September 2012

CENTRAL ASIAN AND CAUCASUS REGIONAL
FISHERIES AND AQUACULTURE COMMISSION

TECHNICAL ADVISORY COMMITTEE (TAC)

First Session

Kiev, Ukraine, 20-22 November 2012

TOWARDS RESPONSIBLE INTRODUCTIONS AND TRANSFERS OF FISH IN CENTRAL ASIA AND THE CAUCASUS: STATUS AND ISSUES

INTRODUCTION

1. This document provides the background information status of introductions and transfers of fish in Central Asia and the Caucasus. It also provides a framework of responsible principles that draws on best practices and global experience in the management of fish introductions and transfers. The draft report "Non-native fish species in Central Asia and the Caucasus: environmentally sound practices for introductions and translocations" (Annex 1) provides available information on the status of introductions and transfers of fish in Central Asia and the Caucasus. It also includes main conclusions of various reviews; defines key driven forces behind the fish introductions and transfers; illustrates environmental, social and economic impacts of fish introductions and translocations. Furthermore, the attached report defines basis principles of management approaches and strategies to reduce negative impacts of introduction and transfer of non-native fish species. It also provides generic guidelines and considerations with regard to management of fish introductions and transfers.

2. The Annex provides a regional review of fish introduction based on data collected from a variety of sources for Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Russian Federation, Tajikistan, Turkey, Turkmenistan, Ukraine and Uzbekistan. It also documents factors related to recipient habitat, population status, adverse impacts and dispersal vectors. The compiled data revealed existence of a total of 465 introduction cases in the above-mentioned countries.

3. Over the last decades, many different introductions of non-native fish species have been reported to cause dramatic ecological and biological immediate problems in terms of inland and marine biodiversity at global, regional, national and local levels. A large amount of literature has indicated irreversible ecological and biological changes caused by such introductions. Despite widespread concerns about the increasing threats from introductions of non-native fish species, the current management instruments have limited effectiveness in

elimination or mitigation of the cumulative impacts associated with such introductions due to overall complexity, unpredictable nature of interactions, and case-specific nature of each introduction. The findings clearly indicate that once an introduced fish species generates established populations in an aquatic ecosystem, the fish species composition and diversity in that ecosystem would be greatly altered both directly and indirectly. Introduced alien species can generate major ecological effects through habitat alteration, competition, predation, disease and loss of genetic diversity. Expansion of aquaculture, use of fisheries resources, biological control, deliberate or accidental release of non-native fish species by human are reported to be key driven forces or reasons for fish introductions while global trade, transport and tourism are increasingly contributing to alien species range expansion.

4. Introductions may cause wide range severe problems in terms of aquatic biodiversity by reversing or altering ecosystem functions, species interactions and compositions. This makes it important to develop an integrated national and regional policy/strategy for addressing the problem of non-native fish invasive fish introductions in Central Asia and the Caucasus regions. Although few number of species have been reported to be invasive in these regions, as a result of introductions, made ether intentional or accidentally, detailed identification of all likely invasive species is a difficult task. The region is observing a relative expansion in inland fisheries and aquaculture production, following a significant interruption that took place from early 1990s to mid-2000s. The expansion would further increase the likelihood of alien species introductions into the region.

5. The region seemly lacks policies and management measures to mitigate the effects of introductions of invasive species. The Central Asian and Caucasus region has trans-boundary rivers and big lakes which makes development and implementation policies and prevention mechanisms for fish introductions and transfers at regional level. Efforts therefore must be intensified to prevent and control invasive fish introduction by, among others, identification of potential pathways for transmission of invasive alien species, identification of potential risks, public awareness and education, effective institutional coordination and cooperation, systematic monitoring and inspections.

6. In this context, the attached report includes a series of modules relevant to managing non-native species in aquaculture, including: (I) a strategy for implementation; (II) the steps to take prior to introducing a new species, including application of a risk assessment strategy; (III) the steps to take after deciding to proceed with an introduction; (IV) policies for quarantining; (V) policies for ongoing introductions or transfers that have been an established part of commercial practice; (VI) the steps taken should an invasive non-native organism be released into the wild. It also contains a decision-support tool to accommodate risk and uncertainty in stock enhancement activities.

7. TAC would have a role in the development of regional mitigation measures for invasive species by the establishment of science-based guiding principles and criteria based on the best available data and best practices, taking into consideration the regional needs and likely actions for future challenges. Additional research needs to be conducted on, among others, determination or estimation of ecological interactions and impacts of invasive species; methodology for invasive species detections; identification of risky species for introduction to inland fisheries and aquaculture. In this respect, TAC would also address key regional needs

and facilitate future action prioritization in terms of development of integrated regional management measures for invasive species prevention and control by CACFish.

SUGGESTED ACTION FOR TAC

Against the above background, the Committee is invited to discuss and generate scientific/technical advice, for consideration of CACFish, on how to improve integrated frameworks for invasive species prevention and control in the Central Asia and Caucasus.

Annex

Non-native fish species in Central Asia and the Caucasus: environmentally sound practices for introductions and translocations

by

Ian G Cowx
Andy D. Nunn
Richard Noble
University of Hull International Fisheries Institute
Hull HU67RX, UK

Raymon van Anrooy
Fishery and Aquaculture Officer
FAO Subregional Office for Central Asia
Ankara,Turkey

Contents

Executive summary

Glossary

1 INTRODUCTION

1.1 Background

1.2 Species introductions and translocation operations in Central Asia and the Caucasus

2 MANAGEMENT OF NON-NATIVE SPECIES INTRODUCTIONS

2.1 Introduction

2.2 Procedures for the introduction/translocation of non-native species

2.2.1 Pre-screening proposal

2.2.2 Risk analysis

2.2.3 Socio-economic considerations

2.3 Quarantining and health checks

2.3.1 Identifying the best source of stock

2.3.2 Responsibilities of exporting agencies/countries

2.3.3 Appropriate documentation for import

2.3.4 Disinfect all imported organisms on export and on arrival

2.3.5 Disease diagnosis and health examinations

2.3.6 Quarantine facilities

2.4 Management responses to unplanned introduction non-native organisms

2.4.1 Rapid detection, rapid assessment, rapid response

2.4.2 Planning an eradication operation

2.4.3 Control, containment and mitigation

2.4.4 Cost

2.5 Legislation

2.6 Decision support tool

REFERENCES

1 INTRODUCTION

1.1 Background

Inland fisheries worldwide are degraded by a wide array of human interventions, not least the introduction of non-native aquatic organisms to enhance the fisheries or supplement the fauna (Cowx & Portcarreo-Aya 2011). In order to be cost-effective, the introduction of non-native species to enhance aquaculture production has become popular within the sector. (Growth in aquaculture production and increasing demand to improve production from inland fisheries has resulted in the spread of non-native aquatic organisms (Welcomme 1992). The introduction and establishment of some species into the wild as a resulted of their escapement (Turner 1988; Casal 2006); accidental transfer and even purposeful releases, creates "biological pollution" with unpredictable and usually irreversible ecological impacts (Naylor *et al*. 2001; Wittenberg & Cock 2001). These impacts are often difficult to measure, mainly because of a lack of baseline information recorded from previous introductions where the impacts have already occurred (Smith & Hammer 2006). Nevertheless, impacts to wild stocks and ecosystems have been reported as a result of the introduction of non-native species. The Central Asia and Caucasus regions are no exception and problems have been recognised with the introduction of non-native species throughout the regions (Ager *et al.* 2011)

Invasive, non-native species can cause loss and degradation of biodiversity, affecting the survival of native species by altering their foraging behaviour and reproduction, in turn affecting the native species abundance and distribution (West, Brown & Hall 2007). Invasive non-native species can also introduce disease and parasites (Bauer 1991; Cowx 1994, 1998; Holmlund & Hammer 2003; Gozlan *et al*. 2005), causing economic losses to aquaculture production and revenue (Naylor *et al*. 2000; Subasinghe *et al*. 2001). Non-native species can have direct negative effects on the gene pool of native species, as a result of hybridisation (Largiadèr 2007), affecting the reproduction and resulting in sterile offspring, which can decrease the population size (Ciruna *et al*. 2004). These potential hazards associated with introductions of non-native species in a hierarchy from species-specific to ecosystem-wide risks are summarised in Table 1.1.

