

Possible Effects of Climate Change on the Spread of Invasive Marine Species and Implications for Maritime Industries

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Abstract

Global climate change stands to have major implications for maritime industries, including fisheries and aquaculture, recreation and tourism, and shipping and ports. Amongst these implications are the possible effects of climate change on the dispersal and distribution of marine species, as environmental conditions in the world's seas and oceans change with climate change. This paper explores, in an introductory manner only, the potential impacts of climate change on marine bio-invasions, the possible effect of these impacts on maritime industries, and the possible implications for the way that we manage these industries, including ship's ballast water and sediments and hull fouling, to prevent and reduce marine bio-invasions. The paper presents the case for the inclusion of this topic on the programme of 1st International Conference on the Impacts of Climate Change on Maritime Industries (ICCMi 2008), planned to be held in Malmö, Sweden in June 2008, where international experts in the science of climate change and marine bio-invasions might present more detailed scientific and technical papers on the issue.

Key words: Climate Change, Maritime Industries, Fisheries and Aquaculture, Recreation and Tourism, Shipping, Invasive Marine Species, Marine Bio-invasions, Hull Fouling, Ballast Water

1 Introductory Note

As part of the preparations for the 1st International Conference on the Impacts of Climate Change on Maritime Industries (ICCMi 2008), planned to be held in Malmö, Sweden in June 2008, this paper is not intended as a technical treatment of the issue of the topic of the *Possible Effects of Climate Change on the Spread of Invasive Marine Species & Implications for Maritime Industries*. Rather, it is simply intended to present the case for the inclusion of this topic in the programme of ICCMi 2008, where international experts in the science of climate change and biological invasions might present more detailed scientific and technical papers on the issue.

This paper is therefore written in narrative form and only introduces general concepts, identifies major themes and asks more questions than it answers, in relation

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to the topic at hand. It is hoped that these issues and questions will be explored in more detail by those more qualified than I at ICCMI 2008.

2 The Natural Dispersal of Species

Over the past millennia, marine species have dispersed throughout the oceans by natural means, carried by currents, ocean surface winds and attached to floating logs and debris. Natural barriers, such as temperature and salinity regimes and land-masses, have prevented many species from dispersing into certain areas. This has resulted in the natural patterns of biogeography observed in the oceans today.

In particular, the environmental barrier presented by the pan-global tropical zone has separated the northern and southern temperate and cold-water zones. This has allowed many species to evolve quite independently in these latter zones, resulting in quite different marine biodiversity between the north and the south.

In tropical areas marine species have not faced the same barriers. This is exemplified by the relatively homogenous marine biodiversity spanning the huge area of the Indo-Pacific, from the east coast of Africa to the west coast of South America.

As ocean currents, climatic conditions and other environmental conditions change over geological time, and as species evolve, the natural patterns of dispersal and the resulting patterns of biogeography and bi-diversity also change, as part of a larger, ever-changing global eco-system.

3 The Influence of Humans – Biological Invasions

Humans have aided the process of species dispersal for as long as they have sailed across the seas. Historically, this has mainly been through the attachment of marine species to the hulls of vessels (hull fouling). Over time, maritime activities via which species can be transferred to new areas have continued to expand. In modern times these include:

- canal developments (e.g. the Suez Canal),
- the movement of large marine structures such as drilling platforms and floating-docks,
- marine organisms attached to floating marine debris,
- the escape or release of species from private and public aquaria,
- intentional and accidental introductions for fisheries and aquaculture purposes; and
- commercial shipping (ballast water and hull fouling).

