

# Introduction of Alien Species/Strains and Their Impact on Biodiversity

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## Abstract

Africa has been the source of alien species that are widely used in aquaculture and fisheries in many parts of the world, but African aquaculture has not benefited greatly either from the domestication of African species or the introduction of improved breed from elsewhere. In efforts to develop African aquaculture further, there is a desire to re-introduce genetically improved tilapia (primarily *Oreochromis niloticus*) back into Africa. However, there are risks to native African aquatic biodiversity that must be dealt within the re-introduction of African species. Analyzing these risks in order to make informed decisions will require, *inter alia*, information; such an information source exists in the FAO Database on Introductions of Aquatic Species (DIAS, <http://www.fao.org/fi/statist/fisoft/dias/index.htm>). An examination of DIAS revealed that 139 species from 87 genera have been introduced into 42 African countries. Most of these introductions were finfish (79 per cent). However, 7 per cent were molluscs and 9 per cent were crustaceans. Tilapia is the most important species of fish that Africa has contributed to world fisheries and aquaculture. FAO Fishery statistics reveal that tilapias are farmed in 61 countries outside of Africa (33 in Africa) and these alien tilapia account for 2 per cent of the world aquaculture production. In Africa, tilapia accounts for about 40 per cent of the aquaculture production. The impacts from tilapia introductions vary greatly. The information on the impacts of the introduction is poor, but tilapia introductions into Africa had positive socio-economic benefits. There were not many adverse ecological impacts reported in Africa, in spite of the indication that most of the introductions led to self-sustaining populations. Developers concerned with both food security and conservation will need to collect information such as that contained in DIAS, process this into knowledge so that informed decisions can be made, and then develop the wisdom to know when and where to make decisions for the greater good of this and future generations.

## Introduction

The use of introduced species in Africa has been called a paradox (Satia and Bartley 1998) because Africa has been the source of alien species that are widely used in aquaculture and fisheries in many parts of the world, but African aquaculture has not benefited greatly either from the domestication of African species or the introduction of improved breed from elsewhere. In efforts to develop African aquaculture further, there is a desire to re-introduce genetically improved tilapia (primarily *Oreochromis niloticus*) back into Africa. Indeed, this desire is also consistent with the Convention on Biological Diversity's intention to share and transfer technology and information (CBD 1994).

However, not all alien species have benefited their new environment; alien species and

alien genotypes are now recognized as one of the major threats to aquatic biodiversity. The WorldFish Center, the developers of genetically improved farmed tilapia (GIFT), had a policy of not re-introducing GIFT fish back into Africa because of fears they would pose a risk to the genetic resources of wild tilapia. Thus there must be a balance between development and conservation objectives. Developers, resource managers, and aid agencies need to know how and when to use alien species and genotypes in a responsible manner.

This will not be a simple task. As developers concerned with both food security and conservation, we need to collect information, process this into knowledge so that informed decisions can be made, and then develop the wisdom to know when and where to make decisions for the greater good of this and future generations.

## Information

Gathering information is the crucial first step in our process. We need information on the extent of introductions, who was responsible, what were the reasons, and what were the impacts (good and bad). To examine the extent of alien species in Africa, we queried the FAO Database on Introductions of Aquatic Species (DIAS, <http://www.fao.org/fi/statist/fisoft/dias/index.htm>). Satia and Bartley (1998) reported that 139 species from 87 genera have been introduced into 42 African countries. Most of these introductions were finfish (79 per cent). However, 7 per cent were molluscs and 9 per cent were crustaceans. Focusing on tilapia, this is the most important species of fish that Africa has contributed to the world fisheries and aquaculture. FAO Fishery statistics reveal those tilapias are farmed in 61 countries outside of Africa (33 in Africa) and these alien tilapia account for 2 per cent of the world aquaculture production. In Africa, tilapias represent about 40 per cent of aquaculture production. Tilapia spp have also been moved about within Africa – production from alien tilapia in Africa is also increasing (Figure 1).