Generic guidelines of this nature exist for aquatic species introductions but these tend to target open systems and not necessarily the aquaculture sector. The structure of these guidelines is usually broken down into six components (Fig.1.1), *viz*.: identification of the objectives for the proposed introduction; identification and evaluation of management options including assessment of potential ecological and environmental risks, implementation and monitoring of activities. The strategy presents a logical review and decision process for the holistic evaluation of introductions, integrating ecological, fishery and aquaculture benefits, socio-economic considerations through to its final implementation. At each stage of the process, decisions have to be made about the acceptability of potential impacts of introductions. However, these guidelines are voluntary in nature and mostly focus in the risks associated with stocking and introductions (see EIFAC 1988; ICES 2005 and IUCN 1987, for examples). The advice is general and not detailed. No guidance on assessing consequences is provided and there is usually a requirement for more information on the ecological, genetic, and pathological impacts of introductions linked to the economic and social aspects of the fisheries enhancement programme to aid decision-making. As a consequence, there is often a need to adopt a precautionary approach to stocking and introductions of aquatic organisms because insufficient information is available to make informed decisions, and is the stance taken by FAO (2005) under such circumstances.

Table 1.1. Potential detrimental impacts associated with non-native species in a hierarchy from species-specific to ecosystem-wide outcomes. (Modified from Molony *et al*. 2003)

Outcome	Relative risk	Certainty	Source(s)
Increased intra-specific competition: due to increased abundance of the species by the addition of hatchery-reared fishes	M	M	Ackefors *et al.* (1991): Rowland (1994):: Su & Liao (1999)
Shifts in prey abundance: changes in the abundance of prey species due to increases in fish predator abundance as a result of stocking	L	M	Blaxter (2000)
Prey-switching by wild predators: changes in the targeted prey of wild predatory species, usually to focus on hatchery reared (naïve) fishes due to large numbers released	L	L	Warburton *et al.* (1998): Wilhelm *et al.* (1999): Willette *et al.* (2001)
Starvation/ food limitation: due to overstocking	L	M	Dushkina (1991): Ackefors *et al.* (1991)
Exceeding the carrying capacity of an ecosystem (swamping): due to continued stocking after recovery	M	M	L"Abee"Lund (1991): Leber *et al.* (1998): FAO (1999): Blaxter (2000)
Inter-specific competition: competition between hatchery reared fish and other species with similar ecological requirements. May lead to a reduction in abundances of competing species and prey species	H	M	Rowland (1994): Wiley (1995): FAO (1999)
Displacement of wild stock: by hatchery-reared conspecifics, although there are no well documented examples	M	L	Blaxter (2000): L"Abee"Lund (1991): Leber *et al.* (1995): (1998): Bannister & Addison (1998): Butcher *et al.* (2000)
Introduction of diseases and parasites: especially due to poor hatchery management and husbandry	H	H	Fjälling & Fürst (1987): Heggberget *et al.* (1993): Loneragan *et al.* (1998): Wootten (1998): FAO (1999): Burton & Tegner (2000): Lee *et al.* (2001)
Genetic bottleneck: due to lack of genetic management of broodstock within the production system	H	H	Rowand (1994): Busack & Currens (1995): Compton (1995): Loneragan *et al.* (1998): Penman & McDrew (1998): Utter (1998): Wootten (1998): Cross (1999): FAO (1999): Hershberger (2002): Lester (2002)
Loss of genetic diversity and fitness: certain alleles of wild fish may become rare due to the release of hatchery-reared fish with a low genetic diversity. This is of higher risk where the wild stock is reduced to very low levels prior to stock enhancement.	M/H	L	Leary *et al.* (1995): Penman & McDrew (1998): Skibinski (1998): Utter (1998): FAO (1999): Burton & Tegner (2000): Lee *et al.* (2001): Lester (2002): Aprahamian *et al.* (2003)
Extinctions: the loss of species due to increase in the abundance of released fish and ecosystem shifts	M	L	L"Abee"Lund (1991): Utter (1998): McDowell (2002)
Ecosystem shifts: shifts in the distribution of biomasses or other species, possibly resulting in the loss of other ecosystem values	M	M	White *et al.* (1995): Crowe *et al.* (1997): Fielder *et al.* (1999): Arnason (2001): Lee *et al.* (2001)
Physical environmental damage: due to stocking operations	L	H	Lee *et al.* (2001)
Hindrance of difficult management decisions: (e.g. reduction of effort) due to the perception that stock enhancement will allow fishing activities to continue unabated.	H	H	Burton & Tegner (2000)
Diversion of management resources from other activities: for example, other management strategies.	M	H	Burton & Tegner (2000)

Table 1.2. Summary of principal guidelines on introductions of aquatic animals.

Organisation	Title	Reference / Web page
FAO	International mechanisms for the control and responsible use of non-native species in aquatic ecosystems	Available from the FAO fisheries publications website: http://www.fao.org/fi/website/FIRetrieveAction.do?dom=topic&fid=16007
FAO	Asia regional technical guidelines on health management for the responsible movement of live aquatic animals and the Beijing consensus and implementation strategy	FAO fisheries technical paper 402 available from: http://www.fao.org/fi/website/FIRetrieveAction.do?dom=topic&fid=16007
OIE	Aquatic Animal Health Code.	Includes guidelines for import risk analysis. Available at:http://www.oie.int/eng/normes/fcode/A_summry.htm
ICES	ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004	http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/resources/aqua/introspec/img/itmo.pdf
EIFAC	Codes of practice and manual of procedures for consideration of introductions and transfers of marine and freshwater organisms.	Turner, G.E. (1988). EIFAC/CECPI Occasional Paper No. 23 44 p.
NACA	Manual on risk analysis for the safe movement of aquatic animals	Arthur, J.R., M.G. Bondad-Reantaso, F.C. Baldock, C.J. Rodgers and B.F. Edgerton. 2004. PEC/DoF/NACA/FAO, 59 p. APEC Publication Number: APEC# 203-FS-03.1 ISBN: 974 92182 4 8
IMO	Global ballast water management programme	http://globallast.imo.org/

(A) IDENTIFICATION OF OBJECTIVES OF PROPOSED INTRODUCTION (AND RELEVANCE TO POLICY)

⬇

(B) IDENTIFICATION AND EVALUATION OF PROPOSED INTRODUCTION

Technical feasibility

Biological issues

Social issues

Economic and financial issues

Legal issues

Regional/national/international policy

⬇

(C) CHOICE OF OPTION(S) TO OPTIMISM OUTCOMES OF PRPOSED INTRODUCTION TO MINIMISE POTENTIAL NEGATIVE IMPACTS AND MAXIMISE SOCIAL AND ECONOMIC BENEFITS

⬇

(D) IMPLEMENTATION PHASE

⬇

(E) MONITORING, CONTROL AND EVALUATION PHASE

Figure 1.1. Framework for Responsible movements of living aquatic organisms.

Consequently, there is a need to develop guidelines that accommodate risk and uncertainity as well as enhancing protocols associated with other aspects that require decision making so introductions programmes are carried out in an environmentally friendly, socially acceptable and economically justified manner. The Central Asia and Caucasus regions have recognised this issue, and the requirement for comprehensive policy instruments to cover the use of non-native species in inland fisheries and aquaculture is needed.

