4. Management challenges and opportunities for marine biosecurity in the Arctic

Oliver Floerl, SINTEF Fisheries and Aquaculture, Trondheim, Norway

4.1 Biosecurity management and its importance

Invasive species are one of the most serious threats to the diversity and integrity of marine ecosystems (Carlton 2001). Once established and undergoing spread, they can be impossible to eradicate and their impacts may be irreversible (Mack *et al*. 2000).

To protect themselves against invasive species, some countries have developed so-called biosecurity systems (Hewitt and Campbell 2007). Different definitions are used for the term biosecurity; a useful one is that of New Zealand:

> *Biosecurity is the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health.*
>
> (Biosecurity Council 2003)

The organisation of biosecurity measures into a defined and regulated system is important. In today's world of trade and transport a multitude of pathways, mechanisms and vectors are able to translocate a wide range of organisms or their propagules. Managing these complex, dynamic and often unpredictable processes is very difficult and the consequences of loopholes can be substantial. The development of an effective biosecurity system requires significant commitment but can offer immense long-term benefits.

The Arctic region is undergoing rapid change, both environmentally and economically. Shiping traffic already connects Arctic ports to a considerable range of other global regions (Ware *et al*. 2013) and this is expected to increase further (Miller 2014, this volume), conceivably with a concomitant increase in invasion risk (Verling *et al*. 2005, Drake and

Lodge 2007). To protect themselves against the impacts of future invaders, Arctic nations now have an opportunity to learn from the experiences of years of biosecurity science and management undertaken at lower latitudes, experience that includes both successes and failures.

This chapter will discuss some of the key elements of marine biosecurity management, drawing on case studies and experiences from a range of maritime nations, predominantly New Zealand and Australia. The purpose of this chapter is not a detailed description of entire biosecurity systems (it takes most countries years to develop these) but, rather, to provide a concise and informal overview of some of their main components relating to the prevention or mitigation of *unintentional* species introductions. Given this specific focus, no consideration is given here to two nevertheless very important components of national biosecurity systems: (1) measures related to *intentional* species introductions for economic or recreational activities, and (2) the requirement for national biosecurity systems to provide sanitary and phytosanitary assurances to trading partners and to avoid protectionist trade measures (WTO 1995, Hewitt and Campbell 2007).

4.2 A simple framework for effective biosecurity management

A primary requirement for meaningful and effective biosecurity management is that the biosecurity risks to a country or region be understood and, as far as possible, quantified. This knowledge should then serve as a foundation for management strategies, including the prevention of non-native species introductions (pre-border management) and efforts for eradication or management of introduced or established species (post-border management). Figure 1 illustrates this process and Box 1 provides information on key terms used in this chapter.