The impacts from these introductions vary greatly. In Venezuela and the Great Lake of Cambodia, for example, tilapia appear not to have had any significant influence on native populations. In the Philippines, however, tilapia has displaced local species as well as the commercially important milkfish from coastal ponds (see Pullin et al. 1997). DIAS attempts to document the nature of the impacts of introductions by asking respondents to classify whether the impact was positive, negative or undecided from both ecological and socio-economical

perspectives (Figure 2). The information on the impacts of the introduction is poor, but generally it was reported that tilapia introductions into Africa had positive socio-economic benefits. In Africa, there were not many adverse ecological impacts reported, in spite of the indication that most of the introductions led to self-sustaining populations (Figure 3).

Another significant type of information needed is on genetic technologies. That is, how different are the alien species or alien genotypes from the wild relatives? Tilapia has been genetically improved through selective breeding programs, such as the GIFT program (Eknath et al. 1993), primarily through hybridization (see review in Bartley et al. 2001) and through the application of sex reversal and chromosome set manipulation (Mair et al. 1997). The use of gene transfer technologies is currently being studied, for example in the USA, the United Kingdom and Cuba.

## Knowledge

One definition of knowledge is “an organized body of information” (Oxford American Dictionary 1979 Oxford University Press); DIAS, FishBase, and FAO statistics do represent knowledge in this regard. But we believe more is needed to be knowledgeable, that is, to use the organized body of information as a decision tool. Risk/benefit analysis is one means to move towards knowledge on how and when to use alien species.

Risk assessment will need to examine both ecological and economic factors. Categories of ecological risk include species interactions,

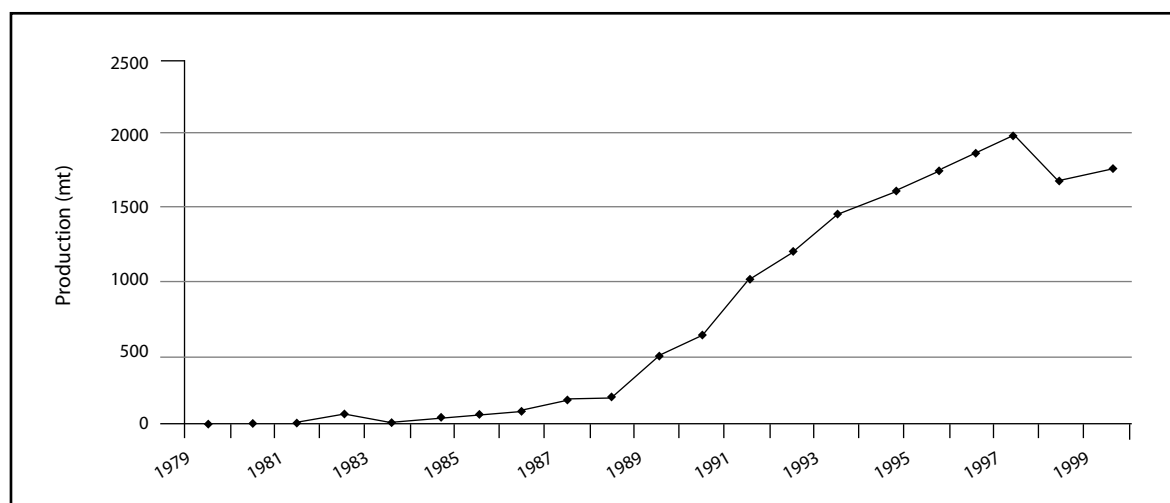


Figure 1. Aquaculture production from introduced tilapia in Africa.

