OPTIONS AVAILABLE FOR THE MANAGEMENT OF MARINE EXOTIC SPECIES

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Abstract

It is not possible to prevent the spread of exotic species with the extensive trade that exists throughout the world, as this would require a complete change to current trade that would be unacceptable to society. Although prevention is not possible, some practical measures, if undertaken, will certainly reduce overall risk. However, to reduce this risk involves a greater understanding of how each organism behaves while transported by different vectors. Their mode of life will determine how their subsequent spread evolves. The same vectors may be responsible for the transportation of either freshwater or marine organisms. To understand what measures may reduce overall risk requires extensive research before management can be effective. Trade facilitates the expansion of species at an apparently increasing rate. Unless establishment from primary movements can be prevented, greater efforts will be needed to prevent secondary populations from establishing and for this reason every effort should target prevention at the primary level. Unless an internationally researched investigation into exotic species management is undertaken we may expect to see more unexplained events, with serious losses to aquaculture and fisheries and impacts on human health. A scientific forum of experts exists worldwide to undertake the needed work to find practical solutions but the funding is presently inadequate or unavailable.

Introduction

We do not have a good understanding of the exotic species component because of the extensive historic expeditions that took place before the development of taxonomic studies. Nevertheless some species may be clearly distinguishable as being either native or exotic. It is likely that many fouling species have become well distributed by these early vessels to many distant regions.

Unfortunately, due to events of these earlier times, exotic species have penetrated new frontiers and are continually spreading by a series of secondary movements. Prevention of their expansion at this stage may not be possible in every case. However, targeting the vectors responsible for the carriage of the wide diversity of species, at the primary level of introduction, could be a likely and effective way of reducing risk.

The Main Vectors

Ships ballast water

Most of the world trade depends on shipping. For ships to travel safely they must maintain a correct immersion level by either carrying cargo, ballast water or both. The amount of ballast water carried can be 30% of the overall weight of the ship. Within the ballast water, or the accumulating sediments, are a wide range of species that can become transported (Carlton & Geller, 1993). There are several ballast tanks on a ship and their number and distribution depend on the type of vessel. Each of these tanks can contain a mixture of water from different ports and so carry different combinations of suites of species. Pumping these large volumes of water when undergoing ballast water exchanges at sea, as recommended by the International Maritime Organisation (1996), is time consuming and costly. The tanks cannot be fully drained, some water remains and so three 'complete' exchanges are recommended. Conditions at sea can result in no exchanges taking place because uneven distributions of ballast water in the tanks can compromise the structural integrity of the ship. In the absence of fully proven sterilisation techniques the mid-ocean exchange is the only 'preventive' approach being regularly employed and is probably most effective when freshwater is exchanged for sea-water or vice versa (Table 1).

Table 1. Shipping: mechanisms that promote and prevent exotic introductions

Mechanisms that promote exotic introductions

- Many ports are moving further downstream to more marine conditions and so there is better port matching and have increased opportunities for species to become established.
- Faster ships are in service with the result that greater numbers of individuals in ballast water may survive.
- Larger vessels are in service with greater ballast volumes and larger hull surface areas and so larger potential inocula.
- Greater frequency of port visits with more rapid turnaround times provide more occasions of ballast water release and opportunities for hull organisms to spawn.
- Hull surfaces where the hull rests on blocks in dry dock escape antifoul painting.
- Cleaning of hull surfaces using underwater robots may allow sufficient numbers of detached biota to survive and become established.
- Improved controls on toxic emissions in port regions make the environment more suitable to colonise.

Preventive measures

- IMO guidelines employed for mid-ocean ballast exchanges reduce the power of a potential inoculum.

  However:
  - Exchanges not be undertaken under poor sea conditions for safety reasons
  - Only effective in the control of a primary inoculation
  - In many cases shipping routes do not enable ballast exchanges
  - Full compliance of mid-ocean exchanges are unlikely
- Toxic antifouling paints such as TBT appear to reduce fouling biomass.

