The Management of Invasive Species in Marine & Coastal Environments

Module 3

Prevention
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3. **PREVENTION**

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3 PREVENTION

Objectives of the module:

- Introduce the concept of prevention
- Outline strategies and procedures for IAS prevention in marine and coastal environments
- Explain the concept of risk analysis
- Discuss the limitations of prevention

3.1 What do we mean by Prevention?

Prevention is the application of measures aimed at reducing or eliminating species introductions, or at preventing their establishment. Such measures can be applied to intentional or unintentional introductions. Examples include permitting procedures for imported species, and shipboard treatment systems for preventing ballast water related introductions.

3.2 Why is the prevention so important in marine and coastal environments?

Prevention is better than cure

All pest reduction and management strategies recognise the medical maxim: “an ounce of prevention is worth a pound of cure”. In other words, the most efficient and cost-effective way of dealing with invasive species is to stop them being introduced in the first place. Prevention is therefore the first step in the IAS management hierarchy.

Prevention is especially important for marine environments given the difficulties of detecting introductions in marine habitats, of eradicating species that have become established, and of functional control and mitigation programs. Problems confronting managers trying to respond to marine incursions include:

- The lack of affordable technologies for targeted containment, eradication or control measures in open coastal waters;
• The limited availability of biological controls for marine species (via pathogens, parasites, predators or genetic or epidemiological manipulation), the development of which is in its infancy compared to terrestrial pest management;
• The fact that most sessile and many mobile marine taxa have propagules or larval stages capable of widespread dispersal via local and regional water currents;
• The fact that many estuarine and brackish water taxa have wide thermal/salinity tolerances and are pre-adapted to take advantage of rapid changes in local conditions.

3.3 Principles of Prevention

The following principles are intended to provide guidance for the development of strategies for the prevention of IAS introductions.

**Principle 1:** Prevention is better than cure: prevention is more cost-effective and environmentally less damaging than measures taken following the introduction and establishment of an IAS.

**Principle 2:** No intentional introduction of an alien species should be allowed unless approved by a suitable regulatory authority. The process for granting or denying approval for an alien species introduction should be based on risk analysis.

**Principle 3:** Unintentional and unauthorised introductions of alien species should be minimised. This can be achieved through the identification of the common pathways and the risks associated with unintentional IAS introductions, and the application of appropriate measures.

**Principle 4:** Apply a precautionary approach: consider every alien species as potentially invasive until convincing evidence indicates that it presents no threat. Every alien species must be considered “guilty” until proven innocent.

**Principle 5:** The intentional and unintentional movement of IAS should be controlled between and within countries.

**Principle 6:** No potentially invasive species should be introduced into protected or vulnerable areas.

**Principle 7:** The concept of “zero risk” for the prevention of IAS is unrealistic – this could only be achieved if trade, transport and travel were halted. However, countries should make every effort to minimise the risk.

**Principle 8:** Every coastal country in the world is a potential source and recipient of marine IAS so it is in everybody’s interest to cooperate to control the movement of IAS.
**Principle 9:** The public should be made aware of the threats posed by IAS, and their role in introducing them, and should be encouraged to become a part of the solution.

**Principle 10:** IAS prevention strategies should be supported by suitable legislation, policy and resources including people, infrastructure and funding.

### 3.4 Where can Prevention be applied?

Measures to prevent the introduction and establishment of IAS can be applied pre-border (before it leaves the country of origin, or en route to the destination), at the border (before it enters a country), or post-border (within a country). Post-border measures are primarily aimed at early detection and rapid response, in other words to prevent establishment. They are dealt with in the next module.

