EDITORIAL

This issue contains a discussion paper on the use of exotic species and genetically modified organisms in aquaculture and enhanced fisheries, together with a summary of ICLARM's current position on this important topic. NTAS members are strongly invited to comment and to give their views about these issues. There is also an account by Dr. David Little of how chicken processing wastes are used to feed catfish in Thailand. Beyond these articles, we have an encouraging expansion of news items and members' letters - just the sort of current awareness materials that the NTAS should be helping to disseminate. As always, we welcome the submission of more such items, photographs that tell a story and articles.
R.S.V. Pullin

Exotic Species and Genetically Modified Organisms in Aquaculture and Enhanced Fisheries: ICLARM'S Position

R.S.V. PULLIN

Introduction

A well-known international, charitable organization Rotary International suggests the following four-way test for decisionmaking: Is it the truth?; Is it fair to all concerned? Will it build goodwill and better friendship?; Will it be beneficial to all concerned? Similar questions are being asked for publicly funded aquaculture and fisheries research and development (R & D). Will they help to alleviate poverty? Will their benefits be distributed equitably with respect to gender, children and disadvantaged persons? Will they harm or help the environment and biodiversity, i.e., be sustainable or not?

Fisheries R & D proposals are now expected to fulfill most if not all of these tough criteria and use of the precautionary principle, that requires negligible risk, is being debated (Garcia 1994a, 1994b). In practice, however, risk taking continues, in the face of uncertainty, insufficient knowledge, and pressing needs, sometimes with consequent damage to the environment and to people who depend upon natural resources. Bodansky (1991) has given an overview of these issues, stating that "The precautionary principle seems to suggest that the choice is between risk and caution, but often the choice is between one risk and another." Risk assessment is therefore the key approach. The application of risk assessment and risk management to policies on genetically modified aquatic organisms has been reviewed by Hallerman and Kapuscinski (1994).

A debate about decisionmaking in natural resources management, the difficulties of achieving scientific consensus and how to cope with uncertainty is also gathering momentum (e.g., Ehrlich and Daily 1993; Ludwig et al. 1993; Meyer and Helfman 1993; Pitelka and Pitelka 1993). Its practical effect in aquaculture and fisheries has been limited so far, although aquatic examples are often cited. Most fisheries R & D, that involve exotic species, proceed without systematic procedures for risk assessment, such as those described by Bomford (1991) for exotic vertebrates except fish. The nearest equivalents for fish are international codes of practice (Turner 1988) but these have seen little use to date (Courtenay and Robbins 1989; Coates 1992) perhaps because their implementation is thought to be complex and difficult. Bartley (1994) has summarized the simple steps involved in implementing the codes (Box 1), showing that this is not so.

Box 1

Proposal to Import Including:
Planned use of exotic species
Location of facility
Passport information
Source of exotic species

Independent Review Including Evaluation of:
Disease organisms associated with exotic species
Ecological requirements/interactions
Genetic structure and hybridization potential
Socioeconomic considerations
Local species that may be impacted

Advise/Advice

Approval

Protocols If Approved:
Quarantine
Confinement
Monitor

Aquatic resource systems are under only limited control by humans and the effects of interventions are usually difficult or impossible to reverse. Moreover, the connective nature of aquatic environments means that impacts may be widespread. Therefore interventions in the aquatic realm need special scrutiny.

Exotic species are defined here as organisms transported outside their natural range, and include unique distinguishable populations or races, as in the US Endangered Species Program (e.g., Waples 1991). Genetically modified organisms (GMOs) are defined as organisms whose genetic characteristics *are* changed, purposefully or otherwise, by *any* captive breeding, selection and genetic management. This is a broader definition than most in common use, which tend to be applied only to populations that have been subjected to genetic management. Genetic management includes hybridization, manipulation of ploidy and sex determination, and gene transfers. The broad definition used here reflects recognition that any captive-bred populations of a given species can have impacts on open water populations of the same species, ranging from disease transmission to disruption of migration patterns, introgression, etc.