  However:
  - It is due to be discontinued
  - In warm seas its effective life is reduced.
- Sterilisation methods for treating ballast water are needed; this urgently requires further research by internationally accredited scientists.
- Port profiles to evaluate current and future shipping routes, likely ballast water sources, exotic species established locally, hydrography of the port region and the other potential vectors for transmission in the port region, need to be undertaken.
- Port management procedures by considering each port as a donor of unwanted species, identify the likely critical periods of transmission for each harmful exotic present and scenarios that may lead to a donation and evaluate a means for reducing the power of receiving or donating a ballast water inoculum.
- Removal of fouling by underwater robots should be undertaken where their survival, once removed, is unlikely, such as over anoxic regions.
- Co-operation by all user groups in port regions is required for effective management.

Ships hull fouling

Ships while in dry-dock are supported on wooden blocks, the regions beneath these blocks are not painted and so fouling may freely develop once the ship is returned to service. Despite the use of tri-butyltin (TBT) many vessels approaching their docking time can have mature fouling on their hulls. This fouling can include mature molluscs with the potential to transmit diseases. Visits by vessels to ports may allow many of the fouling organisms to spawn, even if the vessel remains for only some hours. The spawning event may leave behind a sufficient number of zygotes to create a founder population. Because of unwanted effects to native biota, aquaculture and fisheries in port regions, it is planned to ban the use of TBT in antifouling coatings by 2008. The new generation of antifouling agents will need to be as effective, or more effective than TBT, if it is to reduce fouling (Table 1).

Aquaculture

Some exotic species provide economic opportunities whilst others can impose serious financial loss and unemployment. In the marine environment few exotic species are in cultivation and it is likely that exotics will contribute to future production. Those species tolerant of handling and wide ranges of temperature and salinity, which may be easily manipulated to produce their young and maintained at high densities, are likely to be favoured. However, further introductions could provide access for unwanted and harmful pests, parasites and diseases that may even cancel out the benefits of future production. The International Council for the Exploration of the Sea's (1995) code of practice on introductions and transfers of marine organisms provides a procedure whereby the risks of introducing species can be considerably reduced (Table 2). The introduction of species, using this code, can take some years before its release from quarantine but will result in a disease and parasite-free stock. Whereas unregulated movements of shrimp and oyster broodstock have resulted in a widespread dispersal of viruses, bacteria, protozoa and fungi with subsequent serious declines in production.

Table 2. Aquaculture: mechanisms that prevent and promote the introduction of exotics

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Mechanisms that promote introductions

- Species are normally cultivated at high densities for economic reasons and so are susceptible to pests, parasites and diseases; this will include exotic species.
- Some species in culture are regularly moved to different areas for fattening or for completion of their production cycle, thus enabling transfer of exotic species to new regions.
- Epizootics in culture often emerge as a result of close contact with infected individuals - some of these can be new to science.
- Broodstock may be introduced, without quarantine measures, to invigorate existing stocks.
- Alternative species may be brought from abroad in bulk to replace a species in culture whose production has declined.
- Overlapping vectors: aquaculture may be sited in a shipping port region.

Preventive measures:

- The ICES Code of Practice, when employed, considerably reduces the risk of unwanted introductions.
- On shore tank/raceway cultivation of species, will permit better control of fish health and reduce impact of diseases including exotic species and problems arising from toxic blooms.
- If possible conduct production cycle in one region.
- Separate, where possible, shipping and aquaculture activities.
- Test native species before considering an introduced species for culture.

Should a large industry decline following a serious disease outbreak for example, an exotic species may be imported directly. The politics of such a situation may determine that the precautionary approach is not applied, for reasons of having to rapidly restore production levels. Such moves inevitably lead to an introduction of unwanted species, some of which may reduce future production and opportunities for the cultivation of other species. Should a quarantine facility not be available for the production of disease-free seed, the use of such a facility in a donor country should be considered.

The use of shore-based raceways and ponds for species with intensive feeding regimes allows more effective control of the environment and may even reduce the impact of toxic algal blooms, stinging gelatinous zooplankton and pests, parasites and diseases.