**Figure 3.1:** Summary of pre-border, border and post-border prevention

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<thead>
<tr>
<th>Prevention</th>
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<tr>
<td><strong>Pre-Border</strong></td>
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<td>• IAS proof packaging</td>
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<td>• Pre-quarantine for live plants and animals</td>
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<td>• Compliance assessment</td>
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<td>• Cameras</td>
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<tr>
<td>• Post-entry quarantine for live organisms</td>
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<tr>
<td><strong>Post-Border</strong></td>
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<td>• Public awareness</td>
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<td>• Surveillance</td>
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<td>• active</td>
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<td>• Pre-planned response programmes</td>
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<td>• Pre-planned management programmes</td>
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3.5 Strategies for IAS Prevention in Marine and Coastal Environments

Prevention measures include tools for regulating intentional introductions and for minimising unintentional introductions. In the case of the former, the measures employed are based on the particular species involved, whereas for unintentional introductions, they focus primarily on the management of high-risk pathways. In the context of marine and coastal environments, intentional introductions include introductions for mariculture, the aquarium trade, and coastal management purposes, while the main pathways for unintentional introductions are shipping, canals and marine debris.

For any particular situation, the prevention approach used is usually a combination of several tools, of which the following are the most important:

- Risk analysis;
- Authorisation procedures;
- Species lists;
- Treatment or management of vectors;
- Quarantine and Border control.

3.6 The Role of Risk Analysis

3.6.1 What is Risk?

In their daily lives people often do things, which pose a certain amount of risk (e.g. driving a car). In society there is an implicit assumption that the benefits of at least some of such risky activities outweigh the potential negative outcomes. Similarly, the risks associated with introducing invasive marine species can be weighed and considered against any potential benefits associated with them, or the activities that introduce them.

3.6.2 How should a risk analysis be applied?

Risk analysis traditionally focussed on certain types of impacts (e.g. competition with commercially valuable species), and certain taxa or types of potential invasive alien species only. Increasingly, it is being recognised that risk analysis should apply to all taxa and pathways, and to the full scope of impacts that can potentially be caused.

In terms of marine IAS prevention, risk analysis is usually applied to a:
(1) Particular species, in which case its invasiveness and impacts are assessed, or to a
(2) Particular pathway, in which case potential invasive species and their impacts are assessed.

In the case of a particular species, the risk assessment determines the risk that once that species has been introduced, it could establish, spread and have negative impacts. This is largely based on the characteristics and history of the organism under consideration, and is prepared by reviewing literature and consulting with stakeholders and technical experts. Risk assessments for a particular pathway focus more on determining the risk associated with unintentionally introducing an unknown organism as a consequence of a certain activity (e.g. shipping). These processes should be science-based, politically independent, transparent, consistent with government policy and the country’s international obligations and rights, harmonised as much as possible with international practice and subject to appeal.

The results of a risk analysis can be used to determine if remedial action should be taken and, if so, what kind. For example, the decision whether to allow the intentional importation of a new species is made based on the risk analysis. This includes the decision to authorise the introduction with or without conditions. For pathways, risk analysis will determine whether risk management action needs to be taken and if so what (treatment, health standards, etc.).

**Risk analysis should cover all taxa and pathways, and all potential impacts of IAS, including impacts on diversity and ecosystem functioning.**

### 3.6.3 Components of Risk Analysis

The risk analysis process has three main components (Figure 3.2):

1. Risk Assessment.
2. Risk Management.
3. Risk Communication.
3.6.4 Application of Risk Analysis

The details of a risk analysis will vary depending on whether it is an intentional or unintentional introduction, the purpose of the introduction, and/or the pathway concerned. For example, the factors to consider when importing a new species for mariculture will differ to those when applying to import a species for scientific research or aquarium use.

Risk Assessment

The first step is to identify the proposed species or pathway. The following questions then need to be addressed to assess the risk posed by that species or pathway:

1. The likelihood of the alien species being introduced or, in the case of intentional introductions, escaping into the wild;
2. The likelihood of it establishing following introduction;
3. The consequences of establishment i.e. impacts on the environment, the economy and human health;
4. The level of risk posed by the proposed species without management;
5. The feasibility of managing spread (if it escapes, released, etc);
6. The feasibility of managing incursions;

Figure 3.2: Components of Risk Analysis
7. Residual threat posed by managed risk, with costs.

The risk assessment will identify a level of risk associated with the species or activity (e.g. No, Low, Medium, Acceptable, High, Unacceptable). It must be noted, however, that risk assessments are often subjective, include assumptions, and not all the available information will be reliable. That is why risk management strategies should be considered regardless of the apparent level of risk.