This paper summarizes the issues concerning introduction of exotic species and GMOs in aquaculture and enhanced fisheries, and ICLARM's position.

Decisionmaking

A recent Bellagio conference on Environment and Aquaculture in Developing Countries (Pullin et al. 1993) produced a schema for decisionmaking (Fig. 1) that could be applied to all aquaculture and enhanced fisheries development, including the use of exotic species and GMOs. Its three-fold evaluation process encompasses social effects, environmental effects and assessment of the current state of knowledge upon which decisions can be based.

Such tools are not yet in common use. Proponents of projects, the donors that support them and their intended clients and beneficiaries are under pressure to demonstrate rapid and highly visible impacts. Introductions of exotic species and trials with GMOs can promise rapid recognition. Consultants and entrepreneurs can 'sell' the imported materials, technology, and political benefits for all concerned. This may discourage thorough prior appraisal of the potentials of native species and traditional practices, combining outside knowledge with indigenous knowledge.

Decisionmaking on the use of exotic species and GMOs is therefore a political process that requires, as a key input, the best possible scientific advice, geared towards realistic and practical assessment of risks. Again, apart from existing international codes of practice, good risk assessment tools are lacking. Moreover, most countries lack adequate arrangements for the quarantine of aquatic organisms.

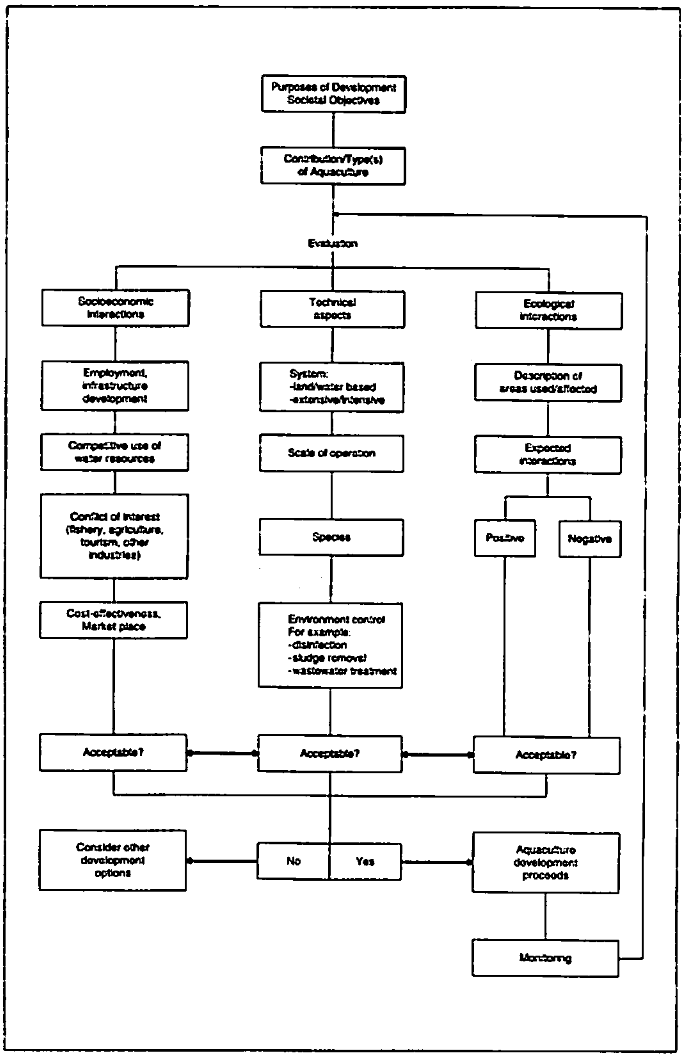


Fig. 1. ***Decisionmaking schema for considering proposed aquaculture developments and their environmental impacts: based on the flowchart published by ICES(1989) and modified at an ICLARM-GTZ Bellagio Conference (Pullin et al. 1993).***

Lessons from History

Much of the world's agriculture and forestry is based upon exotic species. About 95% of all livestock products (meat, milk and eggs) derives from five species. For plants, the corresponding figure is about 100: cereals, fruits, roots and tubers, salad crops, spices and vegetables (Prescott-Allen and Prescott-Allen 1990). For aquaculture, most current production comes from a few major groups, comprising about 200 species (Table 1). However, hundreds more could be screened for their aquaculture potential.