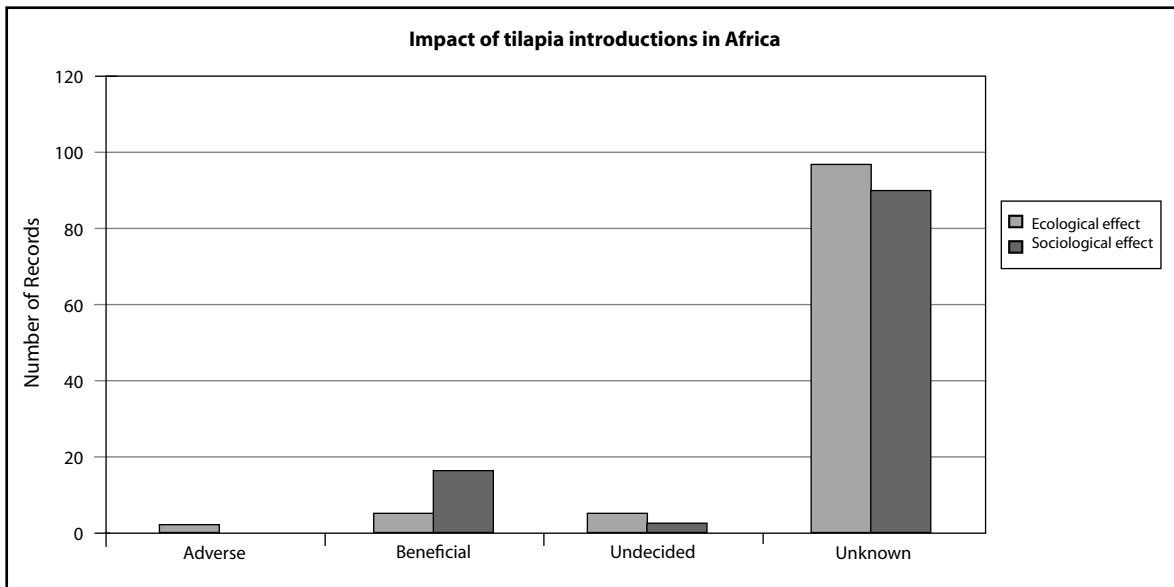


Figure 2. Impact of tilapia introductions in Africa (from DIAS).

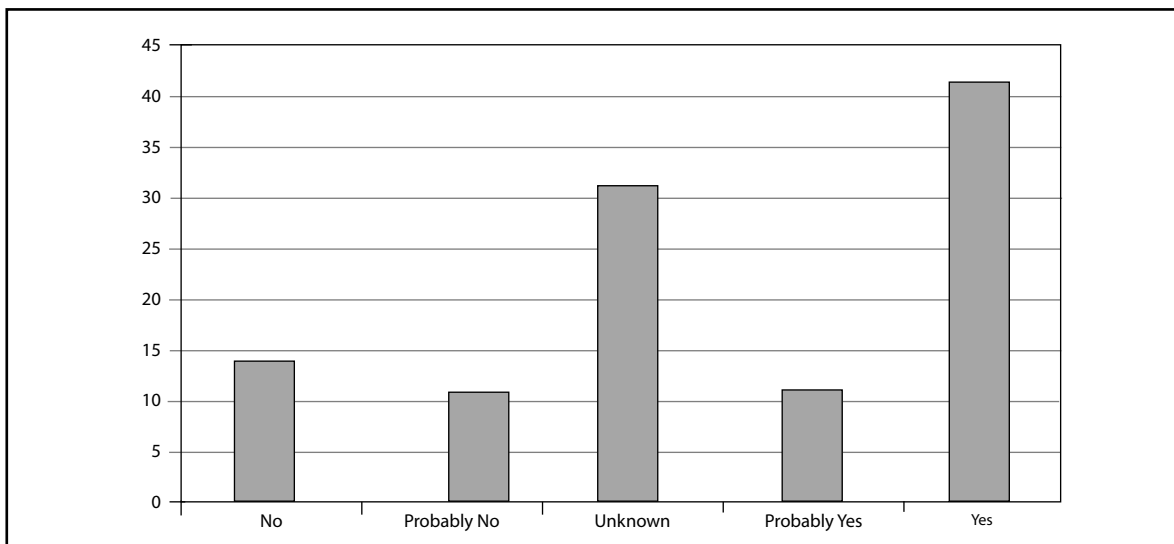


Figure 3. Number of records indicating whether or not tilapia introduced into Africa established self-sustaining populations.

genetics, disease and habitat modification. Economic risk from using alien species or genotypes includes failed breeding programs, poor production and failure to be able to respond to market demands.