Risk Management

The conclusions from the risk assessment are used to decide whether risk management is required. The next step is to determine what risk management options are available to deal with the identified risk, to evaluate the effectiveness of these actions, and identify the most appropriate options. These include emergency responses in case a species escapes or a new species is found during routine surveillance.

Risk Communication

The reason and purpose for using risk analysis should be clearly formulated and communicated to stakeholders including the public. Also, information on the results of the risk assessment and identified management options should be made available to stakeholders. This will ensure their engagement and support for any actions that may need to be taken.

Open, multiple exchanges of information lead to better understandings and decisions i.e. consulting, informing and explaining. Accordingly stakeholders need to be informed throughout the entire risk analysis process.

Summary

Risk analysis evaluates the likelihood of an IAS entering and establishing in a particular area, the potential environmental and socio-economic impacts, and the options for mitigating those impacts.

3.7 Prevention and Intentional Introductions

Intentional introductions into marine and coastal environments are primarily for mariculture and coastal management purposes, and include introductions into the wild and captivity. However, even enclosed mariculture operations are highly susceptible to escapes – a factor which needs to be taken into account in decision-making. In coastal fish farms, for example, because containment of stock held in open water pens is much harder to achieve than in closed systems on land, environmental assessments of these operations must assume that significant escapes will inevitably occur. The exact source, genetic make up and quarantine measures of each proposed stocking operation need to be
carefully vetted. Current research is focused on ways to prevent pen rupture by storms and by sharks, seals, sea lions, dolphins and harbor porpoises, which are frequently attracted to the pens.

Introductions for the aquarium trade also need to be managed with respect to preventing escapes from captivity into the wild. A new aspect of such introductions is the evolving use of aquatic genetically modified organisms (GMOs) and transgenic forms developed for the aquaculture and aquarium trade.

The case of *Caulerpa taxifolia* (Case study in Module 1) highlights the pressures that domestic, public and research aquaria can exert for producing tough, thermally tolerant strains with enhanced growth and regenerative potential. There is a need for the aquarium pet industry to promote the responsible management of domestic aquaria, including free acceptance of any unwanted specimens returned to vendors. Governments should highlight the risks and illegality of aquaria dumping, and review or strengthen their regulations as and where necessary.

The Food and Agriculture Organization (FAO) of the United Nations has developed a framework for the management of species deliberately introduced for fisheries and aquaculture purposes. The framework consists of:

- Code of Conduct for Responsible Fisheries (CCRF):
  - Articles 7 and 9 among others apply to introduced species;
  - Article 7.5 calls on states to apply the precautionary approach to the conservation, management and exploitation of living aquatic resources;
  - Article 9.3.1 calls on states to conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management;
  - Articles 9.2.3, 9.3.2 and 9.3.3 call on states to cooperate in minimizing risks from alien species by consulting with an notifying neighbouring states when an introduction is being planned; complying with other international instruments; and adopting measures to reduce the risk of the spread of disease.

- Technical Guidelines for Responsible Fisheries – Precautionary Approach to Capture Fisheries and Species Introductions
- The International Council for the Exploration of the Sea (ICES) Code of Practice
- Database on Introductions of Aquatic Species
- The Asia Regional Technical Guidelines and the Beijing Consensus (tools dealing with the risk of introducing pathogens through transboundary movement of live aquatic animals).
The ICES Code of Practice on the Introduction and Transfers of Marine Organisms was initially adopted in 1973, and has subsequently been further developed and updated, with revised versions being adopted in 1979, 1990, 1994 and the most recent, 2003. While initially designed for ICES member countries concerned with the North Atlantic and adjacent seas, countries across the globe are now encouraged to implement this code of practice. The most recent version:

- Includes aquarium-related transfers
- Addresses GMO’s
- Includes annexes dealing with:
  - a prospectus of information required for applications
  - risk assessment
  - quarantine
  - monitoring

The ICES code describes the assessment and quarantine measures that should be followed to:

(a) Avoid intentionally introduced species that have undesirable characteristics, including any known or suspected potential invasive, noxious or other pest attributes, and

(b) Minimize the unintentional introduction, release or escape of unwanted pathogens, parasites, commensals or other ‘hitch-hiker’ species via the shipment or handling of cultured species or through other mariculture vectors.