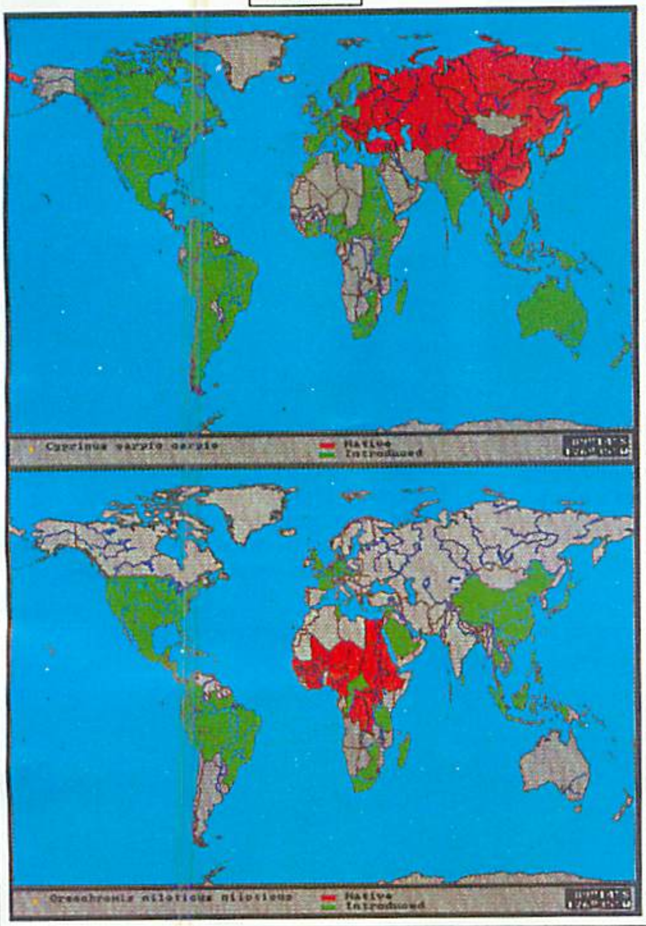
Exotic species that have been proven elsewhere in aquaculture are often considered a quick and easy option for development. Indeed, there is already a long history of use of exotic species - for example, the common carp *(Cyprinus carpio)* and the Nile tilapia *(Oreochromis niloticus)* are essentially in global use (see Box 2). Existing regulations have not prevented numerous unauthorized introductions of exotic species. GMOs are also widely used in aquaculture.

There are also less purposeful or accidental ways through which exotic species are spread. For example, aquarists have been responsible for 65% of the 46 exotic fish species established as breeding populations in open waters of the USA (Courtenay and Stauffer 1990). Household members often cannot bear to kill their aquarium pets when faced with a house move or declining interest, and they release them to the nearest waterbody. In the marine environment, ballast water has been a major cause of the spread of exotic aquatic organisms (Jones 1991).

How much harm or good has resulted? Dr. Robin Welcomme of FAO has led the documentation on this (Welcomme 1988). The ICLARM-FAO FishBase Project (Froese et al. 1992) (see Box 3) includes FAO's records and other sources of information on fish introductions. Clugston (1990) has reviewed the use and impacts of exotic plants and animals in aquaculture in the USA.