Over the last decade, marine biological introductions via these human-induced vectors have become recognized as a major environmental concern. When species that are introduced to new areas become invasive, they can cause significant ecological, economic and/or public health impacts. The literature is rich with case examples: In the USA, the European Zebra Mussel *Dreissena polymorpha* has infested over 40% of

internal waterways and is a major problem for industry, fouling all available hard surfaces, including cooling water intake pipes. In southern Australia, New Zealand and the Mediterranean, the Asian kelp *Undaria pinnatifida* is invading new areas rapidly, displacing the native seabed communities. In the Black Sea, the filter-feeding North American comb-jelly *Mnemiopsis leidyi* has on occasion reached densities of 1kg of biomass per m². It has depleted native plankton stocks to such an extent that it has contributed to the collapse of entire Black Sea commercial fisheries in the 1980s and 90s. Species of planktonic algae that are capable of forming Harmful Algae Blooms (HABs), are believed to have been introduced to new areas in ships' ballast water, sometimes forming HABs, causing fish kills, fouling beaches and and/or contaminating shell-fish eaten by humans – and in turn causing illness and death through poisoning. The list goes on, hundreds of examples of severe aquatic bio-invasions across the globe.

4 Climate Change as a Vector

In addition to the vectors listed above, human-induced climate change is now being identified as a factor affecting biological invasions. Global climate change will certainly affect oceanographic conditions, which will in turn affect the dispersal of marine species, causing changes in their distribution.

Examples of such changes are already being reported, including the discovery of increasing numbers of warm-water marine species in areas such as Scilly Islands and the South West coast of the United Kingdom, and the tropicalisation of Mediterranean marine flora and fauna, as mean annual water temperatures are reported to rise (the latter also relates to tropical species entering the Mediterranean from the Red Sea via the Suez Canal).

The addition of another human-induced factor which alters the dispersal of species – global climate change – undoubtedly raises a plethora of issues that need to be explored. These include the possible affects of climate change on the natural dispersal of species, including the potential for new bio-invasions, the possible effects of climate change on expanding and/or reducing the range of existing bio-invasions, and implications of climate change for the way we manage the other vectors of invasive species, including ships' ballast water and sediments.

5 The Possible Effects of Climate Change on Biological Invasions

There are numerous studies and models that assess the possible effects that global climate change will have on the world's oceans, including changes to:

- temperature regimes,
- salinity regimes,
- acidity; and
- circulation patterns.

As all of these factors affect the distribution of marine species, such changes to oceanography are likely to also cause:

- changes in the ‘natural’ dispersal and distribution of species,
- changes in the range of existing bio-invasions (including range expansions and contractions), and
- new bio-invasions (including existing benign introductions becoming invasive).

The nature of such changes is extremely difficult to model and predict, and given the enormous diversity of marine species and the extremely wide range of their environmental requirements, reproductive and dispersal strategies and evolutionary capacity; the range of possible scenarios is perhaps bewildering.

6 Possible Effects on Maritime Industries – Fisheries and Aquaculture

Marine biological invasions can affect fisheries and aquaculture in many different ways, including but not limited:

- The affects of HABs as mentioned in section 3. In some cases large areas of aquaculture have been closed for extended periods due to HAB contamination, with significant socioeconomic impacts.
- Depletion of fisheries food supply by the invading species, as per the reduction in zoo-plankton stocks attributed to the invading Comb Jelly *M. leidii* in the Black Sea (section 3).
- Direct predation of the invading species on fisheries or aquaculture species, such as Atlantic Lamprey feeding on native fish species in the North American Great Lakes.
- Competition for or alteration of fisheries habitat by the invading species, such as introduced carp displacing native fish species in Australian rivers.
- Interference of the invading species with fishing operations, such as the clogging of fishing nets by masses of the introduced Cladoceran Water Flea *Cercopagis pengoi* in the Baltic Sea.

