ISSN 1020-5292

Food and Agriculture
Organization of the
United Nations

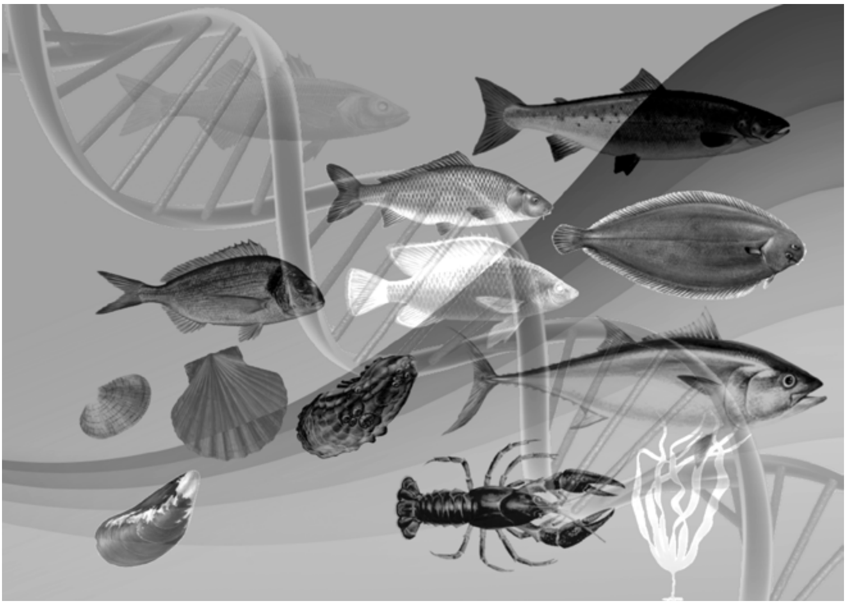
FAO
TECHNICAL GUIDELINES FOR
RESPONSIBLE FISHERIES

5

Suppl. 9

AQUACULTURE DEVELOPMENT

9. Development of aquatic genetic resources: A framework of essential criteria



Cover illustration: José Luis Castilla Civit

FAO
TECHNICAL
GUIDELINES FOR
RESPONSIBLE
FISHERIES

5

Suppl. 9

AQUACULTURE DEVELOPMENT

9. Development of aquatic genetic resources: A framework of essential criteria

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2018

Required citation:
FAO. 2018. *Aquaculture Development 9. Development of aquatic genetic resources: A framework of essential criteria*. TG5 Suppl. 9. Rome. 88 pp. Licence: CC BY-NC-SA 3.0 IGO.

ISBN 978-92-5-131093-9

PREPARATION OF THIS DOCUMENT

An initial Framework was developed by D.M. Bartley and submitted to selected experts in AqGR who made substantial revisions in its organization in order to make the Framework more user friendly and concise, with supporting material included in Annexes. The Framework was further revised through the workshop "SADC-WorldFish-FAO Platform for Genetics in Aquaculture and Validation of the FAO Framework on Sustainable Use, Management And Conservation Of Aquatic Genetic Resources For Aquaculture", 25–29 September 2017, held in Lusaka, Zambia. Finally, the Framework was reviewed by the FAO Committee on Fisheries' (COFI) Advisory Working Group on Aquatic Genetic Resources and Technologies (Working Group), at their second session in Rome. In addition to the members of the COFI Advisory Working Group, the following people contributed to this final version of the Framework: D.M. Bartley, M. Halwart, Z. Jeney, K.K. Lal, D. Lucente, G.C. Mair and A. Stankus. The Government of Germany's support for the development of the Framework is greatly appreciated.

CONTENTS

ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AGRDEU	National Inventory for Aquatic Genetic Resources (Germany)
AqGR	Aquatic Genetic Resources for Food and Agriculture
AREEO	Agricultural Research, Education and Extension Organization (Islamic Republic of Iran)
ARDEC	Aquaculture Research and Development Centre (Ghana)
ASFIS	Aquatic Sciences and Fisheries Information System
BLE	Federal Agency for Agriculture and Food (Germany)
CBD	Convention on Biological Diversity
CCRF	Code of Conduct for Responsible Fisheries
COFI	FAO Committee on Fisheries
CRISPR	Clustered regularly interspaced short palindromic repeats
DOI	Digital Object Identifier
eDNA	Environmental DNA
FAO	Food and Agriculture Organization of the United Nations
FCh	Chile Foundation
FFRC	Freshwater Fisheries Research Centre of Chinese Academy of Fishery Sciences
GIFT	Genetically Improved Farmed Tilapia
the Framework	Framework of Minimum Requirements for Sustainable Management, Development, Conservation and Use of Aquatic Genetic Resources
IBV	Coordination Centre for Biological Diversity

