

Genetic Enhancement and Conservation of Aquatic Biodiversity in Africa

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Abstract

There is a pressing need to enhance fish production in Africa through improved farm management and the use of improved fish breeds and/or alien species in aquaculture while at the same time conserve the aquatic genetic diversity. This paper presents the outcome of the Expert Consultation on Biosafety and Environmental Impact of Genetic Enhancement and Introduction of Improved Tilapia Strains/Alien Species in Africa held in Nairobi, Kenya on 20-23 February 2002. The main topics discussed were status of aquaculture in Africa and the role of genetic enhancement; potential benefits and risks involved in introduction of genetically improved strains and/or alien species with specific reference to tilapias; existing policies and legislation for the conservation of biodiversity, their strengths and weaknesses; capacity for undertaking genetic enhancement research and implementation of policies for the conservation of aquatic biodiversity.

Introduction

Africa is the world's repository of diverse freshwater fish fauna and the home of tilapias. With the increasing interest in aquaculture and the initiatives in progress for genetic enhancement of tilapias, the possibility exists that improved strains and alien species introduced for aquaculture will escape into natural waters. While there is a need to enhance fish production through use of improved fish breeds and/or alien species, it is imperative that valuable aquatic genetic diversity is conserved/protected.

This has been the subject of an expert consultation organized by WorldFish Center in collaboration with the Technical Center for Agriculture and Rural Cooperation (CTA), the Food and Agriculture Organization of the United Nations (FAO), the World Conservation Union (IUCN), the United Nations Environment Program (UNEP) and the Convention on Biological Diversity (CBD) in Nairobi, Kenya on 20-23 February 2002. The discussions focused on the status of aquaculture in Africa and the role of genetic enhancement; potential

benefits and risks involved in introduction of genetically improved strains and/or alien species with specific reference to tilapias; policies and legislation in existence for the conservation of biodiversity, their strengths and weaknesses; capacity for under-taking genetic enhancement research and implementation of policies for the conservation of aquatic biodiversity.

The consultation meeting was attended by 45 fishery and conservation experts, resource managers, geneticists and policymakers from 10 African countries (Cameroon, Cote d'Ivoire, Ghana, Kenya, Malawi, Nigeria, South Africa, Tanzania, Uganda and

Zambia), advanced scientific institutions and regional and international organizations. The major findings from the meeting are presented here in brief while full proceedings are being published separately.

The Issues

The meeting concluded that there is high potential for aquaculture development in Africa with some regional variations. However, to achieve this potential, a number of constraints such as lack of knowledge of indigenous species, shortage of fish seed due to poor hatchery infrastructure, lack of credit facilities,



lack of incentives from existing policies, etc. need to be addressed. While in small-scale aquaculture improvements in farm management are more important, in commercial aquaculture operations the need/demand for improved strains is high.

Genetic improvement programs have been initiated in some countries, but institutional capacity for undertaking the research is inadequate. Alien species/strains are being introduced for aquaculture and impacts of these introductions are not fully known, but are likely to pose threats to biodiversity especially in regions where there is rich diversity of indigenous aquatic species.

Policies

Many African countries have formulated policies, enacted laws and established agencies to conserve

biological diversity. In addition, there are a number of sub-regional and regional conventions. While their existence is acknowledged, these are not specific to conservation of aquatic biodiversity and strategies for their implementation are lacking. Implementation is constrained by lack of human capacity, political will and accountability. Responsibilities for implementation of policies are split among ministries and agencies that are poorly funded and coordinated resulting in poor compliance. There is conflict of interest between development and conservation and the public is not aware of the issues as the stakeholders have not been involved in formulation of these policies and instruments.

A number of international codes of practice and protocols have been developed to deal with the introduction of alien species, but these

have no legal status until governments pass relevant national legislation to bring such laws into effect. Where these exist there is lack of clarity and capacity to implement. The voluntary nature of protocols makes them non-binding.

The participants of the consultation, after deliberating the issues for three days, came out with a formal statement, the *Nairobi Declaration: Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species for Aquaculture in Africa* (see Box 1). The document, which represents the main conclusions and recommendations of the workshop, is expected to serve as guidelines that will help foster the development of aquaculture in the region while maintaining biodiversity.

Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species for Aquaculture in Africa Nairobi Declaration

Fish are a critical source of animal protein to the people of Africa, and fishery resources play a central role in sustaining rural and urban livelihoods across much of the region. Yet for the continent as a whole per capita supply is declining and current projections of supply and demand indicate that this gap will continue to grow in the coming decades.

