the active stages could result in their subsequnt encystment on board and then discharge to other port regions. However the loading of viable cysts in ballasting in port during occaisons when there is much sediment turbulence are likely to result in the transport of this resting stage. Such cysts could innoculate a new region. For this reason the distribution of cysts in sediments, now known for Belfatst Lough, should be determined for Cork Harbour.. As cysts are likely to accumulate in areas of ifine sediment, blallasting should take place in regions where there are no fine sediments, where algal blooms are not known to occur, ausing water to become turbid could Tranfers from these ports during times of *Alexandrium* blooms

Means of further reducing risk from ballast water

By reducing the numbers of organisms in ballast water it is presumed that this also results in a reducion of the risk of generation new populations at the port of destination. This principle has been used as the basis for many of the IMO guidelines. Howevere the full extent of these guidelines can not be used in Irish waters for a number of reasons. The majority of ships arriving in Bantry come from Irish ports. Harmful species are known in Irish ports which are not known in Bantry Bay. The management of ballast water coming from these ports may be important for the integrity of the aquaculture industry in Bantry Bay. PSP events are known in Cork Harbour and also Belfast Lough, these ports are within a days journey from Bantry Bay and either free-living or cyst stages of *Alexandrium* could be transferred. Free-living stages could be loaded and innoculated into Bantry Bay during bloom events and cyst stage could be loaded from areas where there are fine sediments in the harbour at any time of the year but particularly when the water is turbid following storm or strong inundations of fresh-water.

Cork Harbour may be one of the most susceptible port areas in Ireland for receiving new species which may subsequently be transferred on to new localities about the coast. Thus the introduction prior to 1972 of the sea-squirt *Styela clava* to muddy estuaries elsewhere in Ireland is a real possibility. This may take place not in ballast but on the hulls of heavily fouled vessels. The possible introduction of *Phallusia mamillata* to Bantry Bay by British warships is a warning that tunicates, which have a short larval period, could become established in areas such as this. *Styela* is an important fouling organisms in harbours and estuaries in China, Korea and Japan and can also be found on longline culture offshore. It is generally believed that the spread of the Australasian barnacle *Elminius modestus* has been by coastal shipping and boating activities. This is a common species in estuarine areas and in the upper reaches of Cork Harbour is the dominant barnacle. This has also become spread to Bantry Bay and has been observed as being established ther by 1972? (Myers et al.). Thus the costruction of any large engineering works for the development in the oil industry have the ability of iinnoculating Bantry Bay and some cognisance of this should be taken into account.

Management of ballast in Bantry Bay

The volumes of ballast water discharged into Bantry Bay are small, and in terms of relative risk for Ireland this is low. However there are special measures for the management of ballast water by the Bantry Bay Harbour Authority requiring vessels from non-Irish ports exchange their ballast in advance of arriving in Bantry Bay. Vessels on arrival declare that this has been done (Appendix). This measure reduces the already small risk of the establishment of unwanted organisms in Bantry Bay.

<u>High risk donar ports</u>

Implimentation of the IMO guidelines

RECOMMENDATIONS

A risk, albeit small, of moving unwanted species to Bantry Bay exists with increased shipping traffic. The establishment of exotic species within this bay has taken place in the past and the general experience is that those areas which have received species in the past are likely to develop populations of other exotic species. The greatest known risk is the introduction of dinoflagellate species that cause paralytic shellfish poisoning elsewhere. The introductions of such species could result in restricted sales of shellfish within Bantry Bay. A precautionary approach to reduce unwanted introductions should consider the following measures:

Ships coming from Cork Harbour and Belfast Lough:

The main risk is from the importantion of dinoflagellate cysts of *Alexandrium* species. In Cork Harbour this is *Alexandrium tamarense*. This species blooms during the months of . Although cysts of this species are not known from this area, despite a recent study, these are likely to accumulate within the harbour in regions where there are fine sediments. The proposal is that:

1. Vessels should not take on ballast water in regions where there is turbid water or fine sediment deposits or where cysts are already known to exist. Preliminary zones have been defined based on information of sediments within these harbours. This zone may need to be refined using hydrographic models.

2. Ships should be advised when there is an *Alexandrium* bloom so that they can take on ballast water in areas where these blooms do not occur. This will normally be in regions where the water is not strongly coloured. The definition of these zones may require further refining, based on aerial photography and water movements. Normally during bloom events there are calm weather conditions and the possibility of reballasting outside of the harbour should be considered.