How global climate change will affect these effects, will of course be determined by the way that climate change affects the biological invader, as well as the invaded ecosystem and its native species. Effects might be either “negative” or “positive” (from an anthropogenic perspective), and are likely to be very site specific. For example:

- Climate change could, for arguments sake, cause a warming of the Caspian Sea, making it possible for the current invasion of *M. Leidii* there to extend its range into the colder northern parts of the Caspian, where it is currently restricted, and thereby increasing its impacts on the Sturgeon fishery. Alternatively, climate change may well cause a decrease in salinity in the Caspian Sea, through greater runoff of melting ice and snow in the sea’s catchments, thereby reducing the population of *M. Leidii* and enhancing the sturgeon fishery.
- A warming of some parts of the world’s seas could increase the incidence of HABs from algae species that prefer warmer temperatures, increasing HAB impacts on fisheries; whereas in the same area, climate-induced changes to ocean circulation might shut-down a nutrient-rich upwelling, thereby reducing the incidence of HABs.

Again, clearly the nature of such changes is extremely difficult to model and predict, given the enormous diversity of fisheries around the world, and the extreme unpredictability of the effects of climate change on biological invasions that affect fisheries.

7 Possible Implications for Maritime Industries – Recreation and Tourism

Coastal and marine recreation and tourism are often based on clean, healthy and intact environments and ecosystems, such as white sandy beaches and clear coastal waters for bathing and coral reefs for diving and snorkeling. Biological invasions can significantly detract from these values. Changes to the pattern of biological invasions through global climate change will of-course in turn change the way that biological invasions affect recreation and tourism. As with fisheries the results may either be “negative” (e.g. an increase in HABs that foul recreational beaches), or “positive” (in terms of recreational amenity – such as an improvement in water clarity due to an invasion of filter-feeding bivalves that reduce suspended sediments loads, as has been attributed to the invasive Zebra Mussel in parts of the North American Great Lakes).

Again, the nature of such changes is extremely difficult to model and predict, and the ultimate effects will be determined by the way that climate change affects biological invasions.

8 Possible Implications for Maritime Industries – Shipping

Because shipping is considered to be perhaps one of the main vectors for marine biological invasions, both through hull fouling and ballast water, and because shipping traverses all marine eco-regions of the globe, effectively carrying certain species through marine environmental barriers, the implications of climate change for ship-mediated bio-invasions are likely to be significant.

Perhaps the main effect will be to alter the risk profiles presented by certain shipping routes. For example, today, a ship trading between cold water ports in Northern Asia and warm water ports in tropical Australia, may be considered to be low risk even if it discharges large volumes of north Asian ballast water into the Australian ports, as the environments are sufficiently different to preclude cold water species native to north Asia establishing and invading in tropical waters. However, if due to climate change, north Asian ports become tropicalised, this shipping route might become “high risk” for biological invasions in northern Australia. Again, globally the range of possible scenarios is almost endless.

Global climate change is also likely to open up new shipping routes – such as through the Arctic due to a reduction in ice cover – thereby allowing ship-mediated bio-invasions to also enter these new areas.

The way shipping operations are managed in order to reduce biological invasions is also likely to be affected by climate change. For example, today the main management

measure used to reduce biota in ships' ballast water is for the ship to exchange its coastal ballast in the open ocean. This practice requires relatively calm seas; in order to maintain the safety of the ship while large volumes of ballast are exchanged. Should global warming cause an increase in extreme weather, storms and rough seas, as some climate models predict, the opportunity to undertake effective re-ballasting at sea may be significantly reduced, thereby reducing the effectiveness of efforts to prevent marine bio-invasions.

Again, the range of possible scenarios of how global climate change might affect the shipping industry in terms of the invasive species issue is enormous.

9 Conclusions

Global climate change will:

- almost certainly affect the dispersal of marine species in the world's oceans,
- almost certainly alter the range of existing marine bio-invasions and influence new invasions; and
- have implications for maritime industries, and for the way we manage these industries to prevent and control bio-invasions.

The nature of such changes is extremely difficult to model and predict. Given the vital importance of maritime industries, especially shipping, to the global economy, as well as the significance of shipping in particular as a vector for bio-invasions; it is suggested that this topic is worthy of more in-depth exploration through inclusion on the programme at ICCMI 2008.