ICES	International Council for the Exploration of the Sea
ICLARM	International Centre for Living Aquatic Resources Management (now known as WorldFish)
IFSRI	Iranian Fisheries Science Research Institute
IHHN	Infectious Hypodermal and Hematopoietic Necrosis
IMPs	Introduced Marine Pests
INGA	International Network for Genetics in Aquaculture
ISCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
IUCN	International Union for Conservation of Nature
MTA	Material Transfer Agreement
NASCO	North Atlantic Salmon Conservation Organization
PICT	Pacific Island Countries and Territories
PIT	Passive Integrated Transponder
PNG	Papua New Guinea
PPP	Private Public Partnership
R&D	Research and Development
SNPs	Single-nucleotide polymorphisms
SoW AqGR	State of the World's Aquatic Genetic Resources for Food and Agriculture
TIVO	Tilapia Volta
UNDP	United Nations Development Program
URL	Uniform Resource Locator
Working Group	COFI Advisory Working Group on Aquatic Genetic Resources and Technologies

BACKGROUND

1. From ancient times, fishing from oceans, lakes and rivers has been a major source of food, a provider of employment and other economic benefits for humanity. Ocean productivity seemed particularly unlimited. However, with increased knowledge and the dynamic development of fisheries and aquaculture, it was realized that living aquatic resources, although renewable, are not infinite and need to be properly managed, if their contribution to the nutritional, economic and social well-being of the growing world's population was to be sustained.

2. However, for nearly three decades, because of the dramatic increase of pollution, abusive fishing techniques worldwide, and illegal, unreported and unregulated fishing, catches and landings have been shrinking and fish stocks declining, often at alarming rates.

3. Stock depletion has negative implications for food security and economic development and reduces social welfare in countries around the world, especially those relying on fish as their main source of animal protein and income such as subsistence fishers in developing countries. Living aquatic resources need to be properly managed, if their benefits to society are to be sustainable.

4. Sustainability of societal benefits requires a recovery of depleted stocks and maintenance of the still-healthy ones, through sound management. In this regard, the adoption of the United Nations Convention on the Law of the Sea, in 1982 was instrumental. The law provides a new framework for the better management of marine resources. The new legal regime of the oceans gave coastal States rights and responsibilities for the management and use of fishery resources within the areas of their national jurisdiction, which embrace some 90 percent of the world's marine fisheries.

5. In recent years, world fisheries have become dynamically developing sectors of the food industry, and many States have

striven to take advantage of their new opportunities by investing in modern fishing fleets and processing factories in response to growing international demand for fish and fishery products. It became clear, however, that many fisheries resources could not sustain an often uncontrolled increase of exploitation. Overexploitation of important fish stocks, modifications of ecosystems, significant economic losses, and international conflicts on management and fish trade still threaten the long-term sustainability of fisheries and the contribution of fisheries to food supply.

6. In light of this situation, while recognizing that the recovery of depleted stocks is still urgent and avoiding depleting still-healthy stocks as important, FAO Member States have expressed the need to further develop aquaculture as the only immediate way to bridge the gap between the dipping capture fisheries output and the increasing world demand for seafood.

7. Indeed, in the last three decades, aquaculture has recorded a significant and most rapid growth among the food-producing sectors and has developed into a globally robust and vital industry. However, aquaculture also has been shown at times to carry the potential to cause significant environmentally and socially adverse impacts.

8. Thus, the Nineteenth Session of the FAO Committee on Fisheries (COFI), held in March 1991, recommended that new approaches to fisheries and aquaculture management embracing conservation and environmental, as well as social and economic, considerations were urgently needed. FAO was asked to develop the concept of responsible fisheries and elaborate a Code of Conduct to foster its application.

9. Subsequently, the Government of Mexico, in collaboration with FAO, organized an International Conference on Responsible Fishing in Cancún in May 1992. The Declaration of Cancún, endorsed at that Conference, was brought to the attention of the United Nations Conference on Environment and Development Summit in Rio de Janeiro, Brazil, in June 1992, which supported the preparation of a Code of Conduct for Responsible Fisheries. The FAO Technical Consultation on High Seas Fishing, held in September 1992, further

recommended the elaboration of a code to address the issues regarding high seas fisheries.

10. The One Hundred and Second Session of the FAO Council, held in November 1992, discussed the elaboration of the Code, recommending that priority be given to high seas issues and requested that proposals for the Code be presented to the 1993 session of the Committee on Fisheries.

11. The twentieth session of COFI, held in March 1993, examined in general the proposed framework and content for such a Code, including the elaboration of guidelines, and endorsed a time frame for the further elaboration of the Code. It also requested FAO to prepare, on a "fast track" basis, as part of the Code, proposals to prevent reflagging of fishing vessels which affect conservation and management measures on the high seas. This resulted in the FAO Conference, at its Twenty-seventh Session in November 1993, adopting the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, which, according to FAO Conference Resolution 15/93, forms an integral part of the Code. It was also recognized and confirmed that issues of responsible aquaculture development and aquaculture sustainability should be addressed in the formulation process so that these be appropriately covered in the envisaged Code.

12. This implicit recognition of the importance of governance in aquaculture is underlined in Article 9.1.1 of the Code, which requires states to "establish, maintain and develop an appropriate legal and administrative framework to facilitate the development of responsible aquaculture". In addition, at the beginning of the new millennium, there is growing recognition of the significant potential for the use of ocean and coastal waters for mariculture expansion. The outstanding issue in this area is that, unlike in capture fisheries, the existing applicable principles of public international law and treaty provisions provide little guidance on the conduct of aquaculture operations in these waters. Yet, experts agree that most of the future aquaculture expansion will occur in the seas and oceans, certainly further

offshore, perhaps even as far as the high seas. The regulatory vacuum for aquaculture in the high seas would have to be addressed should aquaculture operations expand there.