If this gap is to be bridged capture fisheries need to be sustained and the potential of aquaculture developed. In doing so, attention needs to be given to protecting the rich aquatic biodiversity of Africa especially the freshwater fish biodiversity and its role in sustaining capture fisheries and providing species for aquaculture.

Aquaculture is a relatively new farming activity in much of Africa and the region's production of farm-raised fish remains low. While there are many reasons for this, amongst the most important are poor management practices and the use of undomesticated stocks. This contrasts with crops, livestock and poultry where large increases in production have been achieved through application of breeding programs and other genetic improvement procedures.

To address these constraints, a greater range of management practices and approaches need to be considered. These should include improved pond and broodstock management and better performing breeds/strains. In doing so, however, these approaches need to be adapted to local social, economic, institutional and biophysical context. While the improved strains/alien species have potential to improve production there is clear risk of these improved/alien species escaping into the wild and contaminating the native population and affecting the biodiversity.

In light of these considerations, an Expert Consultation on Biosafety and Environmental Impact of Genetic Enhancement and Introduction of Improved Tilapia Strains/Alien Species in Africa was convened in Nairobi, Kenya from 20-23 February 2002 under the sponsorship of WorldFish Center, CTA, FAO, IUCN-The World Conservation Union, UNEP and the CBD to discuss and develop guidelines that will foster the development of aquaculture while maintaining biodiversity. The meeting was attended by aquaculturists, geneticists

and conservation specialists from Africa and from international organizations. The recommendations of the expert consultation follow hereunder.

Recommendations

1. Given that aquaculture from small-scale, low-input systems to large-scale intensive systems can achieve potential benefits from genetic enhancement, quality seed should be made available and used in conjunction with proper broodstock and farm management.
2. Since genetic resources in cultured populations can be degraded as a result of captive breeding, genetic aspects of broodstock management need to be a basic element within all types of aquaculture and stock enhancement systems.
3. Introductions of fish, including genetically improved (altered) strains and alien species, may have a role in the development of aquaculture. Any movement of fish between natural ecological boundaries (e.g. watersheds) may involve risk to biodiversity and

there is need for refinement and wider application protocols, risk assessment methods, and monitoring programs for introductions of fish, including genetically improved (altered) species and alien species. States have important responsibility in the development and implementation of such protocols and associated regulations, the establishment of clear roles and responsibilities, and capacity building. Such efforts should be linked to obligations pursuant to the Code of Conduct for Responsible Fisheries, the Convention on Biological Diversity, and other relevant international agreements.

4. Unique wild stocks of important tilapia species still exist in many parts of Africa. Priority areas should be identified and managed as conservation areas in which introductions of alien species and genetically altered species should be prevented.
5. The majority of issues and problems associated with movement of fish and the use of genetically altered species are common to most African countries and they are encouraged to (a) look beyond borders for examples of workable policies and legislation, adopt them where appropriate to fill national policy gaps, and harmonize them where

necessary; and (b) use existing regional bodies or form new bodies to assist in coordinating management activities and taking into account ecological realities, in particular transboundary watersheds.

6. Baseline information on fish genetic diversity, environmental integrity and aquaculture practices exist, but it is neither comprehensive nor easily accessible. The existing mechanisms for collection and dissemination of information on fish genetic diversity, environmental integrity and aquaculture practices need to be strengthened.
7. Internationally accepted codes and protocols for reducing the risk of transboundary movement of pathogens (including parasites) through movement of fish including alien species do exist, but they do not address any specific needs regarding genetically improved (altered) species. States and other relevant bodies should evaluate the existing codes and protocols for reducing the risk of transboundary movement of pathogens (including parasites) through movement of fish including alien species and genetically improved (altered) species, and adapt them for African conditions.
8. Policymakers, enforcement agencies, stakeholders and the general public need to be made aware of issues related

to, and the need for, policy on the movement of alien species and genetically improved (altered) species, and this should be high on national agendas.

9. Some policies relevant to movement of fish seem difficult to implement, are unknown to users, create conflicts of interest, or are viewed as restrictive, in part because they have been developed with limited consultation and participation. Formulation of policy and legislation concerning fish movement should seek to engage all stakeholders in a participatory process. In addition, governments should establish advisory groups with links to independent and scientifically competent expert bodies such as FAO, IUCN, and WorldFish Center.
10. Although economic benefits can be derived through the use of alien and genetically altered fish species in aquaculture, in many cases, those to whom benefits accrue do not bear the costs associated with adverse environmental impacts. In view of this, there should be provision for liability, compliance (e.g., incentives), and restoration within policies and legislation concerning the movement and use of alien and genetically altered fish species in aquaculture.