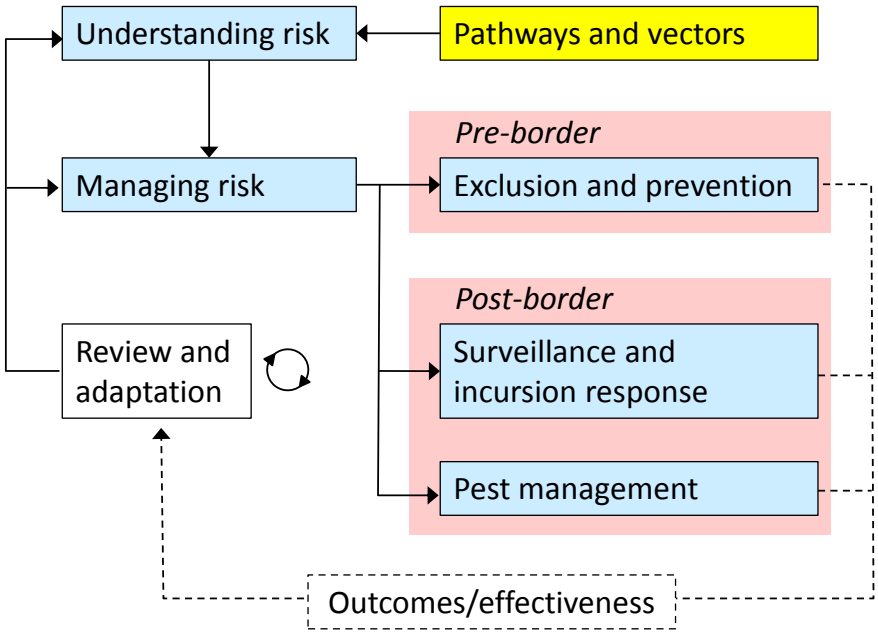
4.2.1 Understanding risk

As described above and in Miller (2014, this volume), there are numerous pathways and vectors that could transport non-native species and propagules to and within the arctic region. What is the relative risk of each pathway and vector? Are there particular non-native species that are established in trading ports that should be prevented from reaching the Arctic? Which arctic areas are most sensitive and which are at highest risk of invasion? These are some of the questions biosecurity manag-

ers should ask and strive to answer. A useful approach for this is risk assessment, a family of tools and techniques that determine the likelihood and consequences of undesired events (Hayes 2003, Drake 2005). Both quantitative and qualitative risk assessment tools are available. Risk assessment can be a useful and objective aid for understanding the relative risk of different pathways, vectors, locations, species, etc., and should underpin decision-making, prioritisation and resource allocation. Risk assessment can also form the basis of measures for managing biosecurity risks pre- and post-border (see sections below).

New Zealand and Australia are two maritime nations that have invested considerable effort into quantifying and understanding the marine biosecurity risks that they are exposed to. For example, in 2004 the New Zealand government commissioned the sampling of nearly 500 international vessels (including merchant, recreational and fishing vessels, as well as towed barges) to determine the significance of vessel biofouling as an introduction vector for non-native species to New Zealand and the relative risk posed by different vessel types (Cawthron Institute 2010, Inglis *et al*. 2010, Piola and Conwell 2010, Bell *et al*. 2011). The role of New Zealand's domestic shipping network was also examined (Hayden *et al*. 2008). In a parallel effort, the New Zealand government commissioned biological baseline surveys in the country's main shipping ports (selected by risk assessment) to create an inventory of established non-native species and their likely mode of introduction (Inglis 2001, Inglis *et al*. 2007). These exercises considerably increased the understanding of the biosecurity risks that New Zealand is subject to and, amongst other things, formed the basis for proposed hygiene standards for international vessel arrivals to New Zealand. Related efforts in Australia involved, for example, comparisons of biofouling and ballast water as introduction mechanisms and an examination of the biosecurity risks posed by the aquarium and ornamental fish industry (AMOG Consulting 2002, Hewitt and Campbell 2008, Morrisey *et al*. 2011). These activities are selected examples of a more comprehensive and on-going effort to understand sources of marine biosecurity risk. They illustrate how a strong motivation to understand risk has brought New Zealand and Australia into good positions for developing effective management strategies.

Figure 1: Framework for understanding and managing biosecurity risk to a nation or region



Box 1: Terminology for biosecurity management

- *Vectors*
  Means by which non-native species can be introduced to or spread within the arctic region (e.g. ballast water in merchant vessels).
- *Pre-border biosecurity management*
  Actions taken to prevent the entry of non-native species and their propagules into the Arctic. For example, ballast water management, biofouling standards for vessel hulls, inspections, etc.
- *Post-border biosecurity management*
  Actions taken to manage non-native species that have been introduced or become established within the Arctic (i.e. where pre-border effects were absent or failed).
- *Incursion response*
  A set of immediate actions taken once a non-native species is detected. Incursion response can include delimitation surveys, vector assessments and feasibility studies (as well as other actions).
- *Pest management*
  Management of established non-native populations. Pest management can involve eradication campaigns, population control or preventing further spread (as well as other actions).

4.2.2 Managing risk

Pre-border

Understanding the types of biosecurity risks that a region is exposed to is essential for the development of effective strategies and measures to manage these risks. A key component of risk management should be pre-border efforts aimed at excluding non-native species and minimising the likelihood of introductions (Fig. 1). This is because attempts to eradicate or otherwise control established non-native marine populations are generally expensive and stand limited chances of success (Bax *et al*. 2001, Thresher and Kuris 2004, Bax *et al*. 2006).

