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Ship Ballast Tanks: How Microbes Travel The World

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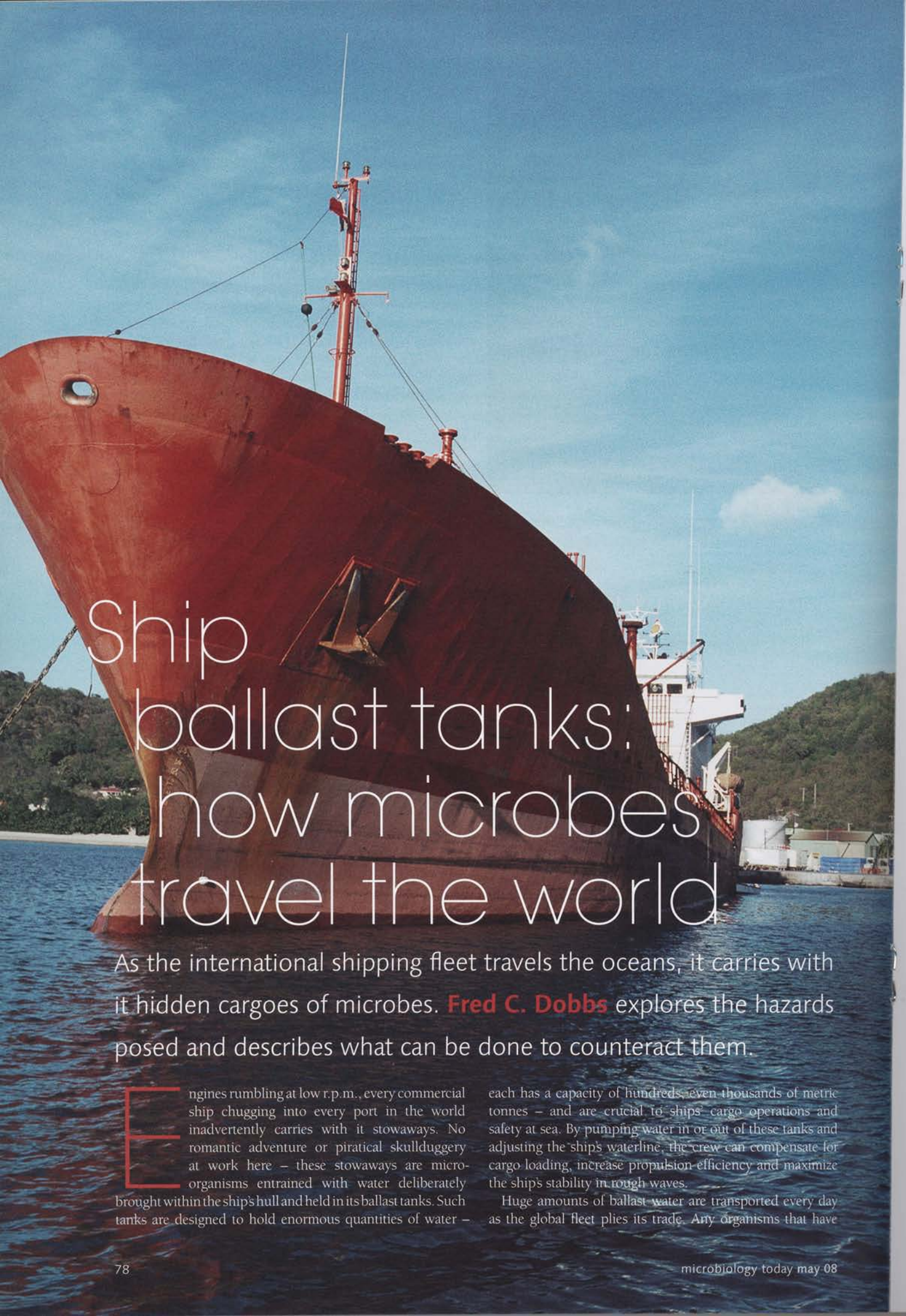


Ship ballast tanks: how microbes travel the world

As the international shipping fleet travels the oceans, it carries with it hidden cargoes of microbes. **Fred C. Dobbs** explores the hazards posed and describes what can be done to counteract them.

Engines rumbling at low r.p.m., every commercial ship chugging into every port in the world inadvertently carries with it stowaways. No romantic adventure or piratical skullduggery at work here – these stowaways are micro-organisms entrained with water deliberately brought within the ship's hull and held in its ballast tanks. Such tanks are designed to hold enormous quantities of water – each has a capacity of hundreds, even thousands of metric tonnes – and are crucial to ships' cargo operations and safety at sea. By pumping water in or out of these tanks and adjusting the ship's waterline, the crew can compensate for cargo loading, increase propulsion efficiency and maximize the ship's stability in rough waves.