Other recent publications have helped advance the view of including a complete prohibition on the use of non-native species and genetically modified strains in any farming or aquarium system in which the potential for escape is greater than near zero.

3.7.1 Authorisation Procedures

Authorisation procedures for permits and licences are important tools for controlling the movement of alien species between and within countries. Countries, in general, use permits and licences as approval processes to assess risks and benefits associated with planned imports.

The assessment which is conducted as an integral component of any permit application procedure for an intentional introduction should include both a risk analysis, and a cost-benefit analysis, and should include the following questions:

- What is the purpose and objective of the introduction?
- Is there not an indigenous species that could be used for the same purpose?
- Is this organism considered a pest in its native range or in any other area where the organism has been introduced?
- Does the organism have any close relatives occurring in the indigenous biota (i.e. it may out-compete native species)?
• What is the biology of the organism including its diet, reproductive habits, size, longevity, diet, etc?
• What is its preferred habitat (i.e. intertidal, pelagic etc)?
• What precautions will be taken to prevent the introduction of pathogens, parasites or attached organisms with, in, or on the introduced organism (i.e., health certification, quarantine, treatments)?
• Are there any existing eradication or control programs for this species?

Depending on the outcome of the analyses, a permit for import may be issued subject to certain conditions. Specific conditions may include details on the pre- and post-border treatment required, inspection of facilities and operations, measures to prevent the potential escape of species from facilities, and the development of plans to take rapid action if a species has escaped.

Border control services should inspect shipments in the country of origin and on arrival at the destination to verify compliance with the relevant conditions of the import licence.

Remember that permits and licences are only useful for authorised intentional introductions – many IAS have been introduced unintentionally or illegally (by smuggling).

3.7.2 Species Lists

In order to facilitate the assessment of intentional introductions, a three-list system has been applied in a number of countries. The system is also used as a basis for prioritising species-based border checks and post-border surveillance.

1. **Black list**

The Black List includes species whose introduction is strictly prohibited as they are considered to be invasive and destructive.

2. **White list**

These are species classified as low risk following a risk assessment or based on long-standing experience. Introduction of these species may be authorised without restriction or under conditions restricting the use of the species to specific purposes (research, public education, others). However, care should be taken to avoid giving the impression that uncontrolled releases of white-listed species are encouraged.
3. **Grey (holding) list**

Any species not included in the black or white list, or for which there is little information, is placed in a gray list, and should be subject to a rigorous risk assessment prior to a decision on introduction.

The listing system should be dynamic, making it possible to transfer a species to a different list if justified (e.g. if a white-listed species is repeatedly introduced over a long period, the risk should be reassessed if there is new evidence of potential invasive behaviour). Species listing and decision-making need to be based on scientific criteria that are periodically reviewed and are transparent.

### 3.7.3 Quarantine & Border Control

Alien species arriving at the borders of a country as a result of an intentional activity may either be:

i) Authorised; or

ii) Unauthorised or illegal.

**Authorised Introductions**

In the case of authorized introductions, the primary role of border controls is to ensure that that permit requirements for reducing the risk of introduction have been, or will be, met. This includes verifying that the organisms in the shipment are, in fact, the species for which the permit was issued; inspecting and verifying any pre-border certification which may have been required; and ensuring that any quarantine requirements at the border are met.

**Illegal Introductions**

In the case of illegal or unauthorised introductions, border controls are the primary method of prevention. Materials – either live organisms, or natural products with ‘hitchhikers’ attached to them – may be brought in by individuals themselves, in their baggage, in unaccompanied baggage, or in the mail. Border controls include:

- declarations from arriving passengers;
- inspections of baggage by border officials and/or detector dogs;
- X-ray screening of baggage and mail;
- Inspection of cargo manifests.
The use of species lists is used here to help border officials prioritise species of particular concern.