An example of a common pre-border effort is the ballast water management that many coastal nations (e.g. New Zealand, Australia, Canada and others) require international vessels to undertake prior to entering coastal waters (BWM 2005, Hewitt and Campbell 2007, Miller 2014, this volume). In comparison, biofouling is a largely unmanaged vector. Proposed guidelines for minimising biofouling risks from shipping have recently been released by the International Maritime Organization (IMO 2011), however, and several countries have also developed their own requirements. Such requirements can be based on different principles. For example, New Zealand has released a draft Import Health Standard (IHS) that, once in force, will require international vessel arrivals to arrive with hulls free of macroscopic biofouling organisms of any kind (MAF Biosecurity New Zealand 2010a, b). In contrast, Australia has taken a species-specific approach. Using a risk assessment process, a list of "species of concern" was developed comprising species that could cause significant economic or ecological impacts if established in Australian waters. Some states, in particular Western Australia, require international vessels to be demonstrably free of these species (Government of Western Australia 2013).

The best way for vessels to reduce their likelihood of transporting non-native biofouling species is to adopt effective hull maintenance schedules that ensure clean hull surfaces. Such practices include regular dry-docking and antifouling coating renewal, or acceptable forms of in-water hull cleaning. Both New Zealand and Australia provide guidance on these practices for a range of vessel types and industries (Commonwealth Government of Australia 2013, MPI 2013). Another option is the use of regular hull inspections to assess biosecurity risk, either for general biofouling presence or abundance, or for target species (Floerl *et al*. 2010). Such inspections can be undertaken pre-voyage, at a vessel's departure port, to enable its operators to carry out appropriate action prior to sailing, if required. Some degree of vector risk as-

sessment can also be undertaken based on predictive models built from hull inspection, maintenance and travel data of an appropriate number of vessels. However, the predictive power of such models can be limited for a range of reasons (Inglis *et al*. 2010).

Post-border

Effective pre-border risk management can considerably reduce biosecurity risk but it can not prevent it entirely. At times pre-border systems fail and non-native species are introduced and become established. Well-designed post-border intervention measures can then help to minimise their potential impacts (Fig. 1). A main aim should be to detect new populations of non-native species while they are small and localised, before they have been able to widely disperse to other locations. New Zealand is using target surveillance (surveys aimed at detecting a set of particular target species) to achieve this for its marine environments. Seasonal surveys for a set of high-risk non-native species are carried out in main shipping ports, marinas and harbours, using sampling methods appropriate for detecting these species (Inglis *et al*. 2006). On several occasions these surveys have resulted in the detection of established populations of target species, most notably an incursion of the Mediterranean fanworm *Sabella spallanzanii* in the port of Lyttelton (Read *et al*. 2011).

To warrant the effort and resources spent on surveillance for early detection of non-native species, systems, strategies and resources for immediate incursion response must be put in place. Incursion response might involve delimitation surveys to assess the size, distribution and demography of newly-detected non-native populations (Gust *et al*. 2006, Gust *et al*. 2008a). Prompt, rigorous and adequately resourced incursion response was a critical determinant for the successful eradication of the blackstriped mussel *Mytilopsis sallei* from an Australian marina shortly after its detection (Hewitt and Campbell 2007). Authorities tasked with biosecurity management should strive to develop incursion response plans based either on target species or habitats at risk of invasion. Incursion response plans should comprise information on the specific objectives of response activities, sampling approaches, decision points, lines of communication and agency responsibilities.

The result of incursion response measures will help management authorities decide whether and in what form "pest management" is feasible (Fig. 1). Pest management measures may involve attempts to eradicate a non-native species from a location or region, to control its population size or density, or to limit its further spread (Culver and Kuris 2000, Miller *et al*. 2004, Gust *et al*. 2008b, Atalah *et al*. 2013). A critical requirement for pest management, particularly eradication attempts, is

ongoing monitoring of the distribution and demography of targeted populations to ensure pest management efforts fulfil their objectives. Ineffective or no monitoring at all can seriously compromise the resources invested in pest management (Simberloff 2003). Indeed, the outcomes and effectiveness of all pre- and post-border measures and strategies should be monitored and reviewed on a regular basis to enable adaptation and improvement as necessary (Fig. 1).