13. The Code was formulated so as to be interpreted and applied in conformity with the relevant rules of international law, as reflected in the 10 December 1982 United Nations Convention on the Law of the Sea. The Code is also in line with the Agreement for the Implementation of the Provisions of this Law, namely the 1995 Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. It is equally in line with, *inter alia*, the 1992 Declaration of Cancún and the 1992 Rio Declaration on Environment and Development, in particular Chapter 17 of Agenda 21.

14. The development of the Code was carried out by FAO in consultation and collaboration with relevant United Nations Agencies and other international organizations, including non-governmental organizations.

15. The Code of Conduct consists of five introductory articles: Nature and scope; Objectives; Relationship with other international instruments; Implementation, monitoring and updating; and Special requirements of developing countries. These introductory articles are followed by an article on General principles, which precedes the six thematic articles on Fisheries management, Fishing operations, Aquaculture development, Integration of fisheries into coastal area management, Post-harvest practices and trade, and Fisheries research. As already mentioned, the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas forms an integral part of the Code.

16. The Code is voluntary. However, certain parts of it are based on relevant rules of international law, as reflected in the United Nations Convention on the Law of the Sea of 10 December 1982. In capture fisheries, the Code also contains provisions that may be or have already been given binding effect by means of other obligatory legal instruments amongst the Parties, such as the Agreement to Promote Compliance with Conservation and

Management Measures by Fishing Vessels on the High Seas, 1993. In aquaculture, the provisions of the Code implicitly encourage participatory governance of the sector, which extends from industry self-regulation, to co-management of the sector by industry representatives and government regulators and to community partnerships. Compliance is self or enforced by peer pressure, with industry organizations having the ability to exclude those who do not comply and governments only checking periodically.

17. The Twenty-eighth Session of the Conference in Resolution 4/95 adopted the Code of Conduct for Responsible Fisheries on 31 October 1995. The same Resolution requested FAO *inter alia* to elaborate appropriate technical guidelines in support of the implementation of the Code in collaboration with members and interested relevant organizations.

18. The expanding role and increasing contribution of aquaculture to economic growth, social welfare as well as global food security was recognized and reiterated at international levels such as the 1995 FAO/Japan Conference on the Contribution of Fisheries and Aquaculture to Food Security, the 1996 World Food Summit, the 1999 Ministerial Meeting on Fisheries, the 2000 FAO/NACA [Network of Aquaculture Centres in Asia and the Pacific] Conference on Aquaculture in the Third Millennium and its Bangkok Declaration and Strategy, and most recently, the 2009 World Summit on Food Security.

19. The application of the ecosystem approach to fisheries and aquaculture as strategies for the development of the sector contributes to the implementation of the provisions of the Code, thereby enforcing the technical, ecological, economic and social sustainability of the industry.

INTRODUCTION

Aquatic genetic resources support and ensure the long-term viability of fisheries and aquaculture. However, developing and managing Aquatic Genetic Resources for Food and Agriculture (AqGR) is a complex undertaking for national stakeholders, with a combination of constraints that has hindered many countries from taking full advantage of the benefits of AqGR.

In recognition of this complexity, the FAO Committee on Fisheries' (COFI) Advisory Working Group on Aquatic Genetic Resources and Technologies (Working Group) recommended that a framework of minimum requirements be developed to assist countries in the conservation, sustainable use and development of their AqGR.[1] As a result, the FAO's Fisheries and Aquaculture Department, in consultation with the Working Group and with support from the Government of Germany, began to develop a "Framework of minimum requirements for sustainable use, management and conservation of aquatic genetic resources of relevance for aquaculture" (the Framework).

The Framework can be used to help countries establish conditions necessary to begin to sustainably and responsibly conserve, use and develop their AqGR in line with national development and conservation goals and policies. The Framework is not an implementation document, but rather a needs assessment document that calls for national dialogue to develop an implementation strategy, and a review or revision of national policy and practice. Annexes are provided here to help with aspects of implementation.

[1] The conservation, sustainable use and development of AqGR would include the adoption of new species and development of genetically improved strains for aquaculture production, the technologies to monitor and assess genetic resources, and the management practices and policies that would ensure that production takes place in an environmentally responsible and socially acceptable manner.

A FRAMEWORK OF MINIMUM REQUIREMENTS

The Framework adheres to the following guiding principles:

1. Sustainable use of AqGR – the priority for the development of AqGR is food security and improved livelihoods;
2. Conservation of AqGR to facilitate achieving food security and improved livelihoods in the long-term;
3. Fair and equitable sharing of benefits derived from the development of AqGR;
4. Science-based – the minimum requirements are based on updated information, good science and internationally agreed principles, and are not based on a country's ability to implement them; it is recognized that countries may have problems implementing some of the minimum requirements, but none-the-less should strive to do so;
5. Private sector involvement - participation of the private sector will, in the long-term, be the main engine for the development and use of AqGR;
6. Transparency – adopting a science-based approach and an open information sharing platform will promote trust and facilitate uptake by the private sector and civil society;
7. Long-term view – it is further recognized that the Framework may initially slow down the development of the private sector, e.g. by applying environmental safeguards and access and benefit sharing regimes, however, the inclusion of these elements will facilitate long term success and the cooperation of other sectors and the international community;
8. Complement international activities, e.g. the collection of aquaculture statistics by FAO.