When considering the special case of tilapia re-introduced to Africa, species interactions and genetic concerns figure most prominently. Most tilapias appear to be able to form viable inter-specific hybrids (Macaranas et al. 1986; Agnèsè et al. 1998; Bartley 2001) and thus on escaping from culture could breed with local species. Agnèsè et al. (1998) pointed out the difficulties in predicting the outcome of various ecological interactions between different tilapia species:

in one example one species would emerge as dominant after a period of hybridization, whereas in another area the interaction would result in the reverse outcome. Thus, transgenes inserted into one species of tilapia would then have a means to move into other related tilapia species. This could have minimal or maximal impact depending on the phenotypic change imparted by the trans-gene in its new host in the new environment.

With the vast array of genetic technologies available, in analyzing risk it will be more important to focus on the phenotypic change these technologies produce than on the technologies themselves. A diverse international

group of experts stated that policies concerning the use of genetic technologies must, “Recognize that in the formulation of biosafety policy and regulations for living modified organisms, the characteristics of the organisms and of potentially accessible environments are more important considerations than the processes used to produce those organisms,” (Pullin et al. 2000).

Disease concerns are discussed in detail by Subasinghe (this volume). We do have good information on tilapia pathogens and disease is not a major hindrance to tilapia culture. However, looking at experiences from other species, there are examples where conspecifics moved outside their range or re-introduced back into their range have caused unexpected disease problems. Atlantic salmon moved from the Baltic Sea to Norway infected Norwegian Atlantic salmon with a parasite to which Norwegian salmon had no resistance. European cupped oysters that were re-introduced to Europe from the Pacific Northwest of North America carried the pathogen bonamia with it that has caused the collapse of the European cupped oyster industry.

Tilapia has been domesticated in Southeast Asia, primarily in the Philippines and it is expected that although disease resistance was not specifically selected, it did come along with the domestication process (Tave 1996). Thus, tilapia genetically improved outside of Africa may be resistant to numerous pathogens to which the unimproved or native tilapia would be susceptible (they may have pathogens that could effect other fish species as well, not only tilapia). The genetically improved tilapia may act as carriers for these pathogens and could serve as a mechanism to transmit disease to native African fish.

We have a variety of information to incorporate into our risk analysis. However, as knowledgeable

scientists we know we will never have enough information to address completely the complexities of moving new species and genes into areas being used by humans. Therefore, we must also insert an element of precaution, that is, how to proceed with limited or incomplete knowledge. FAO and the Government of Sweden produced guidelines and reviews on the precautionary approach to capture fisheries and species introductions (Bartley and Minchin 1997; FAO 1997). Elements of the precautionary approach are outlined in Table 1. This approach does not equate to a ban on species introductions, although by the “reversibility” criterion, alien species are not precautionary. Nor does the approach serve as an excuse not to reduce uncertainty. The establishment of reference points will require scientific rigor and the collection and monitoring of various types of data.

Realizing that we must take special precautions to protect aquatic diversity because of limited knowledge may be considered a type of wisdom, which is the subject of the next section.

## Wisdom

We now move to the most difficult of our steps. If we collect information and organize it into knowledge, then surely wisdom will follow. Hopefully it will, but it is not a certainty. Wisdom has been defined as “soundness of judgement”. And here lies a problem: judgement of one may not be the same as others because of different personal, cultural, and economic backgrounds. It also may be different because of the ways we organize our information and how we deal with uncertainty.