The exchange of ballast water en route to Bantry Bay, although it would reduce the potential impact of an innoculation in Bantry Bay could result in the release and dispersal of cysts which could survive and develop new populations between port areas. Cysts would be distributed over the continental shelf and could emerge at a future time. In addition the reballasting at frontal zones offshore could result in the transport of dinoflagellate species such as *Gyrodinium mikimotoi* into Bantry Bay should they form a bloom there which frequently happens during the summertime. The IMO Guidelines recommend normal ship ballast exchange to take place at sea over depths of 2000m+, no such depths can be found between Belfast Lough or Cork Harbour. There is insufficient information available to determine the viable innoculation size in order to develop a population. The preceding measures would be seen as being adaquate to considerably reduce transmissions.

Ships coming from Britain:

Ships on passage from Britain should avoid ballast water exchange in frontal areas where is likely to be a high density of algal species. Exchange of water in areas which have become stratified (during the summer months) offer a more suitable alternative.

Ships coming from the European continent:
Because of the presence of several toxic dinoflagellate species present on the coasts of Brittany and NW Spain and unexplained toxic events near the Gironde Estuary, the exchange of ballast water at sea is seen as an important measure in controlling the expansion of these species.

1. Ballasting of water should not take place in port areas where the water is either turbid or discoloured. Water should not be ballasted in port regions where there are known restrictions on the sale of shellfish because of harmful algal blooms.

2. Vessels coming from Brittany, the Bay of Biscay of to the south of this region will all have the opportunity of exchanging ballast water over depths of 2000m+. This should be done where possible.

3. Vessels unable to undergo a ballast exchange over depths of 2000m+

Conclusion

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Process of development of viable populations

- **Fouling organisms,** development may be similar to population expansion from an island community.
- Within physiological conditions for reproduction and subsequent survival
- Density on hull surface, the greater the density the greater the population size and the greater the effect of pheromones in the case of spawning synchrony.
- Mode of reproduction, i.e. barnacles must be closely associated for reproduction as this is internal, the duration of the viability of gametes following release for external fertilisation may be of limited vlue except in areas with little or no water movement.
- Spawning triggers
- successful gamete fusion
- Larval duration and dispersal
- Suitable settlement conditions
- Development of critical population densities
- Replacement or increase of numbers within the lifespan of the species
- Opportunistic events

No vertebrate fouling organisms known. Parasites and diseases of marine organisms may have been transferred in the past

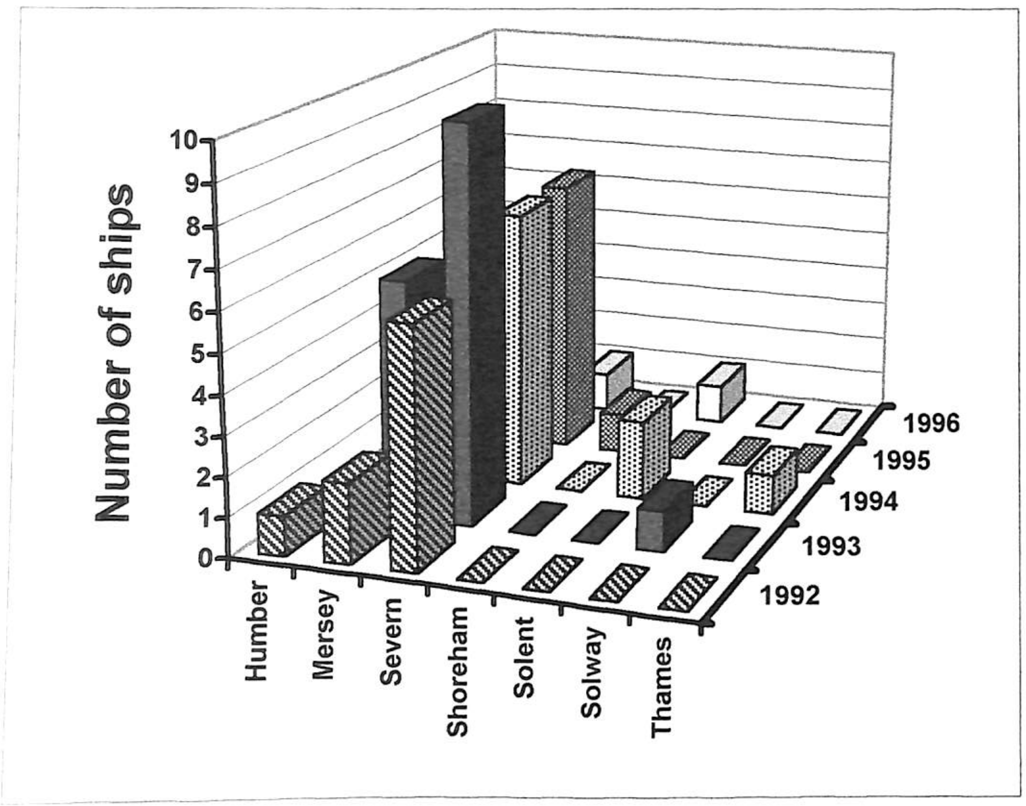
Elminius modestus	**Status:** Introduced species