The Framework contains five main components: (i) information and databases, (ii) governance, policy and planning, (iii) infrastructure and equipment, (iv) capacity building and training, and (v) enabling the private sector.

INFORMATION AND DATABASES

Aquaculture currently farms about 600 species, but has only relatively recently begun to genetically improve those species through breeding and domestication programmes. Unlike livestock and crops, farmed aquatic species have relatively few domesticated strains. Although information on these aquatic farmed types is highly desired, the minimum criterion is for comprehensive information at the species level. Accurate terminology is essential for any communication system, information system and database, and will help implement many aspects of the Framework.

The information and databases component of the Framework calls for:

- Information on AqGR
  - directory of species, including non-native species, farmed in country with standard names and terminology (**Annex 1**);
  - inventory or directory of native and non-native AqGR and their distribution (**Annex 2**); and
  - list and map of significant native AqGR to be protected.
- Information on genetic technologies
  - directory of acceptable technologies and any restrictions on their use (**Annex 3**);
- Information on the impacts AqGR have on society and the environment
  - monitoring programme on which farms (and how many) are using a specific farmed type;
  - monitoring programme on impact of farmed type on the human well-being; and
  - monitoring programme on impact of farmed type on the environment;
- General information
  - directory of laboratories, institutions and centres of excellence working on AqGR;
  - communication plan for dissemination of information to stakeholders and the public;
  - single easily accessible database or information system on AqGR including the above elements; and
  - authoritative glossary of technologies and concepts (**Annex4**).

GOVERNANCE, POLICY AND PLANNING

Several international instruments such as the FAO Code of Conduct for Responsible Fisheries[2] (CCRF), the Convention on Biological Diversity (CBD)[3] and the Voluntary Guidelines on the Responsible Governance of Tenure[3] provide guidance on policies and principles for the effective governance of AqGR. Although the Framework is designed to be a national policy guidance document, countries should strive to engage international, regional or sub-regional entities or countries in order to harmonize policies and practices.

The governance, policy and planning component of the Framework calls for:

- designation of competent authority to manage and oversee AqGR;
- authoritative national policy instrument;
- inclusion of AqGR in national aquaculture strategy and/or development plan;
- inclusion of AqGR in aquaculture management policy (**Annex 5)**
- comprehensive guidelines on AqGR conservation, sustainable use and development, including zoning for aquaculture and AqGR use;
- enforcement strategies;
- human well–being;
  - adoption of international instruments on governance, tenure, and human rights into national legislation
  - a national agency for oversight of food safety and quality
- facilitation of permitting and reporting system for private industry and research sector (academic and government);
- link to regional and international countries and/or entities for harmonization of policies and practices and for improved management of shared AqGR; and

[2] FAO. 2018. Code of Conduct for Responsible Fisheries [online]. Rome. [Cited 25 September 2018]. www.fao.org/fishery/code/en

[3.] Convention on Biological Diversity (CBD). 2018. CBD [online]. Montreal. [Cited 25 September 2018]. www.cbd.int/

[3] FAO. 2018. Voluntary Guidelines on Tenure [online]. Rome. [Cited 25 September 2018]. www.fao.org/nr/tenure/voluntary-guidelines/en/

- effective and transparent engagement between government departments, private industry and other stakeholders, for *inter alia*, exchange of policy and technical information.

INFRASTRUCTURE AND EQUIPMENT

The infrastructure and equipment required in a country will depend on specific national priorities, resources and capacities. Consideration should be given to establishment of partnerships to take advantage of economies of scale in the development and use of infrastructure. The Framework calls for:

- a plan for the development, use and maintenance of all infrastructure, taking into account partnerships and economies of scale;
- access to[4] broodstock development and management facilities;
- access to bio-secure facility(ies) for genetic management and/or genetic improvement of aquacultured species, including effective marking/tagging/identification;
- access to multiplication and dissemination centres for genetically improved strains;
- access to genetic characterization and diagnostic laboratories;
- quarantine and veterinary facilities; and
- research, extension and training centres.

CAPACITY BUILDING AND TRAINING

Improved capacity will help facilitate implementation of the entire Framework. The field of genetics is advancing rapidly and it will be important for governments to continually develop the capacity of technical staff and effective means to advise and oversee the aquaculture industry. Therefore, an effective extension service from

[4] In consideration of partnerships with facilities in other countries and taking advantage of economies of scale, it may not be necessary to have all infrastructure developed in a country as long as the country has 'access to' the infrastructure. Where AqGR are being imported from another country, quarantine and biosecure facilities will be necessary in-country.

government and academia is a long-term mechanism to transfer knowledge to the users of AqGR (**Annex 6**).