Most introductions of exotic species have no discernible effects because the species do not become established, cause no new diseases, etc. Beverton (1992) reviewed 1,354 purposeful introductions of exotic fish into inland waters: 73% had little or no effect on the receiving ecosystems because they disappeared without trace, were unable to spawn naturally or

Box 2



Box 3

Species : *Oreochromis mossambicus*
Introduced in : Kiribati Year: 1958
From: Hawaii
Reason for introduction : Accidental during trials as tuna bait
Occurring in the wild: yes self-producing
Established in aquaculture: no
Significant ecological interactions : yes adverse
Significant socioeconomic effects : yes adverse

Comment:
Accidentally introduced to Fanning Atoll in the Line Islands from research vessels examining the potential use of tilapia as tuna bait. Stunted tilapia populations in inland ponds destroyed traditional culture of milkfish and attempts to eradicate tilapia improved unsuccessful.

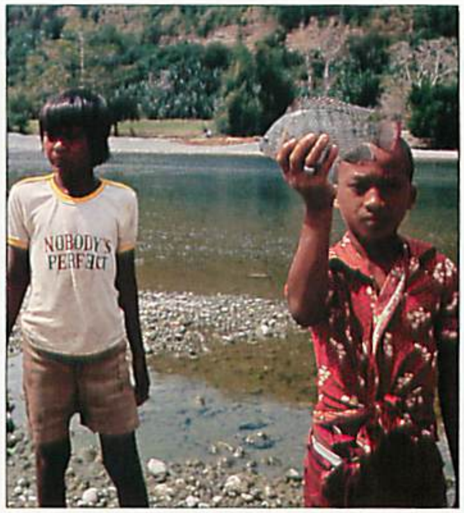
Example of a record from the INTRODUCTION Table in FishBase. The information is based on Lobel (1980), Welcomme (1988) and Nelson and Eldredge (1991). FAO and ICLARM have a collaborative agreement to update this information.

became established to only a limited extent; 3% went through boom and bust cycles; 17% became established with beneficial or neutral effects; and only 7% had discernible harmful effects. It must be emphasized, however, that harmful effects can be severe and may take a long time to develop - for example, 100 years for the sea lamprey (*Petromyzon marinus*) from its entry to the Great Lakes of North America to cause serious harm to their fish and fisheries (Beverton 1992). Also, in aquatic ecosystems, particularly tropical

Table 1. Summary of the commodity groups and numbers of families and species involved in the majority (>95%) of world aquaculture. The total number of species is in fact greater as can be seen from the entries for higher taxa (usually genera). Source: Pullin (in press) - original data and nomenclature from De Luca (1988), Taiwan Fisheries Bureau (1990) and FAO (1991).

Commodity group	No. of families from which cultured species are derived	Total no. of species cultured	No. of species or higher taxa that account for >95% of total production of that commodity group	Names of those species or higher taxa
Seaweeds	5	6	4	*Eucheuma* spp., *Laminaria japonica, Porphyra tenera, Undaria pinnatifida*
Molluscs	9	43	9	*Anadara granosa, Arca* spp., *Crassostrea virginica, Mytilus edulis, Mytilus smaragdinus, Pecten yessoensis, Solen* spp., *Venerupis japonica*
Crustaceans	4	27	7	*Macrobrachium rosenbergii, Natantia, Penaeus chinensis, Penaeus merguensis, Penaeus monodon, Penaeus vannamei, Procambarus clarkii*
Finfish Freshwater and Brackishwater	15	72	17	*Anguilla* spp., *Aristichthys nobilis, Carassius carassius, Clarias* spp., *Coregonus* spp., *Ctenopharyngodon idella, Cyprinus carpio, Hypophthalmichthys molitrix, Ictalurus punctatus, Mugil* spp., *Mylopharyngodon piceus, Oreochromis* spp., *Oncorhynchus mykiss, Parabramis pekinensis, Plecoglossus altivelis, Puntius javanicus, Salmo trutta*
Marine	9	33	4	*Dicentrarchus labrax, Lates calcarifer, Oncorhynchus gorbuscha, Oncorhynchus keta, Oncorhynchus kisutch, Oncorhynchus nerka, Oncorhynchus tshawytscha, Paralichthys olivaceus, Pagrus auratus, Salmo* spp., *Seriola quinqueradiata, Sparus auratus, Sparus major, Trachurus* spp.
TOTAL	**42**	**181**	**58**	

1. Farming native species has the least ecological risks:* Chrysichthys nigrodigitatus, *an African catfish species, under development for aquaculture in Côte d'Ivoire.