1.2. Species introductions and translocation operations in Central Asia and the Caucasus

Data detailing the introductions of aquatic species in the participant countries was extracted and collected from a variety of sources, including the FAO Database on Invasive Alien Species (DIAS), Fishbase and a dedicated questionnaire completed by experts from each country. The information was compiled into a database which was divided into 11 geographical locations (countries) - Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Russian Federation, Tajikistan, Turkey, Turkmenistan, Ukraine and Uzbekistan. In addition, factors concerning the recipient habitat, population status, adverse impacts and dispersal vectors were documented.

The total number of introduction events recorded in the database by October 2011 was 465, of which 213 were target species, 88 non-target species and a further 164 which were listed as unknown, mostly due to a lack of information, but also because some were identified both as target and non-target species in different regions of the same country. The main groups used for aquaculture and stocking activities are bony fishes, crustaceans and molluscs (Figure 1.2). In recent decades the number of introductions of Crustacea and Mollusca has increased, although teleosts remain the dominating group in terms of introduction events with 98%.

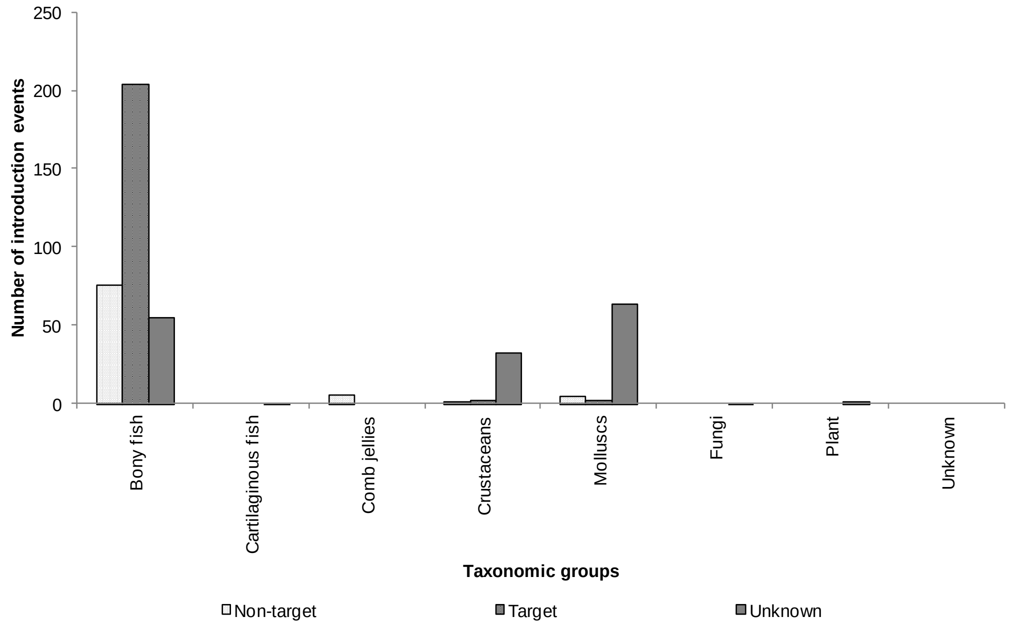

Figure 1.2. Number of target and non-target (accidental or unintentional) species introduced of each taxonomic group (source: Ager *et al*. 2011).

The database provided the capacity to identify the principle purposes for aquatic introduction. Aquaculture contributes to the majority of introductions (26%); capture fisheries (24%), ornamental trade (1%) and biological control (6%), sport (1%), research (2%), natural diffusion (3%); however a further 15% of species introductions have an „unknown" purpose and 22% were accidental or unintentional introductions. Thus, the main objectives of stock enhancement have been to improve commercial or sport fisheries or aquaculture development, which have high social and economic benefits, but can include the rehabilitation of fish stocks (impact mitigation), production and release of exotic fishes to extend the diversity of sport fishes available and bioogical control (Molony *et al.* 2003).

The introductions and translocations of non-native species follow often complex pathways depending on the origin, destination and purpose of the introduction and risks of escape and dispersal. This complexity generally tends to enhance the likelihood of dispersal and establishment of these organisms into the wild (and any non-target organisms they host), and is a major cause of concern. Biocontrol also carries risks when non-native species are involved. These practices are not so widespread but nevertheless they should be planned with great caution. The most striking examples of introduction of non-native fishes for biological control in Central Asia and the Caucasus are the mosquitofishes *Gambusia affinis* and *Gambusia holbrooki*, widely introduced as biocontrol agent against mosquitoes (and mosquito-borne diseases).

2 MANAGEMENT OF NON-NATIVE SPECIES INTRODUCTIONS

2.1 *Introduction*

The output of the analysis of species introductions in Central Asia and the Caucasus highlighted the importance of non-native species in both inland and aquaculture production (Ager *et al*. 2011). Consequently, mechanisms are needed by which any potential detrimental environmental and sanitary impacts are reduced to a minimum and benefits are maximised. Thus there is a need for a mechanism or protocol to improve the management of non-native species introductions for whatever purpose. To this end, a number of guidelines or codes of practice are available in the public domain (e.g. EIFAC 1988; ICES 2005 and IUCN 1987 1995).

Application of the FAO Code of Conduct for Responsible Fisheries [CCRF] (FAO 1995) and the International Council for the Exploration of the Seas [ICES] Code of Practice [CoP] is potentially easier to administer in developed countries with significant scientific and quarantine infrastructure, but in reality it is rarely applied despite being embedded within jurisdictional frameworks. Consequently, adherence to these voluntary codes can be difficult. The CCRF is also a best-practice guide to the management and maintenance of fisheries and aquaculture facilities. The ICES CoP provides valuable input into possible areas that need to be considered when a species is to be introduced. The ICES CoP is divided into a number of steps:

- I) a strategy for implementation,
- II) steps to take prior to introducing a species (including provisions on risk assessment),
- III) steps to take after deciding to proceed with an introduction (including provisions on risk assessment),
- IV) policies for ongoing introductions or transfers that have been an established part of commercial practice,
- V) steps to take prior to releasing genetically-modified organisms (includes provisions on risk assessment), and
- VI) steps to take prior to releasing polyploidy organisms.

Under this CoP, a proponent for a species introduction should provide a detailed species prospectus, which includes, but is not limited to:

- i) information on the potential of transfer of disease agents, parasites, and non-target species;
- ii) a thorough literature review of the species and previous introductions of the proposed species; and
- iii) a contingency plan in case immediate eradication of the introduced species needs to be carried out.

2.2 Procedures for the introduction/translocation of non-native species

2.2.1 *Pre screening of proposal*

The first step is a pre-evaluation by the person proposing the introduction in relation to the species concerned and the facility/environment to which the proposed species is to be introduced. Part of this procedure includes establishing whether the species being proposed is likely to benefit fisheries or aquaculture production and provide an economic advantage and whether the quality of the stock (e.g. in terms of age or size distribution within a fishery) could be improved. This requires not only an assessment of existing production but a review of market demand and the capacity to produce the aquatic products to meet that demand and be profitable. Similarly, for stock enhanced fisheries there is need to assess the status of the extant fish stocks as well as an appraisal of the condition of the water body, and the natural and artificial factors that may limit production.

Specific data on the introduction or translocation include:

- Life history information of the species for each stage
- Interaction with native species
- Receiving environment and contiguous waters
- Monitoring
- Management plans
- Business data
- References

These assessments must be based on firm evidence from scientific studies (preferably of a long-term nature to overcome natural variability) and not on hearsay or unsubstantiated arguments. Descriptions of the data requirements for each of these components is given below. It should also be recognised that much of the information will be required under a full risk assessment (Section 2.3). In all cases the information should be supported by scientifically robust reference material, where available.