Trade

Agreements involving trade do not normally take into account those associated organisms that may extend their ranges as a result of the trading activity (Table 3). This is because should there be restrictions on the product the trade may not evolve. In an attempt to overcome this difficulty veterinarians may classify a series of known diseases that may be moved, and restrict trade for the most serious of these diseases. Unfortunately some diseases, listed at a low level of priority, now can become transferred to areas where they did not previous exist. In addition diseases that have yet to be described do not get sufficient attention until they have been spread. Dealing with pests as well as diseases seems to be an additional set of criteria that could compromise the trade activity itself and often appears to receive little or no attention.

Table 3. Trade: mechanisms that prevent and promote the introduction of exotics

Mechanisms that promote introductions

- Trade agreements do not normally take into account biogeographical considerations and the distribution of unwanted exotic species.
- Agreements between trading partners may classify diseases of species according to their perceived virulence, allowing transfers of some and not others. These normally pertain to diseases and parasites and seldom take into account pests.
- In areas where production may be discontinued because of the presence of toxic algal blooms, consignments from elsewhere may be used to fulfil orders. These may be moved great distances and may result in new organism releases to the wild.
- Thawing of frozen products may allow viruses or other pathogens to new regions.
- Packing materials may contain exotic organisms that may become released to the wild elsewhere, such as seaweed.
- Live bait used for angling/fishing may be released to cause new range extensions.
- Aquarium species may be deliberately/accidentally released to the wild.
- Consignments intended as food may be placed in the sea to improve their condition and/or increase their survival.

Preventive measures:

- Living organisms should be obviously labelled if they are not to be replaced in the sea. Should traded animals, intended as live food require to be revived in sea water, should have their wastes and water appropriately disposed of.
- The ICES code of practice includes measures to suspend trade when unwanted species are found, until new measures acceptably reduce the risk.
- Involve public partnership in the responsibility of managing problems, to reduce risk and prevent range expansions, by means of information campaigns.
- Do not use organic packing materials, i.e. seaweed.
- Wastes from production plants, that may include those of imported animals, should be appropriately treated.
- Be aware of new risks with new trading links in advance of the trade.

The trade in live species, and in particular the trade of half-grown oysters, continues to result in range expansions of molluscan pests and diseases (Minchin, 1996). Because oysters survive under cool damp conditions for several days, large consignments are easily transported long distances. They provide habitats for attaching, cryptic and boring species. Bower *et al*, (1992) have reviewed many harmful organisms of shellfish that may be transferred.

Aquarium species are a likely means for the spread of diseases. Fish prior to their departure are often held at high densities before being widely distributed. Releases of fishes to the wild are probably frequent events in freshwater but may be rarer in the sea. The spread of epizootic ulcerative syndrome from the Indian Ocean, where fish production has declined, with movements of aquarium species to other regions of the world is a serious and likely risk that presently needs preventive measures.

Vulnerable regions

Areas that have received exotic species in the past are likely to have further introductions. Shipping is generally considered to be the most powerful vector of wide suites of species and so these areas are likely to be found around ports. Nevertheless, some ports do not appear to succour many exotic species. Ports' susceptibility consists of a wide range of variables that are not fully known and difficult to quantify, although partly enclosed bays and estuaries with a low tidal amplitude would appear to receive a wide range of exotic species.

Many marine habitats have been modified either from inputs of nutrients, waste materials or due to depletions of biota and habitat changes. Ports modified in this way may be prone to receiving exotics. Presently many port regions have a high level of contamination from tri-butyl-tin (TBT) which may render them less accessible for exotics. However, the current remediation of port areas, following tighter controls on discharges, together with the planned banning of TBT by 2008, will make these regions less toxic and so perhaps more easily invaded. Some of these future invasions may have serious consequences for human society.