There are a few common goals in regard to sound judgement, such as long-term sustainability, equity, and peace. However, these are not independent of a society’s or decision-maker’s

**Table 1. Elements of a precautionary approach to the use of alien species/genotypes.**

Element	Example
Establishment of reference points	Less than 0.1 per cent escape from fish farm
Establish pre-agreed actions and contingency plans as reference points are reached	Improve containment of farm; relocate farm; close farm
Maintain productive capacity of resource	Conserve local diversity in African tilapias
Impacts should be reversible within 20 to 30 years	Difficult to reverse an introduction that has caused environmental problems. Mitigation could be part of pre-agreed actions
Burden and standard of proof	Controversial: who should bear this burden?

background, and achieving them will also require strong political will. Providing for rural populations, conservation, protecting threatened species are all matters to be decided, based on political, social, and economic realities in many areas. Short-term gains from using alien species must be balanced against the long-term threats to natural ecosystems. Can well thought-out, planned, and monitored introductions have long-term gains?

Perhaps the “wisest” thing to do is to follow a precautionary approach (above), and first reflect on the necessity of the importation of exotic species, or even individual fish. If a local alternative exists, why run all these, mostly irreversible, risks of importing individuals or exotic species? An example could be the development of a Genetically Improved Farmed Tilapia for use by farmers in developing countries, based on local populations, by the WorldFish Center (2001). Only if the use of local alternatives is not feasible, the introduction of an exotic species could be considered, using the different codes and guidelines concerning species introduction, such as those developed by the International Council for the Exploration of the Sea (ICES) (1995) that have been adopted in principle by FAO regional bodies and have been incorporated into the FAO Code of Conduct for Responsible Fisheries (<ftp://ftp.fao.org/docrep/fao/003/W3592e/W3592e00.pdf>). The basic elements of these codes require that:

- a proposal to introduce an alien species must be submitted to an independent advisory board for review;
- an environmental impact assessment must be done and reviewed;
- the proposal is rejected, accepted or accepted with modification, following the above review;

- neighboring areas and countries that could be impacted are informed;
- monitoring and quarantine measures are established; and
- the program should be modified as necessary, based on monitoring and evaluation.

In the case of tilapia in Africa, non-introgressed native populations, i.e., those that have not interbred with alien species, are getting harder and harder to find; the domestication process including genetic improvement of native species will create alien genotypes from native genotypes, and the *O.niloticus* has established feral populations in many parts of Africa through its use in aquaculture. It would seem unwise to unduly restrict a developing aquaculture industry from re-importing genetically improved tilapia, or developing breed improvement centers in many parts of Africa where native populations are already introgressed or where the environment has been altered by development. All importation must follow appropriate fish health certification and quarantine procedures.

It would also seem unwise to introduce alien tilapia genotypes into areas where the native tilapia populations are still relatively intact. The genetic diversity of tilapia is extremely complex with different sex determining mechanisms and brooding strategies. This diversity can easily be compromised by alien genotypes. Thus it appears wiser to attempt to zone areas of Africa where alien genotypes would serve aquaculture interests and present minimal threats to the environment. Likewise, there should be zones where alien genotypes are restricted in order to conserve the natural genetic diversity of tilapia. Reference points (for example in Table 2) and monitoring will need to be established to assess the impact and decide on any contingency actions.

**Table 2. Some examples of reference points for the application of the precautionary approach to the use of alien species.**

Description	Reference Point
Conserve rare genes in wild population	$N_e > 100$
Acceptable level of gene flow between alien and native species	$m < 1$
Acceptable level of endangerment for wild population	80, 50, 20 per cent decrease over 10 years or 3 generations
Risk of extinction for wild population	$N_e < 50$ ; order of magnitude decreases; 50 per cent probability in 5 years
Presence of pathogens from alien species in wild population	0 tolerance in many cases

The will to establish and enforce such zoning is a crucial and difficult component. Once an alien species or alien genotype has been imported and used in one part of a country, it will be difficult to keep it from spreading to other areas. In this regard, education and awareness-building will also be necessary in order to convince developers that the responsible use of alien species means that in many places, their use will be prohibited.

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