**Figure 3.3**: Summary of the management procedures for an Intentional Import

3.8 Preventing Unintentional Introductions

The main pathways for unintentional introductions of marine species are shipping, marine debris, and canals which link previously unconnected water bodies. Given the vast array of species which could be associated with any one of these pathways, it is considered more effective to manage the pathway, or vector, rather than to try and target specific species. This is effectively pre-border management. Nevertheless, there is still a need for certain prevention activities at borders.

This module will address prevention strategies related to shipping – in particular, the two main vectors, ballast water and hull-fouling – and canals.
3.8.1 Ballast Water

The shipping industry has grown to rely upon the use of ballast water for the daily operation of vessels around the world (as described in Module 1). Given this reliance, the magnitude of shipping in the world today, and the massive volumes of ballast water being transferred, ballast water presents a very difficult and complex vector for management of species transfers.

3.8.1.1 IMO Recommended Management Tools

The International Maritime Organization (IMO) is the United Nations’ agency responsible for shipping and maritime matters. As such the IMO has been actively engaged in seeking a solution to the ballast water problem since the late 1980’s. A summary of the history of these developments follows:


These Guidelines, which were voluntary, were aimed at providing Administrations and port State authorities with a range of information on the issue and suggested a variety of procedures to manage ballast water with a view to reducing the risk of introduction of unwanted aquatic organisms and pathogens. The suggested measures included:

- Minimizing the uptake of organisms during ballasting, by avoiding areas in ports where populations of harmful organisms are known to occur, in shallow water and in darkness, when bottom-dwelling organisms may rise in the water column.

- Cleaning ballast tanks and removing on a regular basis, sediments that accumulate in the tanks and which may harbour harmful organisms.

- Avoiding unnecessary discharge of ballast.

- Undertaking ballast water management procedures, including exchanging ballast water at sea; non-release or minimal release of ballast water; and discharge to onshore reception and treatment facilities (if available).
Box 3.1: Open Ocean Ballast Water Exchange

One of the recommended procedures for minimising the transfer of species in ballast water is open ocean, or mid-ocean exchange. When a ship takes on ballast water it is usually in a port, and therefore takes on coastal water, likely to contain organisms. Ballast water exchange involves discharging that coastal water into the open ocean, where such organisms are less likely to survive, and taking up new open ocean water, which is less likely to contain organisms that will survive in the coastal waters at the destination.

The process can be achieved by completely emptying the ballast tanks at sea (recommended at least 200 nautical miles from shore), and subsequently refilling them. This procedure is often not practical due to the safety constraints of the vessel. A more viable option is the flow-through, or continuous flushing method, whereby three tank volumes must be pumped through the tanks, while the ship is underway, in order for the tanks to be adequately flushed.

More recently, there has been a move away from ballast water exchange as the preferred ballast water management measure, towards ballast water treatment, as is reflected in the new Convention.

The International Convention (2004) & Ballast Water Treatment

In 1997 when the latest IMO Guidelines were completed it became obvious to IMO and its members that, because of the inherent limitations of Guidelines (principally that they are voluntary only), a legally binding international agreement was needed.
The IMO and its member countries therefore subsequently developed the International Convention for the Control and Management of Ships’ Ballast Water and Sediments, which was adopted in February of 2004. This Convention is broad-ranging and intended to put in place binding, consistent, international arrangements to ensure that ships’ ballast water is handled and managed in a manner that will minimize the transfer of harmful aquatic organisms and pathogens to new territories, with the potential for them to establish and become a harmful nuisance species.

The convention continues to advocate the use of open ocean exchange of ballast water as an interim measure for controlling species transfers. However, the convention acknowledges the limitations of ballast water exchange, as well as the ongoing research and development in the field of ballast water treatment technologies. In so doing, it sets standards for achieving adequate treatment of ballast water in the years to come. Therefore the effective shipboard or quayside treatment of ballast water, to eliminate any organisms contained therein, will increasingly be the dominant goal of most ballast water management regimes.