Huge amounts of ballast water are transported every day as the global fleet plies its trade. Any organisms that have

◀ A cargo ship in port at Gustavia, St Barts, West Indies. *Photos.com / Jupiter Images*

▶ Scientists sampling residual water inside a ship's emptied ballast tank. *Fred C. Dobbs / Old Dominion University*

survived since 'coming on board' are liable to be released when ballast water is next discharged. Unfortunately, we know all too well that many non-native (also called 'non-indigenous') invertebrates and plants have been introduced to new environments in this manner. Some of these introduced species proliferate, their populations released from control by predators, parasites or other factors. When they out-compete and deleteriously affect native organisms, we further classify them as 'invasive species'. In some spectacular cases, such as the zebra mussel in North America and the comb jelly in the Black Sea, invertebrates introduced by ballast water have fundamentally altered the ecosystem to which they were delivered. Such drastic ecological changes have also precipitated significant economic expenditures, e.g. to remove attached zebra mussels from industrial water-cooling systems, and in the Black Sea, wholesale collapse of fisheries.

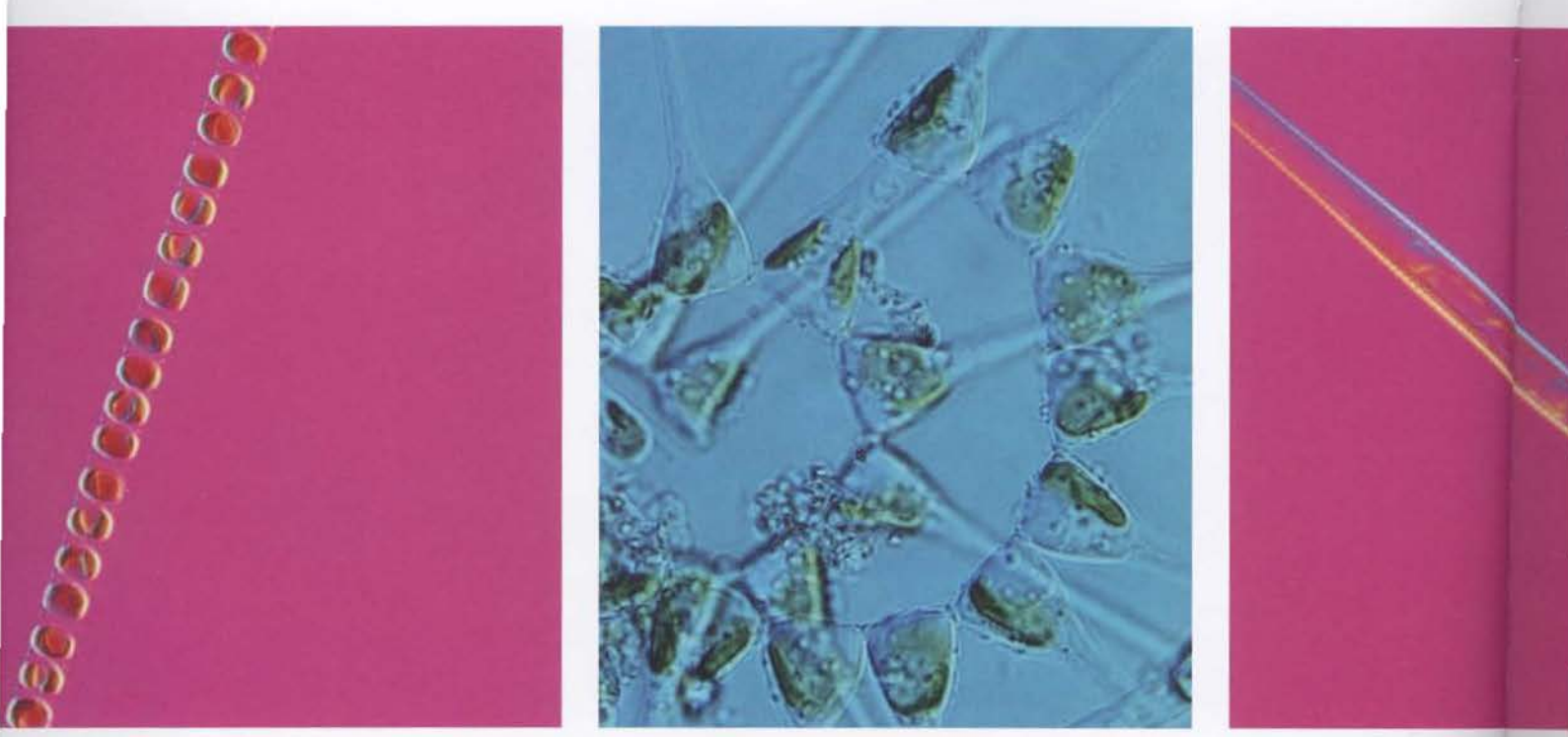
In a parallel sense, are there inimical consequences to transporting and disseminating aquatic micro-organisms in ships' ballast tanks? We are certain only that scenarios envisioned by some have been sufficiently of concern to promulgate regulations concerning ships' handling of ballast water. What are those scenarios and how have they contributed to regulations facing global shipping?