Expert Consultation to Develop Strategies and Plans for Dissemination of Improved Fish Breeds

In recent years, genetic improvement has progressed with the development of national breeding programs in member countries of the International Network on Genetics in Aquaculture (INGA). Improved carp and tilapia breeds now exist in some of the member countries (e.g. Bangladesh, China, Fiji, India, Indonesia, Malaysia, Philippines, Thailand and Vietnam) and some of these breeds are being disseminated to farmers. However, strategies and plans for dissemination of these strains are lacking in most of these countries. The ultimate benefits of a genetic improvement program can only be achieved if improved breeds

are effectively disseminated to targeted beneficiaries without losing, due to inbreeding, the genetic gains. Further, the member countries have been facing constraints in implementing genetic management protocols that will minimize inbreeding and maintain the characteristics of the breed during the process of dissemination. Sustaining the program and farmer confidence will require the demonstration and monitoring of impacts. Unlike in crops, there are no proven dissemination strategies for fish breeds and different social, economic and institutional set-ups in member countries makes it difficult for a single

system to work. In view of this, the need for guidelines that will help the member countries in maintenance and dissemination of improved fish breeds was felt necessary.

With funding support from the Norwegian Agency for Development Cooperation (NORAD), WorldFish Center, in collaboration with National Aquaculture Genetics Research Institute (NAGRI) of the Thailand Department of Fisheries organized an Expert Consultation on Strategies/ Plans for Dissemination of Improved Fish Breeds from 4-7 June 2002 in Pathumthani, Thailand. Thirty nine participants from member countries of INGA, advanced scientific

institutions, regional and international organizations, non-government organizations, private sector, farmers associations and resource persons from crops and livestock sectors attended the meeting. The meeting reviewed the principles, requirements and protocols for effective management/maintenance of improved strains at research stations, discussed the status of and constraints to maintenance and effective dissemination of improved fish breeds in member countries and formulated recommendations for addressing the constraints. The meeting strongly recommended that member countries develop national dissemination strategies with a focus on the development of plans, which lay out a road map for the successful and



Participants of the Expert Consultation on Strategies and Plans for Dissemination of Improved Fish Breeds, NAGRI, Pathumthani, Thailand, 4-7 June 2002

sustainable dissemination of improved fish breeds.

During the last day of the meeting,

the participants visited the tilapia/fish hatcheries in Prachinburi and Chachengsao Provinces, Thailand.

A preliminary genetic study of Vietnamese common carp (*Cyprinus carpio*) using mtDNA sequencing.

Although a significant number of genetic studies have been undertaken in common carp (*Cyprinus carpio*) using a range of approaches, none has examined in detail the genetic variation in mitochondrial (mt) gene regions using direct sequencing. Under a collaborative program between Deakin University, Victoria, Australia and Research Institute for Aquaculture No. 1 (RIA1) in Vietnam preliminary study on molecular genetic variation in Vietnamese *C. carpio* strains using mtDNA sequencing was completed in 2001. Using samples obtained from stocks maintained at the Research Institute for Aquaculture No. 1, Vietnam and specimens from feral populations in Australia, genetic variation was assessed using direct sequencing of fragments amplified from the mitochondrial 16S rRNA and cytochrome *b* gene

regions and from the control regions. As is typical for fish species, the 16S rRNA gene region showed the least variation and the control region the greatest variation (average nucleotide diversity 0.00966, haplotype diversity 0.842).

Genetic variability among 4 indigenous Vietnamese strains, along with Hungarian, Indonesian, Australian and the RIA No. 1 improved strain, was investigated. All three mtDNA gene regions identified a 'Hungarian' or 'European' lineage; however only data from the control region was useful for the identification of indigenous Vietnamese strains. Three distinct indigenous mtDNA haplotypes were identified, however mixing of stocks also appears to have occurred as European and Indonesian haplotypes were also found within indigenous strains. Overall, the level of divergence

between samples originating from European and Asia was found to be surprisingly low considering their original geographic isolation. No differences were detected between the samples of Vietnamese and Australian *C. carpio* derived independently from European stocks.

Generally, results indicate that the analysis of certain mtDNA gene regions has the potential to be a useful additional tool for studying genetic diversity within and between *C. carpio* populations and strains. As part of ongoing collaboration between RIA 1 and Deakin University this project will be extended, using funds provided by AusAID. This will be done through detailed survey of mtDNA variation in indigenous Vietnamese *C. carpio* stocks and sequencing a wider range of *C. carpio* samples from different countries. The latter

will be a first step towards the establishment of a world-wide genealogy of *C. carpio* strains derived from mt DNA sequences which will provide a valuable data base for genetic improvement programs and the management of

genetic diversity within this important species.