2. Farmed exotic fish escape and can become established in natural waters: Nile tilapia (*Oreochromis niloticus*) in northern Luzon, Philippines.

3.Farmed exotic species can become so important in aquaculture that they are eventually regarded as native by farmers and consumers: Majalayan strain common carp (*Cyprinus carpio*) in West Java, Indonesia.

4. Farmed exotic species can become commodities for international trade: red tilapia hybrids, farmed in Jamaica and bought from a supermarket in the United Kingdom.

***5. Fisheries enhancement can use native or exotic species: part of the vast Sepik river floodplain in Papua New Guinea (PNG) where a UNDP/FAO project is introducing exotic species to fill vacant ecological niches and to supply much-needed foodfish. The area already has a successful fishery for tilapias, which are exotic to PNG.* ALL PHOTOS BY THE AUTHOR.**

marine habitats, our knowledge is often so fragmentary that some effects of introduced species and GMOs may go unrecognized. Therefore, the low proportion of introductions and transfers that cause noticeable harm is not an argument for a lack of caution and controls.

Some introductions have brought considerable benefits; for example, the topshell *(Trochus niloticus)* in the central tropical Pacific and the Nile tilapia *(Oreochromis niloticus)* in Asian countries. The latter could be considered analogous to the introduction of the rubber plant to Southeast Asia, the foundation of a sustainable and highly valuable source of livelihood. Occasionally, exotic species that have given rise to valuable openwater fisheries [e.g., the tilapia *(O. mossambicus)* fishery in Papua New Guinea] or have become important in aquaculture [e.g., coho salmon *(Oncorhynchus kisutch)* in Chile] are now themselves a subject for protection regarding further introductions.

The main problem facing scientists and decisionmakers is that the long-term effects on aquatic biodiversity of the escape of exotic species or GMOs from aquaculture, or their release for aquaculture or fisheries enhancement, cannot be predicted with certainty. Decisionmakers rely on informed guesswork and value judgments. For example, Malaŵi keeps out exotic species for aquaculture lest they change the unique faunal assemblage of Lake Malaŵi. Should the same kind of prohibition apply to other countries whose rivers drain into the Zambezi? What effect would exotic escapees have in these rivers? No one knows. The precautionary principle suggests assessment of risks and benefits before introducing exotic species, though some proponents of aquaculture R & D may prefer to try them regardless. The solution is systematic assessment, based on available knowledge and informed opinion, as called for by Turner (1988).

The potential effects of GMOs are hardly known and apart from the effects of captive-bred salmonids on natural stocks, discussions have focused mainly on the theoretical pros and cons of transgenic organisms yet to be produced rather than on captive-bred aquatic organisms in general. Much more information is needed here, based on scientific principles and research.

Towards a Balanced Policy

Most countries already have a long history of introductions and a far from clean slate with respect to escapes or releases of exotic aquatic organisms. GMOs are already used in aquaculture and their use will undoubtedly increase. In aquaculture and fisheries development, some loss of biodiversity is unavoidable, as in agriculture and forestry. It should, however, be possible to establish risk assessment procedures that will enable decisionmakers to weigh potential benefits against potential environmental costs, including losses of biodiversity.

For example, if in a developing country, with little or no aquaculture, a proposal was made to bring in an exotic species for aquaculture or enhanced fisheries, and risk assessment revealed that this species might colonize that country's open waters (and maybe also those of neighboring states) to the detriment of valuable native biota and habitats, then the potential costs may be judged to be too great and a recommendation made to investigate instead the potential of native species, including their scope for genetic improvement.