4.3 Challenges and opportunities for the Arctic region

Most global coastal ports and harbours are connected via an intricate and effective transport network. The commercial shipping network, for example, is far more efficient at connecting any two global ports with each another than the global aviation network is with connecting airports (Kaluza *et al*. 2010). Arctic ports are already frequented by vessels arriving from a wide range of global destinations and regional vessel traffic is going to increase (Miller 2014, this volume, Ware *et al*. 2014). Although the development of an effective regional biosecurity system will present considerable challenges, it would yield significant environmental and economical benefits. Its success will be maximised if the following criteria can be achieved:

- A regional biosecurity system should be based on common goals shared among all Arctic nations. Ideally these common goals should be formalised and anchored in a regulatory framework, such as New Zealand's Biosecurity Act (1993) and Biosecurity Strategy (Biosecurity Council 2003).
- All pathways and vectors need to be identified and their relative risks assessed, enabling development of effective risk management strategies (Fig. 1).
- Strong global and regional relationships across regulatory authorities and industries should be developed and maintained to identify emerging risks (vectors, pathways or species).
- Sufficient capability and resources must be available to ensure: (i) up-to-date risk assessments, (ii) effective and rapid incursion response, and (iii) effective pest management.
- There should be clarity about the roles and responsibilities of all levels of the biosecurity system (e.g. local, regional, national regional organisations), and effective communication and information-sharing.

- Effective education and awareness programmes need to be available for the public, industry and other stakeholders to ensure compliance with regulations and best-practice guidance;
- There should be some level of enforcement of key aspects of the biosecurity system (e.g. mandatory ballast water management, etc.).
- All levels of planning, risk assessment, decision-making and policy development should be underpinned by independent and peer-reviewed scientific advice to ensure management actions are objective and defensible.
- There needs to be a culture of continuous improvement at all levels of a biosecurity system, including the various agencies and individuals that comprise it.

Biosecurity management can serve to protect the natural and historic heritage of the Arctic region, and help safeguard the integrity of its marine ecosystems and the human cultures that depend on them. While the provision of effective biosecurity for a vast, remote and climatically extreme multi-national region presents considerable challenges, the Arctic and its member states have the opportunity to build upon insights gained during decades of biosecurity management at lower latitudes. This unique opportunity should be seized to maximise protection of this region from the impacts of invasive species.

4.4 Acknowledgements

I thank the organisers of the workshop "Marine invasive species in the Arctic: Management issues" at the University of Southern Denmark (SDU) for inviting me to the workshop and to contribute this chapter. Thanks are also due to my previous colleagues, clients and collaborators in New Zealand and Australia where I made most of the insights described here. I particularly thank Ashley Coutts, Whitman Miller and Lisa Peacock for discussions on the topics covered in this chapter and for providing feedback on a draft version.

4.5 References

AMOG Consulting (2002). Hull fouling as a vector for the translocation of marine organisms. Phase I: Hull fouling research. *Ballast Water Research Series*, Report No. 14. Department of Agriculture, Fisheries and Forestry, Canberra, pp. 142.

Atalah, J., Bennett, H., Hopkins, G. A. and Forrest, B. M. (2013). Evaluation of the sea anemone *Anthothoe albocincta* as an augmentative biocontrol agent for biofouling on artificial structures. *Biofouling*, Vol. 29, pp. 559–571.

Bax, N., Carlton, J. T., Mathews-Amos, A., Haedrich, R. L., Howarth, F. G., Purcell, J. E., Rieser, A. and Gray, A. (2001). The control of biological invasions in the world's oceans. *Conservation Biology*, Vol. 15, pp. 1234–1246.

Bax, N., Dunstan, P., Gunaskera, R., Patil, J. and Sutton, C. (2006). Evaluation of national control plan management options for the north pacific seastar *Asterias amurensis*. Natural Heritage Trust, Canberra.

Bell, A., Phillips, S., Georgiades, E., Kluza, D. and Denny, C. (2011). *Risk Analysis: Vessel Biofouling*. Policy and Risk Directorate, MAF Biosecurity New Zealand.,Wellington, pp. 155.

Biosecurity Council (2003): *Tiakina Aotearoa: Protect New Zealand. The Biosecurity Strategy for New Zealand* (www.maf.govt.nz/biosecurity-strategy). Biosecurity Council. , Wellington, 67 pp.

BWM (2005): *International Convention on the Control and Management of Ship's Ballast Water and Sediments*. International Maritime Organization, London. www.imo.org

Carlton, J. T. (2001): *Introduced species in U.S. coastal waters: environmental impacts and management priorities*. Pew Oceans Commission, Arlington, 29 pp.