The collaborative project would welcome receiving donation of ethanol preserved carp tissue samples from researchers working on this species in different parts of

the world for its second part of the project

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Training on quantitative genetics

With the objective of strengthening the capacity of scientists from INGA member country institutions in the field of quantitative genetics, especially in analysis and interpretation of genetic data, INGA and WorldFish Center with financial support from Norwegian Agency for Development Cooperation (NORAD) organized a three week training course on *Quantitative Genetics and its Application to Aquaculture* during 1-21 October 2001 in Bangkok, Thailand. A total of 28 participants from 12 member countries of INGA (Bangladesh, China, Egypt, Fiji, Ghana, India, Indonesia, Malawi, Malaysia, Philippines, Thailand and Vietnam) attended the course. The course program was developed specifically to meet the needs of the participants and was based on needs assessment survey undertaken prior to the training. The course curriculum covered the following modules: strain comparisons and crossing, estimation of heritability, phenotypic and genetic correlations,



selection index methodology for single and multiple traits, selection methods and prediction response, BLUP methodology, breeding program design and use of statistical softwares (SAS, ASREML). The training program comprised lectures and practical exercises but emphasis was placed on hands-on analysis of actual breeding/genetic datasets. The three-week training also included presentations by

participants on the status of genetic improvement/breeding programs in their countries and a visit to aquaculture station/farms in Chonburi Province, Thailand.

Each participant who completed the training was provided a CD-ROM copy of non-commercial software (ASR, GPEX, SIP and KUNZI) to assist them in analysis of breeding datasets.

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Developing the capacity on fish molecular genetics in Vietnam

Through a grant from the Australian government (AusAID), Deakin University and its partner institution in Vietnam, the Research Institute for Aquaculture No. 1 (RIA 1) are undertaking a collaborative project that focuses on capacity building in molecular genetic research and education in Vietnam. The project aims to heighten awareness of and skills of young researchers in the application of molecular genetic approaches in a range of fields relating to the management of fish biodiversity and genetic improvement of fish for aquaculture. These will be achieved through a range of activities that will include short-term and Masters level training of technicians and

researchers at Deakin University and in-country workshops and research activities that focus on genetics of wild and cultured populations of catfish of the genus *Pangasius* and grass carp (*Ctenopharyngodon idellus*).

The first of two planned workshops was held on 1-7 July 2002 at RIA1 (Vietnam). Twenty young Vietnamese researchers and a researcher from Thailand, an INGA sponsored participant, attended the workshop. The workshop provided an introduction to basic theory relating to the application of molecular genetic techniques and population genetics and an introduction to protein-based (allozyme) and DNA-based

(RFLPs, SSCPs and RAPDs) techniques for assaying and measuring genetic variation.

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National genetics meeting in Malaysia

The Malaysian national network of INGA held its second national genetic workshop on 19 April 2002 in Kuala Lumpur. The meeting was hosted by University of Malaya and was attended by 31 participants

from Malaysian national research institutions involved in fish genetic research and WorldFish Center. The workshop identified three research priority areas for collaborations: invasive species and their impacts,

population genetics and genetic improvement of *Macrobrachium rosenbergii*, and use of markers in tilapia selective breeding research.

Training on analysis of genetic data

Through the project 'Transfer of Selective Breeding Technology for Aquaculture Improvement from Asia to Sub-Saharan Africa and Egypt, a 5-day training course on the

Analysis of Breeding Data was organized for 17 scientists from Cote d'Ivoire, Egypt, Ghana, Kenya, Malawi and South Africa at the WorldFish Center Regional Center

for West Asia and Africa, Abbassa, Egypt on 12 – 16 May 2002. The training focused on analysis of data from selective breeding experiments and estimation of genetic parameters.

Publication of interest

A special issue on genetics

The proceedings of the Seventh International Symposium on Genetics in Aquaculture (ISGA) hosted by the Australian Institute of Marine Science (AIMS) and held in Australia in July 2000 has been published in a special issue of *Aquaculture* (volume 204, nos. 3-

4). The 517-page journal which was edited by J.A.H. Benzie and G. Hulata contains abstracts and 21 full papers under 6 topic areas: (i) gene expression, transgenesis and molecular techniques; (ii) application of molecular markers; (iii) gene/genome mapping; (iv) ploidy manipulation; (v) breeding and quantitative genetics; and (vi)

wild and farmed genetic resources.

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