This species was first recorde in Europe from the south coast of Britain following the Second World War. It has subsequently spread as a result of larval dispersal and marginal dispersal of fouled ships to new areas

Colpomenia peregrina **Status:** Introduced species

Phallusia mammilata **Status:** Cryptogenic species

Gyrodinium mikimotoi **Status:** Introduced species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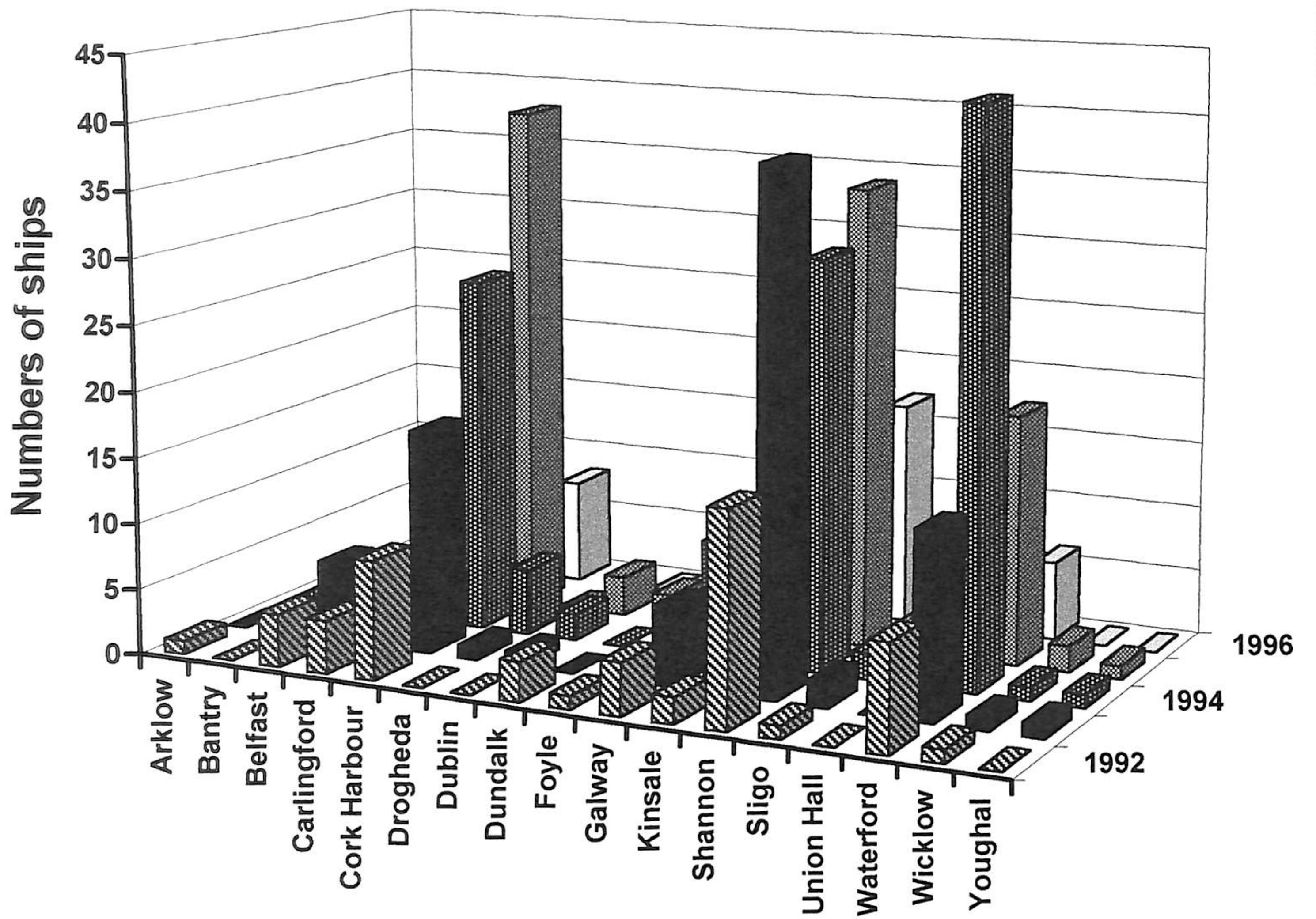
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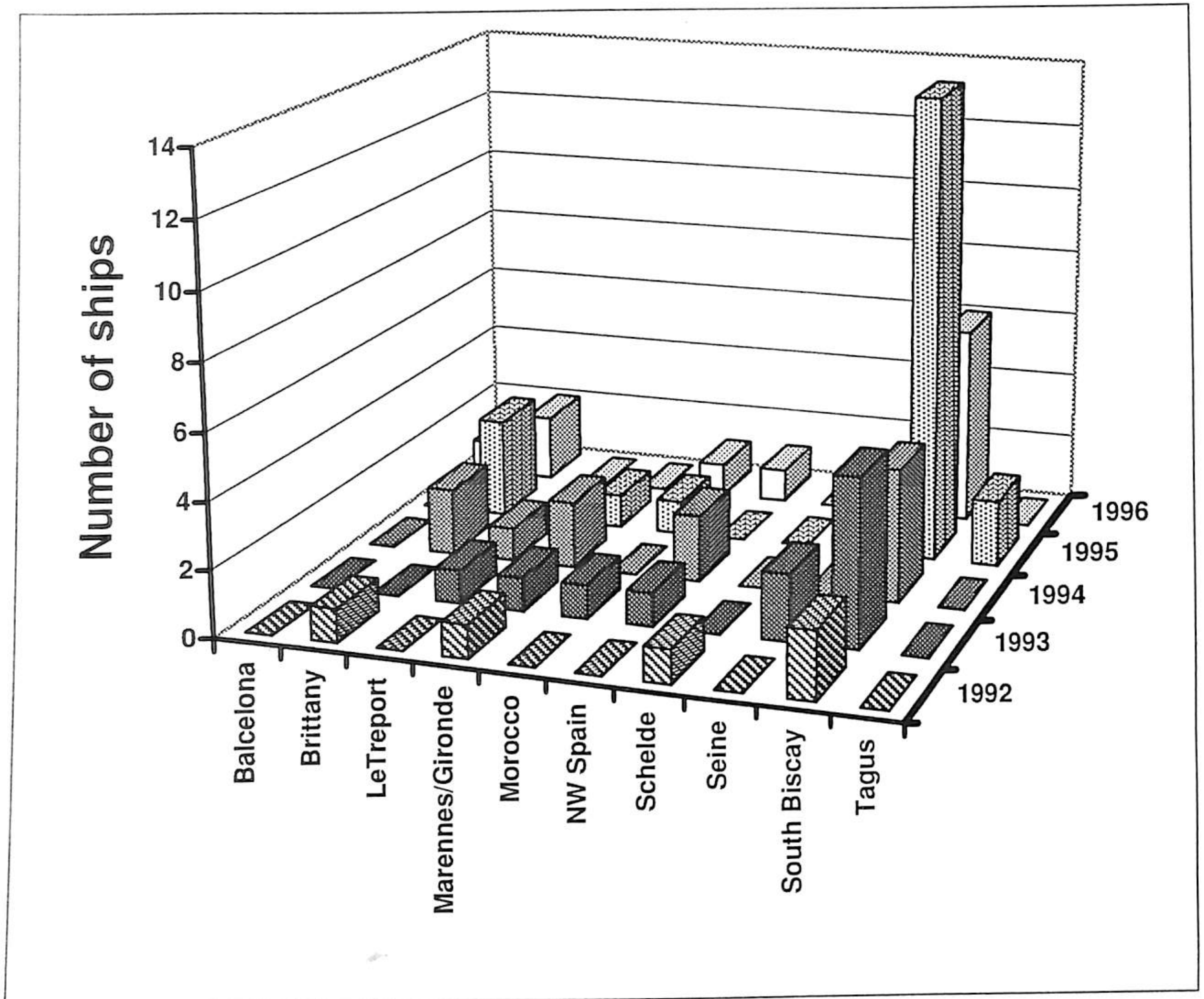
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Schelde
Seine
South Biscay
Tagus
1992
1993
1994
1995
1996