The Framework calls for:

- Extension service – government and/or academic; and
- Capacity building and training in all components of the Framework, i.e.:
  - Information
  - Governance, policy and planning
  - Operation of infrastructure
  - Working with the private sector.

ENABLING THE PRIVATE SECTOR

The engine for the development and long-term responsible use of AqGR will be the private sector (**Annex 7**). Therefore governments should:

- put in place policies and practices that create an enabling environment for the aquaculture industry;
- have an aquaculture development plan that provides clear guidance for the industry;
- establish an effective extension service from government or academic extension agencies, or from international agencies, in the absence of national services; and
- establish a forum for industry to be involved in government decision and policy-making.

In several countries, public support for genetic improvement programmes facilitates the growth of the aquaculture industry. However, experts developing this Framework were divided on whether the following should be part of the Framework of essential requirements for the development of AqGR:

- consider providing financial and technical support to facilitate development and implementation of medium and long-term genetic improvement programs by industry;
- develop appropriate business models for the industry and for benefit sharing between public, cooperative or private operations; and

- private sector mechanisms to fund research through Private Public Partnerships (PPP).

HOW TO USE THE FRAMEWORK

The Framework should be viewed in light of a national aquaculture development plan and conservation strategy and goals. The above elements of the Framework have been listed in Tables 1–5 in order to facilitate using the Framework. Countries or areas planning to develop and manage AqGR could map current practices and policies onto Tables 1–5 and assess which requirements would need to be created or better developed in a particular area. Several annexes are included to help guide the implementation of the Framework.

To successfully implement the Framework, the five components should be developed together as a package. Capacity is needed to develop improved strains in aquaculture, but without infrastructure, a national strategy, accurate information and the support of private industry, there will be no place to put the improved capacity to use; infrastructure without capacity will only gather dust; information will not be used in a farm that does not have capacity for AqGR management; private industry without oversight and good governance is not sustainable. All efforts should be made to implement the entire Framework and seek assistance where needed.

It is recognized that some elements of the Framework already exist in some countries or regions. Stakeholders should map current policies, practices, infrastructure and resources onto the elements of the Framework. For this reason, Tables 1–5 include blank columns that can be used to identify gaps and priorities.

Table 1: Framework of Minimum Requirements – Worksheet (Information and Databases)

Information and databases – accurate and accessible information on AqGR will facilitate many of the elements of the Framework		
Framework component	Included in current country policies and practices (Yes/No)	Comments and prioritization [scale of 1 (not essential or practical) -10 (extremely essential and practical)]
Information on AqGR		
1. Directory of species, including non-native species, farmed in country with standard names and terminology		
2. Inventory or directory of native AqGR and its distribution		
3. List and map of significant native AqGR to be protected		
Information on genetic technologies		
4. Directory of acceptable technologies and any restrictions on their use		
Information on the impacts AqGR have on society and the environment		
5. Monitoring programme on which farms (and how many) are using a specific farmed type		
6. Monitoring programme on impact of farmed type on the human well–being;		
7. Monitoring programme on impact of farmed type on the environment		

Table 1 (*continued*)

Information and databases – accurate and accessible information on AqGR will facilitate many of the elements of the Framework		
Framework component	Included in current country policies and practices (Yes/No)	Comments and prioritization [scale of 1 (not essential or practical) -10 (extremely essential and practical)]
General information		
8. Directory of laboratories, institutions and centres of excellence working on AqGR		
9. Communication plan for dissemination of information to stakeholders and the public		
10. Single easily accessible database or information system on AqGR including the above elements;		
11. Authoritative glossary of technologies and concepts		

Table 2: Framework of Minimum Requirements – Worksheet (Governance and Policy)

Governance and policy – effective governance will involve private industry, civil society and consumers and will provide for human and environmental well-being		
Framework component	Included in current country policies and practices (Yes/No)	Comments and prioritization [scale of 1 (not essential or practical) – 10 (extremely essential and practical)]
1. Designation of competent authority to manage and oversee AqGR		
2. Authoritative national policy instrument		
3. Inclusion of AqGR in national aquaculture strategy and/or development plan		
4. Inclusion of AqGR in aquaculture management policy (**Annex 5**)		
5. Comprehensive guidelines on AqGR conservation, sustainable use and development, including zoning for aquaculture and AqGR use;		
6. Enforcement strategies		
7. Human well–being: a) adoption of international instruments on governance, tenure, and human rights into national legislation		
8. Human well-being: b) a national agency for oversight of food safety and quality		
9. Facilitation of permitting and reporting system for private industry and research sector (academic and government)		
10. Link to regional and international countries and/or entities for harmonization of policies and practices and for improved management of shared AqGR		
11. Effective and transparent engagement between government departments, private industry and other stakeholders, for among other things, exchange of policy and technical information		

Table 3: Framework of Minimum Requirements – Worksheet (Infrastructure and Equipment)