Mode of life

The dispersal of a species from its point of introduction and the speed at which it expands its range will depend on the behaviour of its life history stages. Species without planktonic stages and with limited mobility are likely to remain close to the site of introduction, unless carried elsewhere by other means. Whereas buoyant species may be carried by combinations of wind and current speeds and dispersed in directions determined by the principle vectors. Most species have dispersal potentials that lie between these extremes. Some crustaceans and fishes may become distributed over a wide range as a result of their own activities. With a better knowledge of the behaviour of organisms during their life history stages and of the physical vectors from a point of release, theoretical models of dispersal should be possible. Such models would be valuable tools for port management of ships ballast water and for evaluating relative risk scenarios of transmitting or receiving exotic species.

The distribution of an exotic species in a port region may be limited by its mode of life and by various coastline features. Collectively therefore, exotic species may remain confined to an 'exotic species cell' and unless carried elsewhere are likely to remain. Management of species within these 'cells' may be possible; their spread to adjacent 'cells' may be managed by controlling the likely vectors that may transmit them elsewhere. The shape and extent of these 'cells' will most probably depend on the extent of the residual drift, local hydrography and topography.

Overlapping vectors

Many shipping ports are situated close to aquaculture activities for reasons of shelter and a nearby market. The proximity of shipping to aquaculture activities poses the unquantifiable threat that some imported organism will impair survival, compromise growth, or render the cultivated product unmarketable. Ballasting by ships in ports, for example, may result in loading untreated discharges of human sewage and bacteria, such as Vibrio cholerae, and may enter the food chain in distant ports through nearby aquaculture activities. Also of concern are the discovery of new algal toxins associated with phytoplankton and their apparent spread throughout the world. There is good evidence that ballast water may be distributing these organisms (Carlton & Geller, 1993).

Small vessels such as yachts and motor boats may develop fouling of their hulls that may include established exotics in marinas in port areas. Once these leave the port region the hull fouling species may become spread to small inlets and lagoons, areas where ships do not normally trade.

In ports vectors are likely to overlap because many people normally live in these regions and engage in a wide range of activities. Untangling the regions where these vectors overlap may be socially unacceptable although it may be possible to undertake some compromise measures to reduce the overall risk. For example aquaculture and marinas being moved to different sections of the coastline may reduce or prevent the spread of species established in ports. For many species, the dilution of water may be sufficient to reduce the overall probability of an inoculum becoming established. Should this be the case, shipping may reduce the impact of a potential inoculum by extending their ballast water discharge trails on entry to a port.

Conclusion

Primary inoculations should be prevented where possible because the subsequent control of the species will involve a wide range of vectors requiring more resources to manage, if indeed this is possible. Proactive management in coastal zone planning by reducing the level of overlap of different vectors may reduce the rate at which a species may spread once established. The undertaking of port profiles for managing specific regions may greatly enhance the understanding of what species are likely to be transmitted from a port and by considering each port as a donor region may greatly assist in the management of exotic species worldwide. In the case of the movement of useful species the precautionary approach adopted in the ICES code of practice is recommended. The involvement of the public as a responsible partner in the management of exotic species is likely to reduce management costs due to earlier detections of unwanted species. However, this approach requires provision of an up-to-date supply of information by state agencies.

References

Bower, S.M., McGladdery, S.E. & Price, I.M., 1994. Synopsis of infectious diseases and parasites of commercially exploited shellfish. *Annals and Review, Fisheries Diseases*, 4: 1-199.

Carlton, J.T. & Geller, J.B., 1993. Ecological roulette: the global transport of nonindigenous marine organisms. *Science* 261: 78-82.

International Council for the Exploration of the Sea, 1995*. ICES Code of Practice on the Introductions and Transfers of Marine Organisms, 1994.* International Council for the Exploration of the Sea, Copenhagen, Denmark, 12pp.

International Maritime Organization, 1996. Unwanted Aquatic Organisms in Ballast Water: Guidelines or the Implementation of Annex VI of MARPOL 73/78 to minimize the introduction of unwanted aquatic organisms and pathogens from ships' ballast water and sediment discharges. *Marine Environmental Protection Committee* 38/13/1, 3 April 1996.

Minchin, D., 1996. Management of the introduction and transfer of marine molluscs*. Aquatic Conservation: Marine and Freshwater Ecosystems*, 6: 229-224.