SPECIFIC DATA ON THE INTRODUCTION OR TRANSLOCATION

As a starting point for the screening procedure, baseline information on the species to be introduced, how many, their source, at which life stage, the receiving water body and the strategy for the introduction, is required. This information should be linked to the objectives and rationale for the proposed introduction. Imperative within defining the objectives is an explanation why it cannot be met through the utilisation of an indigenous species or through alternative strategies for increasing production or product diversity.

SPECIES ECOLOGICAL DATA

Also critical for making a judgement on the potential success of an introduction or the likely impacts of the introduced species on the receiving ecosystem, is baseline information on the ecology of the species, its reproductive and dietary habits, growth characteristics, physiological tolerance, potential interactions with other species both in its native and introduced ranges, and potential disruption to the receiving ecosystem. This information underpins the risk assessment procedures and will be needed for a final judgement whether a proposal should be allowed to go ahead and what restrictions are imposed on the introduction. This type of information is often readily available, such as the FAO aquaculture species fact sheets (http://www.fao.org/fishery/factsheets/en) and FISHBASE (http://www.fishbase.org/search.php).

RECEIVING ENVIRONMENT AND CONTIGUOUS WATERS

Information on the receiving environment is required, not only to assess the likelihood of the introduction being successful, but also whether critical habitats or species (especially conservation species listed in the IUCN Red Data List) may be potentially disrupted by the introduction. Barriers (physical, chemical and physiological) likely to restrict dispersal of the introduced species should it identified to aid the risk assessment.

MONITORING

One area that has received little attention is monitoring the success of an introduction to support future assessments. There is therefore a need to describe plans for follow-up assessments of the proposed introduced species" success and how any negative impacts on native species and their habitats will be assessed and mitigated. It is imperative that this information is made available for reference by others proposing to introduce the same or different species and should be uploaded to the FAO DAIS database (http://www.fao.org/fishery/dias/en).

MANAGEMENT PLANS

An important part of any proposal is plans to respond to any unforeseen consequences. This includes quarantining and health check procedures and contingency plans in the event of an unintentional, accidental or unauthorised liberation of the organisms from rearing and hatchery facilities or an accidental or unexpected expansion of the range of colonisation after release. Details of these elements are described in Sections 2.4 and 2.5.

2.2.2 Risk analysis

Where a non-routine movement of a non-native species is proposed, a thorough analysis of the risks associated with the exercise must be undertaken. Risk analysis is used to determine the likelihood that an event may occur and what the consequences of such an event will be. A risk framework operates by establishing the context (i.e. proposed introduction event); identifying the risks on the existing situation (consequence and likelihood); analysing the risks; and treating the risks. A measure of risk is typically derived by multiplying likelihood by consequence. A risk matrix, such as that based on the IECS Code of Conduct for Species Introductions (after Campbell 2006), is typically used to determine the level of risk (Table 2.1). The ratings refer to the probability (likelihood) of the impact (consequence) occurring if a species is stocked in a receiving water based on attributes about the ecology of the species and the environment to which the species is being stocked. The likelihood of an event happening according to the ratings in Table 2.1 is defined in Table 2.2.

Table 2.1. Risk Matrix. N = negligible; L = low, M = moderate; H = high; E = extreme

Likelihood	Consequence				
	Insignificant	**Minor**	**Moderate**	**Major**	**Massive**
Rare	N	L	L	M	M
Unlikely	N	L	M	H	H
Possible	N	L	H	H	E
Likely	N	M	H	E	E
Almost certain	N	M	E	E	E

Table 2.2. Likelihood rating

	Description	Percentage
Rare	Event will only occur in exceptional circumstances	<5%
Unlikely	Event could occur but not expected	25%
Possible	Event could occur	50%
Likely	Event will probably occur in most circumstances	75%
Almost Certain	Event is expected to occur in most circumstances	>95%

Table 2.3. Proposed weighting to account for uncertainty of information about potential risks from an introduction

Degree of certainty of risk from stocking	Description	Rating scale
High	Well established knowledge from existing introductions and stock enhancement programmes	0.5
Medium	Knowledge from limited stock enhancement programmes supported by documented ecological and environmental studies	1.0
Low	Little or no previous knowledge from stock enhancement programmes and little or no supporting ecological and environmental studies	3.0

One further element associated with risk is the degree of isolation of the receiving water. For, example, an internal, fully recirculatory aquaculture unit (closed facility) will carry minimal risk compared with an aquaculture facility with a direct discharge to a river or lake with no form of containment or direct introduction into an open water body. Consequently, as part of the assessment procedure a weighting factor can be applied to the scoring system to reflect the degree of isolation (Table 2.4).

Table 2.4. Proposed weighting to account for degree of isolation of receiving water body

Degree of isolation of receiving water body	Rating scale
Internal, fully recirculatory aquaculture unit/ quarantine unit	0.5
Open aquaculture system with full discharge water treatment facilities	1.0
Open aquaculture system with secondary discharge water treatment facilities	1.5
Stocking into isolated water body, e.g. pond or reservoir	1.5
Open aquaculture system with minimal discharge water treatment facilities	2.0
Stocking of culture in open water body with connectivity to with catchment	3.0

It should also be recognised that the risks associated with species introductions can be reduced by mitigation actions such as quarantining or stocking with reproductively sterile fishes (e.g. triploids). If applied, these procedures should be weighted into the overall assessment.

The risk analysis process addresses the major social and economic, biological, and environmental components. With species introduction or stock enhancement activities, it provides a standardised approach for evaluating the risk of genetic and ecological impacts as well as the potential for introducing a non-target species, especially pathogens, that might impact on the native flora and fauna in the proposed receiving area. It should be noted that a number of assessment modules have been developed to address specific steps of non-native species risk analysis by Copp *et al*. (2008, 2009), viz.:

- FISK (freshwater fish)
- FI-ISK (freshwater invertebrates)
- MFISK (marine fish)
- MI-ISK (marine invertebrates)
- AmphISK (Amphibia).

These risk identification toolkits can be downloaded http://www.cefas.co.uk/media/410780/decisiontools_description.pdf. These toolkits encapsulate the procedures described below, and comprise a series of specific modules to assess the environmental and economic risks of species introductions, and provide managers and policy makers with the information necessary to develop mitigation measures to minimise adverse impacts.

Predicting ecological risks

Before an introduction is undertaken, the suitability of the recipient habitat should be assessed. Details of physical and chemical factors as well as environmental tolerances of the species to be introduced should be included in the evaluation. Unsuitability of the habitat of the receiving water may be grounds for rejecting a proposal. If the introduction proceeds, the risks of ecological disruption must be assessed, together with levels of uncertainty. Issues to be examined include interactions through predation, competition, disruption of habitat, and whether there will be niche overlap with native species and negative impacts on species of high conservation value. Food webs should be constructed using whatever information is available, and the potential effects of the species introduction on trophic structure evaluated.

Management procedures to minimize impacts, according to environmental issues and constraints, are also necessary following the introduction of a non-native species. When their introduction has been regulated and subject to the risk analysis procedures already outlined, then the risks posed by that introduction are inherently low, and negligible if into a secure, isolated unit (closed system). However, even with these protocols in place, introductions of non-native species into less secure waters may still occur, such as escapes from otherwise secure aquacultures sites when biosecurity is breached or as contaminants of consignments. Consequently, there is a need to minimise the risk where an unregulated introduction of a non-native species into a water body with inadequate security for containment of that species has occurred. This requires establishing a rapid detection, rapid assessment, rapid response protocol as described in Section 2.4.