Infrastructure and equipment – consideration should be given to develop partnerships and take advantage of economies of scale		
Framework component	Included in current country policies and practices (Yes/No)	Comments and prioritization [scale of 1 (not essential or practical) – 10 (extremely essential and practical)]
1. A plan for the development, use and maintenance of all infrastructure, taking into account partnerships and economies of scale		
2. Access to[1] broodstock development and management facilities		
3. Access to bio-secure facility(ies) for genetic management and/or genetic improvement of aquacultured species, including effective marking/tagging/identification		
4. Access to multiplication and dissemination centres for genetically improved strains		
5. Access to genetic characterization and diagnostic laboratories		
6. Quarantine and veterinary facilities		
7. Research, extension and training centres		

[1] In consideration of partnerships with facilities in other countries and taking advantage of economies of scale, it may not be necessary to have all infrastructure developed in a country as long as the country has 'access to' the infrastructure. Where AqGR are being imported from another country quarantine and biosecure facilities will be necessary in-country.

Table 4: Framework of Minimum Requirements – Worksheet (Capacity Building and Training)

Capacity building and training – capacity building will be required for many of the above activities		
Framework component	Included in current country policies and practices (Yes/No)	Comments and prioritization [scale of 1 (not essential or practical) – 10 (extremely essential and practical)]
1. Extension service – government and/or academic		
2. Capacity building in all components, i.e.		
2.1 Information		
2.2. Governance, policy and planning		
2.3 Operation of infrastructure		
2.4 Working with the private sector		

Table 5: Framework of Minimum Requirements – Worksheet (Enabling the Private Sector)

Enabling the private sector – the private sector will be the long term driver of the development and sustainable use of AqGR		
Framework component	Included in current country policies and practices (Yes/ No)	Comments and prioritization [scale of 1 (not essential or practical) – 10 (extremely essential and practical)]
1. Put in place policies and practices that create an enabling environment for the aquaculture industry		
2. Have an aquaculture development plan that provides clear guidance for the industry on conservation, sustainable use and development of AqGR		
3. Establish an effective extension service from government or academic extension agencies, or from international agencies in the absence of national services		
4. Establish a forum for industry to be involved in government decision and policy-making		

ANNEX 1 – AQUATIC SCIENCES AND FISHERIES INFORMATION SYSTEM LIST

Each Member Country contributes information to FAO as part of their commitment to the responsible use of fishery and aquaculture resources. The species/species item names contributed by Member Countries should conform to the Aquatic Sciences and Fisheries Information System (ASFIS) list and the classification system of the International Standard Statistical Classification of Aquatic Animals and Plants (ISCAAP).[5] The ASFIS list is for statistical purposes and is the standard that countries should use for reporting to FAO. The 2018 edition of ASFIS list of species includes 12 751 species items selected according to their interest or relation to fisheries and aquaculture.

However, several countries farm aquatic species that are currently not on the ASFIS list. This demonstrates that more AqGR are being used than previously thought. However, FAO as developer and curator of the ASFIS nomenclature is reluctant to add additional items to the list unless it can be shown that the new taxon, i.e. new hybrid or species, would be reported in a reliable and consistent manner by Members of FAO and that there is sustained commercial production.

For information below the species level, there is no mechanism within the structure of the ASFIS list to include strains, stocks or subspecies. Therefore, for the minimum requirements, listing at the species level will be sufficient. More detailed descriptions of farmed types, such as strains or polyploids, are useful and desirable but can be developed at a later stage.

FAO names are not intended to replace local species names, but their standardisation is considered necessary to overcome the considerable confusion caused in some cases by the use of a single name for many different species, or several names for one species. As FAO deals with aquatic species at a global level, selected names should be recognizable as much as possible at both local and international levels.

[5] FAO. 2018. ASFIS List of Species for Fishery Statistics Purposes [online]. Rome. [Cited 25 September 2018]. www.fao.org/fishery/collection/asfis/en

ANNEX 2 – GENETIC TECHNOLOGIES FOR THE CHARACTERIZATION OF AQGR

Accurate identification of species at the genetic level is essential for proper conservation, sustainable use and developmentof AqGR. Genetic diversity can be assessed at several different levels (Table 6), from sequencing an organism's DNA to morphologically inferring the genotype based on phenotype. Countries and breeding programs need to decide on what level of analysis is most appropriate and cost effective given the available capacities and resources. In some breeding programmes it will be important to identify family lines and determine pedigrees, and the technology of single-nucleotide polymorphisms (SNPs) is considered the most appropriate for this purpose. If a country does not have this technology, capacity is present in many laboratories around the wold and thus samples can be sent abroad for analysis. The strategy of sending samples to other laboratories may be appropriate in the short and medium term as countries develop their capacity in genetic analysis.

Ordinary pedigree information could also be effective for identifying families if fish are physically tagged, e.g. using PIT (Passive Integrated Transponder) tags. This low-tech method of physical tagging and simple phenotypic recording can be used so that limited access to gene technology such as SNP analyses will not hamper/limit characterisation of AqGR and application of selective breeding programmes.

For identification of species, such as for traceability and trade purposes, molecular identification of species based on the sequence of a section of the mitochondrial or nuclear DNA has been used, e.g. the Barcode of Life[6]. This system has become an accepted technique in trade and legal disputes.