Cawthron Institute (2010): *Vessel biofouling as a vector for the introduction of non-indigenous marine species to New Zealand: Slow-moving barges and oil platforms*. Report prepared for MAF Biosecurity New Zealand Clearance Directorate, Wellington, 40 pp.

Commonwealth Government of Australia (2013): *Anti-fouling and in-water cleaning guidelines*. Department of Agriculture, Fisheries and Forestry and Department of Sustainability, Environment, Water, Population and Communities and New Zealand Ministry for Primary Industries, Canberra, 22 pp.

Culver, C. and Kuris, A. (2000): *The Apparent Eradication of a Locally Established Introduced Marine Pest*. Biological Invasions, Vol. 2, pp. 245–253.

Drake, J. M. (2005): Risk analysis for invasive species and emerging infectious diseases: Concepts and applications. *American Midland Naturalist*, Vol. 153, pp. 4–19.

Drake, J. M., and Lodge, D. M. (2007): Hull fouling is a risk factor for intercontinental species exchange in aquatic ecosystems. *Aquatic Invasions*, Vol. 2, pp. 121–131.

Floerl, O., Wilkens, S. and Inglis, G. (2010): *Development of a Template for Vessel Hull Inspections and Assessment of Biosecurity Risks to the Kermadec and sub-Antarctic Islands Regions*. Report prepared for Department of Conservation. National Institute of Water and Atmospheric Research, Christchurch, 55 pp.

Government of Western Australia (2013): *Western Australian marine pest management guidelines*. Western Australia Department of Fisheries, Perth, 2 pp.

Gust, N., Inglis, G., Floerl, O., Peacock, L., Denny, C. and Forrest, B. (2008a): *Assessment of population management options for* Styela clava. MAF Biosecurity New Zealand Technical Paper No: 2009/04, Wellington, 228 pp.

Gust, N., Inglis, G. , Peacock, L., Miller, S., Floerl, O., Hayden, B., Fitridge, I., Hurren, H. and Johnston, O. (2006): *Rapid nationwide delimitation surveys for Styela clava*. NIWA Client Report CHC2006-24, prepared for MAF Biosecurity New Zealand. Christchurch, 81 pp.

Hayden, B. J., Unwin, M., Roulston, H., Peacock, L., Floerl, O., Kospartov, M. and Seaward, K. (2008): *Vessel Movements within New Zealand: Evaluation of vessel movements from the 24 ports and marinas surveyed through the port baseline survey programmes*. NIWA Technical Report prepared for MAF Biosecurity New Zealand.

Hayes, K. R. (2003): Biosecurity and the role of risk assessment. Pages 382–414 in: G. Ruiz and J. T. Carlton, editors. *Invasive species: vectors and management strategies*. Island Press, Washington.

Hewitt, C. L. and Campbell, M. L. (2007): Mechanisms for the prevention of marine bioinvasions for better biosecurity. *Marine Pollution Bulletin*, Vol. 55, pp. 395–401.

Hewitt, C. L. and Campbell, M. L. (2008): *Assessment of relative contribution of vectors to the introduction and translocation of marine invasive species*. Report for the Department of Agriculture, Fisheries and Forestry. National Centre for Marine Conservation & Resource Sustainability, University of Tasmania, Launceston, 45 pp.

IMO (2011): *Guidelines for the control and management of ship's biofouling to minimize the transfer of invasive aquatic species (Annex 26, Resolution MEPC.207(62)).* (www.imo.org/blast/blastDataHelper.asp?data_id=30766). International Maritime Organization, London.

Inglis, G. J. (2001): *Criteria for identifying and selecting high value locations and locations at risk of invasion by exotic marine organisms in New Zealand*. NIWA Client Report for New Zealand Ministry of Fisheries, Wellington, 44 pp.

Inglis, G. J., Floerl, O., Ahyong, S. T., Cox, S. L., Unwin, M., Ponder-Sutton, A., Seaward, K., Kospartov, M., Read, G., Gordon, D., Hosie, A., Nelson, W., D'Archino, R., Bell, A. and Kluza, D. (2010): *The Biosecurity Risks Associated with Biofouling on International Vessels Arriving in New Zealand: Summary of the patterns and predictors of fouling*. NIWA Client Report prepared for MAF Biosecurity New Zealand, Wellington, 182 pp.