Predicting genetic impacts

Genetic impacts through hybridisation, inbreeding, and loss of genetic diversity and co-adapted gene complexes, can hamper the outcome of species introductions. Carvalho (1993) and Ryman *et al.* (1995) suggested that the released of fish should aim to minimise genetically-based changes and to conserve genetic resources. Therefore, any programme should be adopt procedures to minimise the risk.

Where there is evidence of potential genetic contamination, there is a need to develop strategies that will minimise the effects of species introductions on native stocks in recipient water bodies. The following provides some mechanisms that could be adopted:

1. Closed culture – this provides better containment of farmed organisms, for example in land-based operations, but full containment remains difficult.

2. Avoid introducing species or strains that have the potential to inter-breed with species in the receiving water body.
3. Avoid species that have the potential to reproduce – this avoids direct genetic effects. This could be achieved through sterilisation, for example through the use of triploid fish.
4. Localisation – localise fishery or aquaculture facilities far from wild populations, and choose locations for ranching that minimise straying, and reduce gene flow to wild populations.
5. Reserves – areas where aquaculture ad introductions for fishery purposes are prohibited, to protect valuable wild populations.
6. Restrictions on transport – the spread of exotic genes and diseases can be reduced by restricting the transport of live organisms.

PREDICTING RISK OF DISEASE, PATHOGEN AND NON-TARGET SPECIES

With any species introduction there is major concern over the spread and impact of diseases and parasites, and there is a need to protect natural environments from unwanted pathogens. Minimising the inadvertent introduction or transfer of parasites and disease is an important aspect of any movement of fish. Many examples of the translocation of parasites and disease have been identified, thus measures that minimise or eliminate these problems should be introduced. Consequently, minimising the risk of disease and parasite transference is one of the main criteria that must be predicted and addressed to achieve maximum benefit from fish introductions. Four possible strategies exist (Kohler & Stanley 1984; EIFAC/ICES 1988; DeKinkelin & Hedrick 1991):

- risk assessment;
- improved control over fish movements through legislation;
- veterinary inspections and health checks;
- quarantining.

Most agencies have established protocols to assess the health risk posed by introductions to the wild, and The World Organisation for Animal Health (OIE 2011, 2012) have established standards and protocols for such procedures (see http://www.oie.int/international-standard-setting/aquatic-manual/access-online/). All organisms stocked into open waters must first be checked for a range of parasites and symptoms of clinical disease. Presence of any one of an established list of pathogens or significant evidence of clinical disease (see OIE list of notifiable agents; OIE 2011) is grounds for rejecting a proposed introduction and or stocking operation. Fish movements into fully enclosed systems (closed facilities), where the risk of transfer to the wider environment is negligible, should also have a mandatory health check.

2.2.3 Socio-economic considerations

On a global scale, the majority of introductions of non-native freshwater fish have provided great societal and economic benefits (FAO DIAS database - http://www.fao.org/fishery/dias/en; Gozlan 2008, Gozlan *et al*. 2010). However, before a non-native species introduction is considered acceptable or desirable it is recommended that there is a need to justify its potential for providing economic and social benefits that exceed potential environmental costs. International agreements recognise that economic considerations form part of the risk analysis process and the following section provides guidelines explaining factors that need to be assessed when considering economic impacts of non-natives.

Benefits related to the outcomes of the introduction event include:

- Improved harvest yields;
- Opportunity of employment;
- Improved of aquaculture and fishery status;
- Recreational benefit for people (income, employment);
- Reduction of „pest" species (e.g. control of macrophytes);
- Habitat improvement (e.g. phytoplankton control);
- Benefit to conservation of wild species.

In the first instance evidence of harm caused by the organism in question should first be sought from regions where it already exists. Impacts can be considered as either direct or indirect, and commercial or non-commercial (environmental and social). All possible impacts should be considered. Direct commercial effects include types, amount and frequency of damage, commodity losses (yield and quality), costs of control and other additional costs on top of existing production practices. Direct environmental impacts that should be considered include reduction of keystone species; reduction of species that are major components of ecosystems (in terms of abundance or size), reduction in endangered native species diversity (including effects below species level where there is evidence of such effects being significant); significant reduction, displacement or elimination of other species.

Indirect environmental/social impacts include changes to ecosystem services such as effects on human use (e.g. water quality, recreational uses, loss of tourism – an aquatic invasive plant may choke swimming or boating areas making them unsuitable for swimming or boating, hunting, fishing); and costs of environmental restoration. Indirect effects cannot be directly correlated with a specific host or habitat and do not, therefore, directly affect the level of production.

Methods are available to measure both the direct and indirect impacts of the introduction on the existing fishery and ecosystem (see Jones *et al.* 2008). Once the outputs from the impact assessments are available, they should be used to compare the potential economic and social harm against the benefits likely to accrue from the introduction. Where provision of this information is problematic and costly, expert judgment can substitute in the first instance. Expert judgment is used to provide an evaluation of the likely scale of impact, and should take account of both short-term and long-term effects for each level of risk.

The likelihood of impacts materializing is also categorized within a scale of five divisions (Table 2.6).

Table 2.6. Impact likelihoods and definitions defined in the UK Non-native risk assessment scheme (Baker *et al.* 2005)

Score	**Description**	**Definition**	**FREQUENCY**
1	Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
2	Unlikely	This sort of event has not occurred anywhere in living memory	1 in 1,000 years

3	Possible	This sort of event has occurred somewhere at least once in recent years, but not locally	1 in 100 years
4	Likely	This sort of event has happened on several occasions elsewhere, or on at least one occasion locally in recent years	1 in 10 years
5	Very likely	This sort of event happens continually and would be expected to occur	Once a year

2.3 Quarantining and health checks

There are three major steps to deal with non-native species; prevention, early detection and rapid response, and eradication and control (Wittenberg & Cock 2001). The first of these steps should always be the main thrust of any action to minimise the inadvertent introduction or transfer of parasites and diseases. The high costs of control and eradication (Britton *et al.* 2008) highlight the importance of prevention rather than cure in managing species introductions, whether they are deliberate or accidental.

At the international level, prevention is encapsulated in the broad concepts of health certification and diagnosis and quarantining to minimise the risk of introducing pathogens to the importing country and their transmission to susceptible species. Quarantine and pathogen diagnosis procedures should be applied if, and when, there is a risk of introducing or transferring an exotic disease and/or parasite, whether identifiable or not, together with the organisms in question or if there is a risk of introduce a non-target species (fellow traveller). Such procedures should serve to protect the natural environment and natural aquatic biota, as well as serve to support and protect trade in aquatic species, including non-native resources that may not be native but provide significant economic benefit to the host country, e.g. Atlantic salmon in Chile. This will prevent of the introduction of potentially harmful organisms (pathogens or non-target organisms) that have not been approved for introduction (ICES 2005; OIE 2011). The actual procedures recommended depend very much on the disease history of the stocks in question, the likelihood of a fellow traveller, the expertise available at the point of origin of the stocks, the degree of confidence in the abilities of the exporting agency, and the expertise and facilities available at the place of arrival of the stock to be moved. The purpose of an effective strategy is to minimise any risks as far as possible, whilst still enabling the movement, and eventual release, of the organisms in question. Note quarantining is one possible outcome of the risk analysis.