With the advent of environmental DNA (eDNA) analysis and information on species-specific DNA markers, it is possible to detect

[6] Fish Barcode of Life (FISH-BOL). 2018. FISH-BOL [online]. Guelph. [Cited 25 September 2018]. www.fishbol.org/protocols.php

the presence of an organism through DNA that is sloughed off or excreted by an organism. eDNA analysis is being used to detect Asian carp in the Mississippi River (USA).[7] It could also be used to detect low levels of pathogens in a farming system or in farm effluent, so treatment could be quickly initiated.

[7] Shogren, A.J., Tank, J.L., Andruszkiewicz, E., Olds, B., Mahon, A.R. Jerde, C.L. & Bolster, D. 2017. Controls on eDNA movement in streams: Transport, Retention, and Resuspension. Scientific Reports: 7(1): 5065

Table 6: Methods and technologies for characterising genetic diversity

Method	Resolution[1]	Main use	Capacity needs[2]
Pedigree (parent) information	L–H	For individual and population level analysis (inbreeding coefficients and genetic diversity)	L
Phenotypic recording and Estimated Breeding Value	L–H	For individual and population level analysis and heritability of specific traits	L-H
Proteins/allozymes	L	For population and species level analysis	M
RFLPs	L	For individual, population and species level analysis	H
AFLPs	H	For species level analysis	H
DNA barcoding	M	For species level identification; it is also used in product traceability and court cases.	L–M
Microsatellites	H	For individual and population level analysis, including parentage assignment and stock assessment	M–H
SNPs	H	For individual and population level analysis, including parentage assignment, identification of quantitative trait loci, linkage group analysis, marker assisted selection, genomic selection and identification of locally adapted stock units	M–H
eDNA	H	To detect species in nature	H
Chromosomes	L	Can assess species differences and presence of polyploids	L
Meristic counts	L	Can assess species differences, but can be environmentally influenced	L
Morphology	L	Can assess species differences, but can be environmentally influenced	L

[1] Resolution refers to the degree to which genetic diversity can be determined (L = low; M = medium; H = high).

[2] Capacity needs refer to the technical skills and laboratory tools required to use the technology (L = low; M = medium; H = high)

ANNEX 3 – TECHNOLOGIES FOR GENETICALLY IMPROVING AQUATIC SPECIES

Genetic improvement is essential to the long-term growth of aquaculture. Apart from traditional selective breeding, modern breeding programs and biotechnologies provide the basis for a sustainable and resource effective production of aquatic species. A range of technologies exist for the genetic improvement of aquatic species (Table 7) and include long term and short term strategies. For all of these technologies, good farming practices, e.g. proper husbandry, fish health, broodstock management and the avoidance of inbreeding will be required.

Countries should establish a risk based directory of accepted technologies and any restrictions on the use of those technologies, in commercial use as well as in research. Some technologies may require a permit, for example hybridization or genetic engineering (transgenic and gene editing), and information on how to obtain such a permit should be easily available.

Table 7: Description of technologies for the genetic improvement of aquatic species

Technology	Description and comment
Traditional selective breeding	An established and effective long term strategy for genetic improvement. Organisms with desirable characteristics, e.g. growth rate, can be bred to increase and pass on those characteristics to the next generation. The family structures and phenotypic data collected with well-structured selective breeding programs are often necessary precursors to application of more advanced molecular methods such as genomic selection.
Genomic selection	Genomic selection uses the estimated effect of many loci across the entire genome at once, not just the small number of linked loci as done with marker-assisted selection.
Marker-assisted selection	Uses genetic markers to select for desirable characteristics that may not be easy or possible using traditional selective breeding.
Crossbreeding	The crossing of two different strains within a species to exploit heterosis or ‘hybrid vigour’. Multiple generations of crossbreeding can be used to create a new improved, introgressed, strain that can become stable over time.
Hybridization	The mating of individuals of different species to combine desirable characteristics of both species into a single farmed type and/or to exploit heterosis or ‘hybrid vigour’ for commercially important traits. Beyond the first generation F1 hybrids, these farmed types would not be stable because subsequent mating of hybrids would yield a mix of parental and intermediate types. Sometimes hybrids are not fertile.
Sex reversal and breeding for sex control	Sex of many fish species can be environmentally determined by temperature or hormone treatments; sometimes surgically as in removing or implanting androgenic glands in crustaceans. Used directly or indirectly (via breeding programs) to produce monosex populations to take advantage of desirable characteristics of a particular sex, e.g. male tilapia grow faster, or to reduce chance of unwanted reproduction.
Chromosome set manipulation	Chromosome sets can be manipulated by temperature, chemical or pressure treatments to gametes and/or zygotes, to produce gynogens, androgens, polyploids (triploids and tetraploids) and clones. Triploid organisms are usually sterile and may grow faster than diploids because energy is not devoted to reproduction.