Conversely, where exotic species or GMOs are already the basis of important aquaculture and enhanced fisheries, with no evidence of them having caused significant environmental harm, then it would be reasonable to pursue further development of such aquaculture or fisheries. Indeed, expansion to new areas could be supported, *given prior thorough appraisals of the possible environmental and social consequences.*

ICLARM's Position

ICLARM recognizes the needs of development and conservation and is involved in strategic research with exotic aquatic species and GMOs because these will undoubtedly have important roles in helping developing countries to meet future food security needs as their counterparts do in agriculture and forestry. ICLARM considers that genetic enhancement and genetic conservation are interdependent and that rational scientific principles must be applied to both aspects.

ICLARM's quantitative genetics research in Asia currently uses an exotic species (*O. niloticus*) introduced to Asia from Africa long before ICLARM's foundation. Selectively-bred strains (GMOs) of *O. niloticus* are being disseminated by ICLARM and its collaborators, under strict quarantine and research protocols, to different parts of the Philippines and to other Asian countries that already farm this species.

ICLARM secures independent appraisals of the possible environmental consequences of tilapia transfers and holds that the risks and benefits of transfers of exotic species and GMOs must be thoroughly appraised.

ICLARM has not been and will not be the agency to bring tilapias or any other exotic species into a country or waterbody for the first time, without legal permission from the appropriate government and and other authorities and, without thorough prior appraisal of the possible consequences, including an assessment of public attitudes. The prior concurrence of all parties that might be affected would also be needed.

ICLARM realizes that GMOs that gain access to the natural ranges of the species from which they have been developed (e.g., tilapias, genetically modified in Asia, then shipped back to their natural ranges in Africa) could affect native populations. Again, thorough official formal approval and appraisal of the possible consequences and the concurrence of all potentially affected parties would have to precede any transfers.

ICLARM has been active in investigating and promoting responsible and careful practices with respect to the use of exotic species and GMOs as follows:

- ICLARM is one of the few organizations to have applied international codes of practice (Turner 1988) for transfers of exotic species (Costa-Pierce and Soemarwoto 1990).
- ICLARM was instrumental, in 1985, in getting regional agreement on a code of practice for the introduction or transfer of tridacnid clams in the Indo-West Pacific region (Munro et al. 1985).
- New founder stocks of Nile tilapia for research on genetic improvement, transferred by ICLARM to the Philippines from Africa in 1988, were rigorously quarantined for 3-7 months in a custom-built facility.
- ICLARM convened, in 1991, a workshop on the status of the common carp as an exotic species in Malaŵi and its possible impacts (Msiska and Costa-Pierce 1993).
- ICLARM convened, in 1992, a workshop on giant clam genetics with the objective of providing a basis for selective breeding of giant clams and for re-establishing locally extinguished giant clam stocks on a sound genetic basis (Munro 1993).
- ICLARM convened in 1992 an international workshop to discuss research approaches and environmental safeguards with respect to aquatic germplasm (ICLARM 1992).
- ICLARM hosted, in 1993, an FAO workshop, the purpose of which was to make existing international codes of practice on transfers of aquatic organisms more user-friendly and therefore, hopefully, more widely used.
- For the ICLARM-coordinated International Network on Genetics in Aquaculture (INGA) (Seshu et al. 1994), the member countries have agreed upon a set of import and export protocols with which they will comply when transferring fish across political boundaries (INGA 1994).
- The ICLARM-FAO FishBase project helps to monitor fish transfers and their effects.

ICLARM will continue to use the best 'instruments' that are available for assessing and lessening the risks associated with the use of exotic species and GMOs and will strive to set an example to the world of aquaculture and fisheries R & D by caution, by thorough compliance with national and international regulations and protocols (binding or otherwise) and by encouraging all concerned with the use of exotic species and GMOs in aquaculture and enhanced fisheries to do likewise.

The entry into force in December 1993 of the International Convention on Biological Diversity has started a new era of documentation, evaluation and sustainable use of living organisms. There will be new guidelines, laws and protocols under this convention with respect to the use of exotic species and GMOs. ICLARM looks forward to assisting with their evolution and implementation, wherever it can make useful contributions.

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