Quarantining and pathogen diagnosis can be broken down into a number of measures (Table 2.7). These include measures relate to facilities and associated activities to hold organisms prior to release into an aquaculture unit, or ultimately into the wild and measures taken prior to and during the importation process to minimise the likelihood of pathogens and disease organisms and fellow travellers being introduced with the target species. In principle, a quarantine strategy should list, amongst other things,

- the source(s) of the proposed stock,
- their disease and parasite history and status,
- what testing has been done and the methods used,
- who has undertaken the testing,
- how the stock is maintained at source,
- who maintains it,
- what pre-shipment certification on the disease status of the stock is available,
- whether that certification is reliable,

- the method of shipping including packaging,
- routes and life-history stages to be shipped,
- where the stock is to be kept on arrival; and
- the chances of the inadvertent transfer of exotic diseases and parasites.

If this information is not included in the proposal then an evaluation of these factors will need to be made. An independent review should advise on whether the level of risk is acceptable, and what modifications to the proposed strategy should be made to improve upon the quarantine aspects of the proposal.

Table 2.7. Summary of requirements for the importation of fishes (adapted from Australia Quarantine Inspection Service (http://www.aqis.gov.au)

Stage	Level	Requirement
Pre-boarder	Source population	Certificate from competent authority attesting to health of fish in consignment and that their source was free of specified disease agents
	Export permits	Certificate from competent authority that consignment is currently approved for exportation
	Husbandry	Certificate from competent authority attesting that fish had not been kept in water in common with farmed food fish and that treatment had been applied for notifable diseases.
Boarder	Documentation accompanying each consignment	To include the name of the species, the number of packages, the number of fish, the permit number and the health certificate.
		Check agency or importer has good record of past performance in delivering valid certification.
	Visual inspection	All fish examined on arrival at port to identify overt disease or cryptic species, and to ensure fish are species approved for importation.
	Quarantine detention	If risk analysis indicates a potential problem, mandatory detention in approved facilities for specified period depending on species.
		Annual renewable permit and approval of premises.
		Supervision by approved officers of procedures in quarantine premises, including disposal of sick/dead animals, transport water, packaging and waste.
	Disease testing	As required by competent authority
Post-boarder	Treatment	If the presence of specific disease agents is suspected or confirmed following diagnostic testing, the consignment should be reject and destroyed or treated by a competent agency in quarantine conditions

2.3.1 *Identifying the best source of stock*

The choice of stock is an important factor in any importation or other movement. Extensive searches should be made to find the most reliable source and avoid countries where the risks of introducing a non-target species are high. In the first instance, countries where notifable disease are known to proliferate, as listed by World Organisation for Animal Health (OIE 2011). The search should include details of where the stock originated, how long it has been kept there, what disease examinations have been performed (and by whom, by what methods and with what frequency) and the results. From this, a picture will emerge of the disease status of the stock. This information will determine the subsequent strategy.

2.3.2 *Responsibilities of exporting agencies/countries*

The exporting agency/country should inform the importing agencies/countries of the risks involved with any particular movement, or method of movement, even when not requested to do so. The extent of responsibility will vary between countries, but is particularly prominent where the exporting agency/country has expertise well in excess of that available to the importing agency/country.

2.3.3 *Appropriate documentation for import*

Appropriate documentation for the movement of live organisms (including eggs) or gametes from one country into another should be provided with all movements. Quarantine and health certification procedures should be conducted pre- and post-transfer in collaboration between fisheries scientists, veterinary scientists and quarantine authorities. Documentation must contain information on the origin of the stock, the stage at which it is to be exported, the disease history and the assurance of all specified tests. An import permit should list prescribed diseases found under inspection and also certify if the shipment was found free of all parasites.. Movements without the appropriate documentation or from export agencies that do not have a good record of performance in health checks must be considered as illegal and destroyed.

2.3.4 *Disinfect all imported organisms on export and on arrival*

Irrespective of the source of stock, confidence in its status and the supplying agency, all shipments should be disinfected at source (prior to shipment) and immediately after arrival in the country in question to reduce the risk of pathogen transfer. Note, treatment of external parasites and bacterial infections may only reduce infection levels, removing the clinical signs of disease but not eradicating the pathogen(s).

2.3.5 *Disease diagnosis and health examinations*

An enclosed area that can be used as a laboratory is necessary to prepare samples and where possible undertake microscopic examinations health checks. Diagnostic methods used to test for the presence of pathogens will examine the organism externally for surface parasites and also internally by dissection. When sampling fish less than 8 cm in length, only a transverse body section is dissected including analysis of the visceral organs, but with larger fish the liver, kidney, spleen and pyloric caecae should be examined. Fish that are visibly unhealthy, diseased or dead during the transfer period in quarantine need to be examined by a fish-health specialist. If the fish-health specialist needs a second opinion the organism must be stored in formalin and transported to a second fish-health specialist. It is critical that personnel are trained in disease recognition, basic diagnostic techniques and the identification of protozoan and metazoan parasites. The following are recommended to support these actions.

- A checklist of diseases or pathogens known to affect the candidate species should be complied and used as a basis for health certification for freedom from such diseases/pathogens. Microscopic examination for external protozoan and metazoan parasites is readily undertaken by individuals with a basic knowledge of biology and access to dissecting and compound microscopes. All animals that are dead, moribund or unhealthy should be examined. Health examinations are necessary to detect sub-clinical or unapparent infections/pathogens. At least one such examination should be conducted pre-introduction and at least one such examination conducted post-introduction. The number of organisms sampled should be in accordance with standard sampling procedures, and the number taken commensurate with the known or suspected pathogen/disease prevalence of specific pathogens/diseases.

2.3.6 *Quarantine facilities*

Where deemed necessary, especially where the risks of introducing a pathogen or fellow traveller is high, the import material should be placed in quarantine. It is not possible to stipulate the exact duration of quarantine evaluation or containment, since this will vary depending on the candidate species and the risks associated with its movement. However, time spent in quarantine should be determined by the relative risk of the transferred species introducing non-native diseases. Organisms must not be released from quarantine in the importing country until approval is given by the certifying authority. Quarantine facilities should comply with specific construction and equipment requirements.

Quarantine facilities should be approved and inspected regularly by competent government specialists to ensure effectiveness. Quarantining must operate under strict standards compatible with the level of risk associated with the proposed introduction. Where the quarantine facility is in private hands, it is essential that a framework exists whereby the proper government authority can control the quarantine process. Usually, this is achieved by legislation where strong penalties for breaches of quarantine security are enforced. Such legislation must include powers to seize and destroy the organisms in question (where necessary).

2.4 Management responses to unplanned introduction of non-native organisms

Fundamental to any management scheme for non-native organisms is preventing their introduction where they are not intended. A prerequisite for this is the design and implementation of predictive risk assessments and protocols to evaluate proposed introductions, with only those deemed to be of low risk allowed to proceed, and usually only into isolated water bodies such as temporary reservoirs (e.g. Kohler & Stanley 1984; Kohler & Courtenay 1986; Kolar & Lodge 2001, 2002; ICES 2004; Copp *et al*. 2005b).

Introduction prevention must be considered as only the starting point of management for non-native organisms and should nest within fully integrated schemes that also incorporate aspects including rapid responses to newly detected introductions, and containment and mitigation programmes for established non-native species.

There are two key factors that must be recognised when methods to control and eradicate non-native fish are considered:

1. There is an almost total lack of tools to adequately control the distribution and

dispersal of invasive fishes.

2. Existing methods to control and eradicate non-native fish are generally lethal and designed to incur high mortality rates in target fishes, and so some sections of society may find their use ethically undesirable.

Thus, any management response to the detection of a non-native fish or pathogen where they are not intended must be targeted to prevent their dispersal and when lethal methods are employed, their use must be justifiable on the basis of contemporary science and long-term benefits to society (Zavaleta 2002; Fraser *et al*. 2006). Even where managers may prefer to use a non-lethal method(s) to remove individual fish from the water body concerned (e.g. electric fishing), legal constraints usually prevent their translocation to a new water body, and thus the fish must still be humanely dispatched.