Micro-organisms in ballast water – can they be 'non-indigenous'?

For more than 20 years, scientists have reported a variety of large, easily recognized phytoplankton (e.g. dinoflagellates and diatoms) and protozoa (e.g. ciliates and foraminifera) in ballast water. On the other hand, the diversity of smaller, less readily discerned forms, especially bacteria and viruses, is nearly unknown. We do know something, however, about their abundance. In lakes and oceans, every millilitre of surface water contains about 10^2 protists, 10^6 bacteria, and between 10^7 and 10^9 viruses. It is inevitable, therefore, that hundreds of trillions of micro-organisms enter a single ship's ballast tanks during normal operations.

Although the overwhelming majority of these aquatic micro-organisms is not harmful to humans, some species in ballast water do indeed represent potential risks to public health, notably pathogenic bacteria such as *Vibrio cholerae*, the aetiologic agent of human cholera, and dinoflagellates, some species of which are responsible for harmful 'red tides'. Other pathogens and faecal-indicator micro-organisms reported from ballast tanks include: enteroviruses, *Escherichia coli*, enterococci, *Cryptosporidium parvum* and *Giardia duodenalis*. Reported harmful algae species include: *Pfiesteria piscicida*, *P. shumwayae*, *Aureococcus anophagefferens*, *Microcystis* spp. and *Anabaena* spp. While to the best of our knowledge, no outbreaks of disease have been associated with ships' ballasting activities, it is only on very, very rare occasions that ballast tanks are sampled for their microbiological inventories.

Are there microbes discharged with ballast water that could be classified as non-indigenous species? The answer is not as clear as it is for invertebrates, and microbial ecologists debate the biogeographic distribution of microbes. Some argue free-living bacteria and protists must be distributed worldwide, simply because their small size facilitates their dispersal. If micro-organisms indeed are ubiquitous in their distribution, then they cannot be considered to be non-indigenous. Another school of thought disagrees and contends some microbes clearly do have a biogeography. Many examples support this contention, among them inter-oceanic transfers of marine phytoplankton species. The English Channel and coastal European seas, for example, have in the past century experienced introductions