Current research on ballast water treatment technologies has included many types of approaches, including the following:

- Chemical treatment (e.g. chlorination, biocides, ozonation)
- Mechanical treatment (e.g. filtration, pressure based systems)
- Hydrocyclone systems
- Heat treatment
- Ultra violet light exposure
- Combination treatments

In specific areas where conditions are appropriate, research is also investigating the possibility of developing shore-based reception facilities for handling ballast water. Similar systems are already operational for separating oil from ballast water when discharged from large tankers. The challenge of effective elimination of all species, while maintaining adequate flow rates for normal vessel operation, make such treatment options very difficult to engineer.

**Box 3.2: Ballast Water Treatment Standards from the IMO Convention**

*Regulation D-1 Ballast Water Exchange Standard:*

*Ships performing Ballast Water exchange shall do so with an efficiency of 95 per cent volumetric exchange of Ballast Water. For ships exchanging ballast water by the pumping-through method, pumping through three times the volume of each ballast water tank shall be considered to meet the standard described. Pumping through less than three times the volume may be accepted provided the ship can demonstrate that at least 95 percent volumetric exchange is met.*
Regulation D-2 Ballast Water Performance Standard:

Ships conducting ballast water management shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 micrometers in minimum dimension and less than 10 viable organisms per milliliter less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometers in minimum dimension; and discharge of the indicator microbes shall not exceed the specified concentrations.

The new IMO Convention differentiates between responsibilities that fall upon the ship owners/operators, and the responsibilities of the coastal or port state. Some examples of these are summarised below:

Responsibilities of Shipowners/operators

- Ship-board ballast water management plans
- Adherence to ballast water exchange procedures
- Installation of certified ballast water treatment technology (when it becomes available)
- Record keeping and reporting

Responsibilities of Coastal/Port State

- Development of compliance monitoring and enforcement systems (including reporting, inspection of ballast water management plans/verification of ballast water exchange records etc).
- Installation of ballast sediment disposal systems

3.8.2 Hull Fouling

Biofouling occurs on a variety of structures including ship’s hulls, oil rigs, fishing equipment, marine debris etc. and has to be effectively addressed if the risk of marine bioinvasions is to be reduced significantly. To date, efforts to manage biofouling have largely been focused on the benefits to the industry, and, at the international level, have not dealt with the invasive species aspects in any significant way. Nevertheless, several codes have been developed at the national level for the cleaning of commercial and recreational vessel hulls – for example, in Australia, New Zealand and North America.

Suggested management measures include the following:

- Adherence to effective hull cleaning and anti-fouling programs, with sea chests and seawater systems being examined and cleaned on a regular basis. This applies to all vessels, particularly those that have been laid up for long periods.
• Education programs are required to make boat operators and ship owners aware of the potential for their vessels to transport unwanted fouling marine species and the steps they should take to reduce this vector.

• Management of the hull cleaning industry and their areas of operation. This includes regulations on in-water cleaning of hulls and fouled objects, as well as cleaning on slipways and in dry docks. In the case of the latter two, any dislodged material should be trapped and removed to a landfill site.

In the absence of international regulations, many ships are travelling to ports where no regulations on hull-fouling exist, in order to have their hulls cleaned. It is therefore important that governments cooperate collectively to limit the threat posed by such practices.

**Box 3.3: Hull Fouling & Recreational Vessels**

In recent years the role of recreational yachts in transferring fouling species across oceans and between regions has been investigated. As a consequence, New Zealand has expanded its regulations to include inspections of arriving yachts, and recommendations for hull cleaning in situations where appropriate. A specially designed rolling camera is used to view the underwater parts of the vessels’ hulls to inspect for any unwanted fouling species.

![Image of yachts and a person inspecting the hull](https://example.com/image)

### 3.8.3 Canals

The construction of canals linking previously unconnected water bodies represents a unique challenge to managers aiming to restrict movement of potentially invasive species. Although the number of such canals in a strictly marine context is very limited, they can, and have lead to significant bioinvasions (see Module 1). Nowadays the construction of such a canal is likely to be preceded by an environmental impact
assessment, which should include an evaluation of the risk of species translocations, as well as the options for minimising such risks.