2.4.1 *Rapid detection, rapid assessment, rapid response*

„Rapid detection, rapid assessment, rapid response" to procedures designed to detect an introduced non-native organism as early as possible in its invasion pathway (IUCN 2000, Manchester & Bullock 2000, Cacho *et al*. 2006; Genovesi 2005). The aim is to detect and then manage that non-native species whilst its distribution is still highly localised (Rejmánek & Pitcairn 2002). It is particularly important for managing those introductions that have occurred without adequate risk assessment and are considered to have the potential to develop pest populations (Zavaleta 2002; Anderson 2005).

RAPID DETECTION

Rapid detection of new introductions requires detection networks to be established with the primary aim to identify the introductions of new species at the earliest opportunity. The establishment of two principal networks should be considered (Lodge *et al*. 2006), an active detection network and a passive detection network.

An active detection network would comprise an organisation or agency with the specific responsibility to detect the occurrence of non-native species as a part of their routine activities. It is unfortunate, however, that the effort required to detect a species is usually inversely proportional to its population size (Barry 2004, Hayes *et al*. 2005). Consequently, for any active detection network to be cost-effective, there must be a careful balance between the high costs of surveying for potentially very small populations (and perhaps unsuccessfully) and the high cost of eradication if that surveying fails to detect a nascent population in the initial stages of invasion.

Passive detection networks are organisations and individuals who may fortuitously detect invasions as they conduct other routine activities. These networks are heavily reliant upon the establishment of a clear line of communication to the active detection network that enables any potential new introductions to be reported quickly. Examples of members of a passive detection network would be conservation and angling groups.

Once a new introduction has been detected and then confirmed as a newly introduced non-native fish to the geographical area concerned, information on the species should be passed immediately to those involved in rapid assessment so that the appropriate response can be formulated

RAPID ASSESSMENT

On the detection of a new, unregulated introduction, there is requirement for rapid assessment of its risk to the receiving water and also the wider environment if that water is not isolated. This can be achieved through the use of habitat mapping and comparison to determine the likelihood of invasion and can be conducted using a GIS platform. To facilitate this action, if a non-native species is detected where it should not be found, its life history characteristics should be elucidated, efforts should be made to determine if it is breeding and thus potentially invasive, and action plans to control or eradicate the population implemented. In addition, existing predictive risk analysis procedures (as outlined in Copp *et al.* 2008) can be used to make decisions over what action is appropriate for that species introduction. Following this appraisal, the appropriate management interventions that may be implemented for an introduced species will range from eradication through to containment and monitoring, monitoring only, or taking no action against the species.

RAPID RESPONSE

Once the appraisal of status and potential risk has provided an objective output on the inherent issues relating to the presence of that species, the management response can be determined. These decisions should be made against pre-agreed contingency plans for either eradication or control (see sections 2.4.2 and 2.4.3). When establishing contingency plans there are a number of overriding constraints that may need to be considered.

- *Resources*: Eradication exercises are often expensive and it is important to determine who is to meet the economic and manpower costs.
- *Opposition*: Even during the early stages of an invasion by an non-native species, eradication attempts remain controversial to the public, politicians and some scientists who believe it is unachievable, unrealistic and, often, morally unacceptable.
- *Inadequate legislation*: Where detection of a new introduction requires a rapid and effective response, it is essential that there is a basis in law to facilitate that response. This will improve the chance of an eradication attempt being initiated quickly.
- *Invasion pathway remains open*: Unless the pathway by which the invader arrived has been closed, for example through increasing the biosecurity of an aquaculture facility, then re-introduction of the non-native species remains a possibility.
- *Feasibility of eradication*: If an eradication is the preferred option, the likelihood of it being successful needs to be assessed through an analysis of logistical constarints, the biological characters of the species concerned, the water characteristics and the management required.
- *Presence of protected species*: Consideration must be given over the presence of any native species with legal protection or high conservation status in the receiving water-body that would be adversely impacted by any eradication attempt.
- *Resource value*: If the receiving water is an exploited fishery of high societal and economic value, assessment must be made of how this will be impacted by the eradication attempt. Where the eradication is carried on a fishery of high resource value, then it may be considered necessary to provide education and awareness campaigns for relevant stakeholders, and consider compensation payments.

2.4.2 *Planning an eradication operation*

Eradication of non-native organisms is used within a rapid response framework or within programmes to extirpate established populations from defined spatial areas. Eradication is viewed by many as a controversial and almost impossible goal due to its high expense, difficulty of success and the likelihood of imposing substantial collateral damage on native species (Simberloff 2002; Britton *et al*. 2008). Nevertheless, once the decision has been taken that an eradication operation is the preferred and accepted option, a comprehensive planning phase is needed. This must integrate across the whole of the operation and not focus solely on the method being employed to deliver eradication. It can be broken down into a number of steps:

1. Description of the initial situation by analysis of components of the ecosystem;
2. Define the desired outcome and determine the most appropriate eradication methodology;
3. Assess the feasibility of a successful eradication, including gaining public support;
4. Execute the eradication attempt;
5. Monitoring the success or failure of the eradication;
6. If successful, assessing the impact of the eradication on native species; and
7. Establishment of a control system to prevent new invasions by the target species

DEFINING THE DESIRED OUTCOMES

There are essentially two scenarios of eradication schemes dependent upon the extent to which the non-native species has proceeded in its invasion pathway when first detected. If the species distribution is highly localised, then eradication may be carried out to prevent potential impacts of that species identified during the risk analysis. Where eradication of an established non-native species is being considered, then the desired outcomes in terms of recovery of native species, habitats or ecosystem functionality, and/ or mitigation of socio-economic impacts must be identified. These can then be used to identify the appropriate evaluation measures of the eradication and a robust post-operation monitoring scheme can be designed accordingly.

DETERMINE ERADICATION METHOD

When an eradication operation is being planned the choice of method crucial. It must be acceptable to all stakeholders, yet still be effective within a pre-defined budget. The methods available to eradicate non-native fish are described in Table 2.8. In the decision over which eradication tool is most effective to use, there are several factors that need to be considered:

Efficiency: The most appropriate eradication method is the one that provides the highest probability of delivering sufficient mortality in the target species to satisfy the desired outcomes.

Feasibility: Although the desired outcome of eradication and the method chosen are critical in the planning phase, an equally important assessment has to be made over feasibility.

Selectivity: Ideally, the eradication method chosen is only lethal to the target species (Sorensen & Stacey 2004; Cotton & Wetekind 2007). Being highly selective minimizes the opportunity for incurring collateral damage, but non-host specific methods are usually more effective.

Undesired effects: When a non-host specific method is chosen, then the effects on the non-target species must be evaluated, especially if these are threatened, endangered and/ or protected. While a limited amount of collateral damage may be unavoidable, this can often be minimised by, for example, removal of non-target fishes from the water body prior to eradication and holding off-site until the conclusion of the eradication operation (Britton & Brazier 2006).

Financial and resources: Prior to the commencement of an eradication operation, the time, personnel, and budget needed to achieve the desired results should be carefully estimated, and the necessary resources raised (Genovesi & Shine 2004).

Public acceptability: The extent to which public acceptability should be considered when determining the most appropriate tool to eradicate a non-native species is debatable, but public opinion can adversely impact eradication operations. Consultation with stakeholders can also be used to raise awareness of the issues of non-native species and to demonstrate their threat to conservation. Eradication publicity can include information on ecological and socio-economic impacts and the efforts to restore the native ecosystem.