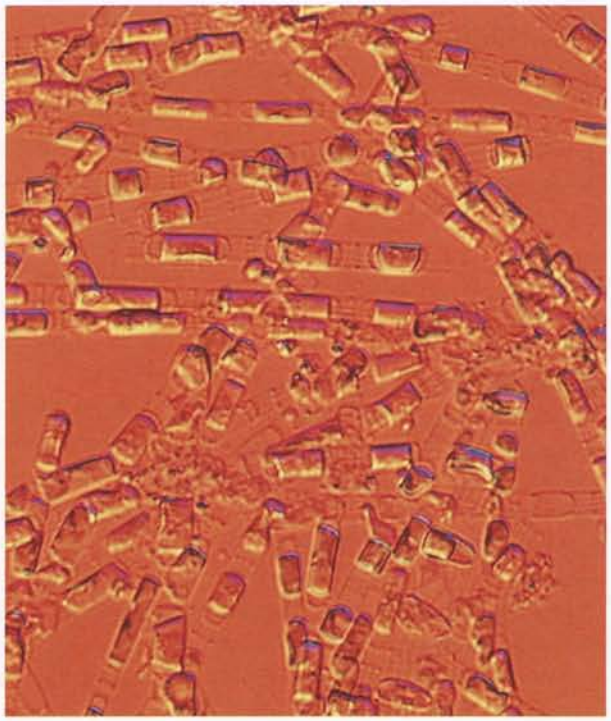


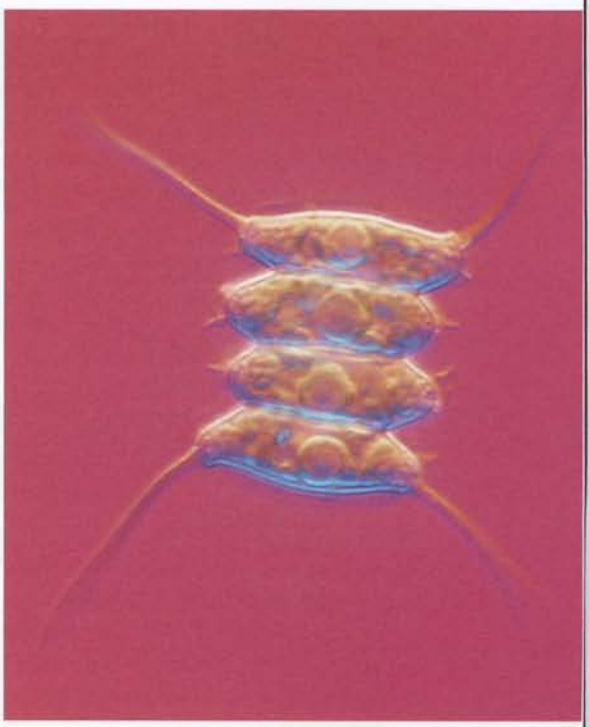
▲ A range of phytoplankton such as those found in ship ballast water. From left to right: unidentified chain-forming centric diatom; *Asterionellopsis glacialis* (diatom); unidentified pennate diatom; *Skeletonema costatum* (diatom); *Scenedesmus* sp. (colonial green alga). *Lisa A. Drake / United States Coast Guard Academy*

of two diatom species, *Odontella sinensis* and *Coscinodiscus waelesii*, phytoplankton previously known from the East China Sea and North Pacific coasts, respectively. If the second group of scientists is correct, then aquatic micro-organisms can be non-indigenous, are therefore potentially invasive, and their presence in ballast water is indeed of concern.

Regulations and technological solutions

While microbial ecologists have not resolved the biogeography argument, many government and international agencies have, in a sense, already decided for themselves. Consider microbiological mandates proposed by the International Maritime Organization (IMO), which sets rules and standards for the global shipping industry. The IMO has issued an 'International Convention for the Control and Management of Ships' Ballast Water and Sediments', now being considered for ratification by its member states. It reads in part: '*Ships conducting ballast water management shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 µm in minimum dimension and less than 10 viable organisms per ml less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension...*' Numerous species of aquatic micro-organisms, notably fresh- and saltwater phytoplankton and protozoa, fall into these size-predicated limits, particularly the smaller one. While the IMO Convention has no specific call-outs for total numbers of bacteria, it does stipulate maximum concentrations for *V. cholerae*, *E. coli* and intestinal enterococci.





In the United States, there are no similar federal regulations and in their absence, several states are enacting their own. California, for example, has issued standards for discharged ballast water that call for orders-of-magnitude reduction in total bacteria and total virus numbers relative to their natural concentrations.

How will ships reduce the number of micro-organisms discharged with their ballast water? The past decade has seen a flurry of technological development in this regard, and a cornucopia of techniques has been tested in the laboratory and in full-scale, land-based installations. In a few cases, treatment units have already been installed on ships. Proposed technologies range widely in their mechanisms, from filtration to biocides, ultrasound to ultraviolet irradiation, and more. It is imperative, of course, that the treatment does not corrode the steel ballast tanks, and furthermore, it must yield water that meets any chemical discharge standards for harbours. What a challenge it will be for technologies to effect such low numbers of micro-organisms in enormous volumes of discharged ballast water! And what an equally daunting challenge for scientists to measure those numbers accurately!

Playing Johnny Appleseed?

There is a folk legend in the US about a character named Johnny Appleseed, who, as he roamed the mid-western portions of the country in the first half of the 19th century, sprinkled apple seeds wherever he went. The result – apple trees proliferated and the region was characterized by an abundance of orchards. Are we playing Johnny Appleseed with aquatic micro-organisms as global shipping inadvertently spreads them around the world in discharged ballast water? And if so, need we be concerned that some of those microbes are harmful? Certainly these questions are ones of considerable interest to microbial ecologists, but given the context, are pertinent to water-quality managers and regulatory agencies as well. Our understanding of the issues involved will increase as additional and more sophisticated studies are performed, especially those employing the tools of modern molecular biology.

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Further reading

Dobbs, F.C. & Rogerson, A. (2005). Ridding ships' ballast water of micro-organisms. *Environ Sci Technol* 39, 259A–264A.

Ruiz, G.M. & others (2000). Global spread of micro-organisms by ships. *Nature* 408, 49–50.

www.europe-aliens.org/index.jsp DAISIE – Delivering Alien Invasive Species Inventories for Europe. Inventories of alien species in Europe, many of which represent ballast-water introductions.

www.imo.org/home.asp – International Maritime Organization