This is a relatively new consideration in canal construction, and the options are limited. The use of locks in some canals, for example the Panama Canal, has been found to be effective as a barrier to species movement. However this technology was not necessarily intended for that purpose, and is not always practical.

The concept of using electric barriers to prevent self-mediated spread of invasive species along canals and waterways has been the subject of research and testing since the 1950s, when these barriers were first used in attempts to halt the sea lamprey invasion. Trials continued until the 1960s when they were terminated after the chemical lamprey larvicide TFM was found to provide a cheaper and more effective population containment and control method. Problems with the first generation of electrical barriers included unsafe use of alternating current, salinity conductance, power failures, debris damage and overtopping during winter spates. They could also not be used on any stretch of waterway used by trading or recreational vessels. Developments in technology have led to promising ‘second generation’ systems which have been recently trialled at several locations in the United States to control invasive carp and other introduced freshwater fish. However, it is unclear what application they might have in the marine context.

3.9 Limitations of prevention

Although prevention should always be the preferred option in an IAS management strategy, there are a number of factors, some currently intractable, which will continue to put constraints reliable prevention strategies for at least the short- to mid-term. These include:

- The operational nature of the international shipping industry, including the present overriding economic imperative placed on the need not to disrupt the movements and needs of trading vessels;
- The fact that marine species and ecosystems straddle political boundaries, making it imperative to have a regional approach if control measures, are to be effective;
- The large number and range of different marine organisms which can be translocated by ballast water and hull fouling;
- The considerable knowledge gaps in marine taxonomy, life-cycle biology and contemporary native and introduced range distributions (even for some well-known marine pests);
- The problem in predicting which species are likely to become invasive;
- The present and near-future unavailability of safe, practical, effective and affordable methods for treating ballast water;
- The difficulties in managing hull-fouling without recourse to overly toxic additives, such as the recently banned use of organotins (TBT) for anti-fouling coatings.
It is therefore important to acknowledge that no prevention system can guarantee a 100% exclusion of potentially invasive species, and that a management system based solely on the prevention approach will fail. Moreover, most countries already have a large number of alien species present within their borders. Management systems must, therefore include post-border controls to detect and eradicate new entrants early on, or for those that cannot be eradicated, to contain/slow the rate of spread, and to protect sensitive areas. These concepts are covered in the next few modules.

**Box 6: Developments in Electric Barrier Methods**

Since the first attempts in the 1950s-1960s (Section 3.1), there have been several improvements to the efficiency of electrical barrier designs for preventing non-native migratory fishes from entering rivers and watersheds for spawning and spread (e.g. sea lampreys, salmonids, Asian carp etc.). Systems trialled in various North American watersheds during the 1990s typically use a Graduated Field Fish Barrier (GFFB; as developed and promoted by Smith-Root, Inc.). The GFFB provides a substantial improvement over the earlier alternating current and single-field direct current barriers. By using an electrical array mounted in an insulated concrete pad to produce the graduated field, they can also be installed without posing a major navigation obstacle and are less prone to debris damage. As a fish swims into the electrical field, the increasing voltage inhibits the swimming ability of the fish and the fish are quickly swept clear of the field by water flow. The most efficient electric field pattern for blocking or guiding fish has electric field lines running parallel to the water flow. The advantage of this parallel field orientation is that fish which turn crosswise to the electric field receive almost no electric sensation or muscle paralysis. Fish learn very quickly that by turning side ways to the flow they minimize the effect of the electric field. In this orientation, upstream migrating fish are swept clear of the field by the water flow. The figures below show reactions of migrating fish when they try to migrate across a GFFB. In slow or static water a high percentage of fish learn to turn and swim away from the electric field. However water velocities >0.6 metres/second are required to avoid fish kills by helping to quickly sweep the fish downstream and out of the field. Details on designs and locations of electrical barriers trials in the US are available as downloadable files from [www.smith-root.com](http://www.smith-root.com).