Table 2.8. Methods commonly used to eradicate aquatic organisms

Options	Uses and limitations
Eradication methods	
Chemical treatment:	• Usually rotenone, which affects gill-breathing animals through inhibition of oxygen utilisation at the cellular level (Lockett 1998). • Toxicity variable according to species. • Readily degrades following application. • Effectiveness determined by temperature, exposure to light, suspended matter and absorption by bottom deposits. • Successful use is dependent on achieving an even distribution of the required dosage to all parts of the water body. • Areas of extensive macrophyte growth require careful attention. • Aquatic invertebrate populations also need to be considered when determining potential collateral damage incurred on non-target fishes.
Drain-down and disinfect	• Possible in small lakes/ponds where eradication is preferred option. • Difficult to drain a water body completely and this may mean that some individual fish survive in wetted areas and may be the source for recolonisation once the lake refills. • Risk of inadvertently dispersing the non-native fish into river catchments in drainage water. Once fish removed, they will have to be destroyed. • Following drain down, disinfect using lime application to increase pH to lethal levels for all life stages. • Technique disruptive to both the flora and fauna of the target lake and to recreational activities.
Pathogen introduction	• Common approach used in pest management but not for fish. • Too little is known about host specificity of pathogens being introduced. • High risk strategy.
Control methods	
Mechanical control	• Involves directly removing individuals of the invasive non-native species either by hand, mechanically, or draining of infested water body. • Use of barriers to control non-native species largely ineffective but installation can reduce movement of migratory non-native species. • Difficult to produce a barrier suitable to stop invasive species whilst not causing any barrier effects to native species. • Screening can be used to stop the movement of non-native species but are ineffective in preventing the movement of all life stages.
Chemical control	• Involves use of piscicides such as rotenone, neem and pyrethrum (see eradication methods).

Biological control	• Involves intentional use of organisms (e.g. Natural predators and pathogens, sterile individuals) to suppress populations of invasive non-native species (Ciruna *et al.* 2004). • Changing environmental conditions can also be used to remove target species (Gillian et al. 2005); for example water levels can be manipulated to exclude non-native species from spawning areas (Diggle *et al.* 2004). • Provides the safest and most cost efficient approach to solve many invasive non-native species problems. When it is successful, biological control is highly cost-effective, permanent, and self-sustaining (Ciruna *et al*. 2004). • Lack of certainty about the level of control that will be achieved and over what time scale (Wittenberg & Cock 2001). • Debate about the safety of classical biological control, particularly potential adverse affects of introduced biological control agents on non-target organisms.

POST-ERADICATION EVALUATION

Evaluation of the eradication is critical to ensure the desired outcomes were achieved, although it can be difficult to verify the success of eradication (Usher 1989), particularly to determine the timeframe after which point the eradication can be definitively described as successful. This is because even a small number of organisms surviving result in recovery of the non-native invasive species in the long-term. To determine if eradication has been successful, methods must be capable of detecting a species at very low densities.

In addition to monitoring the effect of eradication on the target species, evaluating the operation in relation to the desired outcomes is also important, including assessment of the effects of the action on the native species and ecosystems.

Integral to an eradication campaign is the establishment of practises that prevent reinvasion, such as the closing of open dispersal pathways. Contingency plans should be put in places that enable rapid removal of new propagules if prevention fails.

2.4.3 *Control, containment and mitigation*

Where eradication is not appropriate or feasible, containment and mitigation strategies for can be considered for managing non-native fishes, for example, in a water body containing native species of high conservation value or where the detection of that species that already has a wide distribution (Manchester & Bullock 2000; Secord 2003; Sorenson & Stacey 2004). In such situations, managed control and containment of that species would be more appropriate. The aim is to prevent dispersal to new water bodies, particularly at the inter-catchment/ river basin level. An important component of a containment programme is the ability to detect the invasion of a non-native species rapidly before control measures are implemented (West, Brown & Hall 2007). Containment and control measures should focus on reducing the damage caused as well as reducing the number of invasive non-native species (Principle 15 of the CBD 2002). Effective control will often rely on a range of integrated management techniques, including mechanical control, chemical control, biological control and habitat management (Table 2.8), implemented according to existing national regulations and international codes.

2.4.4 *Cost*

Prevention of the introduction of invasive non-native species is the most obvious first and most cost-effective measure against invasive non-native species and their negative impacts (Ciruna *et al*. 2004). However, if prevention fails, eradicating the entire population of an invasive non-native species within a managed area is often the most desirable option

(McNeely *et al.* 2001). Once an introduced species has become established it can be extremely difficult or more often impossible to eradicate (Ciruna *et al.* 2004), thus control measures are generally not implemented until a species becomes a problem, by which stage the cost of the control of a species increases dramatically (McNeely *et al.* 2001; Marchetti *et al.* 2004)

While eradication may involve high initial economic costs, it is invariably more cost-effective than any measure that requires continuous expenditure over long periods of time (McNeely *et al.* 2001). Short-term control methods are preferred as they can be more economical than eradication procedures, as funding and commitment do not need to be at such high levels and can be balanced out over a period of time. However, if the funding ceases, the population and the corresponding negative impacts will normally increase, possibly leading to irreversible damage (Wittenberg & Cock 2001).

For the removal and control of non-native invasive species, several management techniques used together is more likely to be successful than the use of a single method (Rowe 2003). Eradications are a politically sensitive and controversial issue, because of factors such as adverse impacts on non-target species (Britton *et al.* 2008). Community support is often essential to achieve success in eradication work, and is particularly effective when developed through consultation.

2.5 Legislation

Movements of aquatic organisms should be controlled by legislation. The main provisions are:

- a list of diseases and susceptible aquatic organisms;
- approval of OIE zones (OIE 2011) on the basis of this list;
- a principle of freedom of trade between approved zones;
- the obligation to monitor zones and record species introduced;
- equivalent rules for aquaculture animals or products imported from third countries to be introduced into national waters.

Generally, three criteria are relevant to the control of disease and introductions: the species to be moved, and the places of origin and destination of the fish or fish products. The regulation centres on the following: establishment of health status zones according to the presence or absence of specified fish diseases; protection from contamination of approved zones free of the more serious fish diseases; and the free movement of live fish and shellfish between farms and zones of equivalent health status.

2.6 Decision support tool

The procedures described provide a systematic approach to decision-making regarding the use of non-native species in aquaculture or fishery enhancement. Integral to the procedures are risk analysis and contingency plans that aid the decision to proceed with any introduction. If these procedures are to be used, it is important to recognise that each species and proposal should be treated individually as no situation is alike. The decision to allow an introduction to occur must therefore lie with the competent authority who will assess the information provided by the proposer and evaluate the overall risk of a new species becoming a nuisance and having considerable environmental, economic and social costs. The decision support trees allow the proposal to be evaluated at different levels and stages and will effectively curtail a proposal at an early stage should the proposal be potentially impractical or unviable.

It is recommended each proposal should go through a full risk assessment. This is not simply a disease appraisal but must cover the environmental, ecological, genetic and disease aspects as well as social and economic criteria. The latter is particularly important but may be difficult to carry out, but qualitative procedures based on previous examples may assist until such time as appropriate tools are available. The input information should be validated by an advisory panel and the output used to make the decision on whether to allow the introduction. The protocols assess the environmental and economic risks of species introductions, and provide managers and policy makers with the information necessary to develop mitigation measures to minimise any potential adverse impacts. Where the risk is minimal with a high degree of certainty the introduction can be permitted. Where knowledge is scant, the movement should be subject to a full risk assessment.

All movements should be subject to health checks and inspections to ensure no diseases or non-target organisms are transferred. It is preferable that the consignment undergoes quarantining, especially where veterinary controls in the country of origin are limited. In all cases, movements of new species should only be accepted should a rapid response framework be defined and in place in case the species or a non-target organism becomes invasive. This should include an eradication plan or contingency plans for the control of non-target organisms if eradication is impractical.