Inglis, G. J., Hurren, H., Gust, N., Oldman, J., Fitridge, I., Floerl, O. and Hayden, B. J. (2006): *Surveillance design for early detection of unwanted exotic marine organisms in New Zealand*. NIWA Client Report, For New Zealand Ministry of Fisheries, Christchurch, 47 pp.

Inglis, G. J., Kospartov, M., Fitridge, I., Gust, N., Floerl, O., Fenwick, G. D. and Hayden, B. J. (2007): *Port Baseline Surveys for Introduced Marine Species: Summary of results*. NIWA Client Report prepared for MAF Biosecurity New Zealand Post-Clearance Directorate, Christchurch, 109 pp.

Kaluza, P., Kolzsch, A., Gastner, M. T. and Blasius, B. (2010): The complex network of global cargo ship movements. *Journal of the Royal Society Interface*, Vol 7, pp. 1093–1103.

Mack, R., Simberloff, D., Lonsdale, W., Evans, H., Clout, M. and Bazzaz, F. (2000): Biotic invasions: causes, epidemiology, global consequences and control. *Ecological Applications*, Vol. 10, pp. 689–710.

MAF Biosecurity New Zealand (2010a): *Draft guidance document in support of the Import Health Standard for Vessel biofouling*. Ministry of Agriculture and Forestry, Wellington, 12 pp.

MAF Biosecurity New Zealand (2010b): *Import Health Standard for Vessel Biofouling (Draft, BNZ-STD-BIOFOUL)*. Ministry of Agriculture and Forestry, Wellington, 3 pp.

Miller, A. W., Chang, A. L., Cosentino-Manning, N. and Ruiz, G. M. (2004): A new record and eradication of the Northern Atlantic alga *Ascophyllum nodosum* (Phaeophyceae) from San Francisco Bay, California, USA. *Journal of Phycology*, Vol. 40, pp. 1028–1031.

Morrisey, D., Inglis, G., Neil, K., Bradley, A. and Fitridge, I. (2011): Characterization of the marine aquarium trade and management of associated marine pests in Australia, a country with stringent import biosecurity regulation. *Environmental Conservation*, Vol. 38, pp. 89–100.

MPI (2013): *Clean Boats, Living Seas*. (http://www.biosecurity.govt.nz/video/ clean-boats-living-seas-1). New Zealand Ministry of Primary Industries, Wellington.

Piola, R. F. and Conwell, C. (2010): *Vessel biofouling as a vector for the introduction of nonindigenous marine species to New Zealand: Fishing vessels*. MAF Biosecurity New Zealand Technical Paper 2010/11. Cawthron Institute, Nelson. 57 pp.

Read, G. B., Inglis, G., Stratford, P. and Ahyong, S. T. (2011): Arrival of the alien fanworm *Sabella spallanzanii* (Gmelin, 1791) (Polychaeta: Sabellidae) in two New Zealand harbours. *Aquatic Invasions*, Vol. 6, pp. 273–279.

Simberloff, D. (2003): Eradication-preventing invasions at the outset. *Weed Science*, Vol. 51, pp. 247–253.

Thresher, R. E., and Kuris, A. M. (2004): Options for managing invasive marine species. *Biological Invasions*, Vol. 6, pp. 295–300.

Verling, E., Ruiz, G. M., Smith, L. D., Galil, B., Miller, A. W. and Murphy, K. R. (2005): Supply-side invasion ecology: Characterizing propagule pressure in coastal ecosystems. *Proceedings of the Royal Society – Biological Sciences* (Series B), Vol. 272, pp. 1249–1256.

Ware, C., Berge, J., Sundet, J. H., Kirkpatrick, J. B., Coutts, A. D. M., Jelmert, A., Olsen, S. M., Floerl, O., Wisz, M. S. and Alsos, I. G. (2014): Climate change, non-indigenous species and shipping: assessing the risk of species introduction to a high-Arctic archipelago. *Diversity and Distributions*, Vol. 20, pp. 10–19.

WTO (1995): *The application of Sanitary and Phytosanitary Measures*. (http://www.wto.org/english/docs_e/legal_e/15-sps.pdf). World Trade Organization, Geneva.