Table 7 (*continued*)

Technology	Description and comment
Gene transfer (transgenics)	Genes of foreign species (or a con-specific) can be incorporated into a farmed type to confer special characteristics not usually found in that species. Extremely controversial technology that has only been approved for production or sale in a very small number of countries.
Gene editing (CRISPR)	Very recent and powerful technology to edit, i.e. remove or insert, sections of DNA more precisely to produce a desirable outcome or prevent an adverse outcome. As of 2018, this technology is not being used commercially in aquaculture.
Sperm cryopreservation	Gamete (usually sperm) freezing technology for aquaculture species can be vital for transfer of improved germplasm, germplasm exchange programs, long-term storage of improved material, improving domestication of new species, and increasing population size in on-farm conservation.
Stem cell technologies	Stem cell technology is useful to preserve diploid germplasm which can be revived, species restoration, application in surrogate broodstock technology and aiding domestication.

ANNEX 4 – GLOSSARY

Realizing the importance of clear definitions when discussing AqGR, FAO proposed the general term ‘farmed type’ to signify an organism raised in aquaculture facilities (Table 8). A farmed type could be a genetically improved strain, a hybrid, a polyploid, a genetically engineered organism, for instance by gene transfer or gene editing, or a sex-reversed organism. If the farmed species is simply captured from the wild, e.g. for broodstock or for grow-out, the farmed type would be ‘wild-type.’ Where more specific reference is needed, the type of organism should be explicitly stated, e.g. triploid oysters.

Throughout the Framework accurate and consistent terminology will be essential. FAO maintains glossaries on biotechnology and on genetic technologies in fisheries and aquaculture[8]. These glossaries are being revised following the preparation of the State of the World’s Aquatic Genetic Resources for Food and Agriculture Report, and should become standard references for correspondence, policies and publications at national, regional and international levels.

[8] FAO. 2018. FAO Term Portal [online]. Rome. [Cited 25 September 2018]. www.fao.org/faoterm/en/?defaultCollId=14

Table 8: Nomenclature suggested to designate genetic diversity in fisheries and aquaculture based on the *Revised Draft Report on The State of the World's Aquatic Genetic Resources for Food and Agriculture*[9]

Term	Definition
Cultivar or variety	A plant or grouping of plants (including aquatic plants) selected for desirable characteristics that can be maintained by propagation and have characteristics that easily distinguish it from any other known cultivar; the cultivar must retain these characteristics under repeated propagation.
Farmed type	Farmed aquatic organisms that could be a strain, hybrid, triploid, monosex group, other genetically altered form, cultivar, variety or wild type. Note: a 'species' is a higher level classification than 'farmed type'. A farmed type would normally be a species (unless it is a hybrid or introgressed strain) being cultured but requires a further level of definition beyond just the species name, e.g. wild type or triploid, such that every species in culture would have a farmed type associated with it to provide more information on the genetic resource.
Strain	A farmed type of aquatic species having homogeneous appearance (phenotype), homogeneous behaviour, and/or other characteristics that distinguish it from other organisms of the same species, and that can be maintained by propagation.
Stock	A group of similar organisms in the wild that share a common characteristic that distinguishes them from other organisms at a given scale of resolution.
Wild relative	An organism of the same species as a farmed organism (conspecific) found and established in the wild, i.e. not in aquaculture facilities.

[9] FAO. 2018. Aquatic Genetic Resources - A valuable and unexplored reserve of biodiversity for food and agriculture [online]. Rome. [Cited 25 September 2018]. www.fao.org/aquatic-genetic-resources/home/en/

ANNEX 5 – TOOLS FOR THE EFFECTIVE MANAGEMENT OF AQGR

This annex includes some useful tools for responsibly managing the movement of AqGR:

- Codes of Practice on species introductions
- Material Transfer Agreements
- Precautionary Approach

Codes of Practice on Introductions

The responsible use of non-native species has many issues that are similar to those for the responsible use of AqGR. A code of practice has been established by the International Council for the Exploration of the Sea (ICES) to assist with the use of non-native species. The ICES Code of Practice (Annex II)[10] provides advice on how to reduce the risk of adverse effects from the intentional introduction of marine and brackish-water alien species. The general principles of the code also apply to freshwater ecosystems. This code has been adopted in principle by several international agencies[11] and can serve as a model on which to base national, regional and international legislation, and similar instruments[12].

The basic code is conceptually simple and contains the requirements that any person, agency or business planning to use alien species should follow. The requirements start with the preparation of a proposal that will be reviewed by an independent body. The results of the review will be communicated back to the proposers for

[10] ICES. 2005. ICES Code of Practice on the Introductions and Transfers of Marine Organisms [online]. Copenhagen. [Cited 25 September 2018]. www.ices.dk/reports/general/2004/ICESCOP2004.pdf

[11] The FAO Committee on Inland Fisheries and Aquaculture in Africa, FAO Commission for Inland Fisheries of Latin America, the FAO European Inland Fisheries Advisory Commission, and the FAO Regional Commission for Fisheries (Persian Gulf and Gulf of Oman).

[12] Other similar codes have been developed (e.g. Hewitt, C.L., Campbell, M.L. & S. Gollasch. 2006. Alien Species in Aquaculture. Considerations for Responsible Use [online]. IUCN Gland, Switzerland and Cambridge, UK. [Cited 25 September 2018]. https://portals.iucn.org/library/sites/library/files/documents/2006-036.pdf

revision if necessary. When the proposal to introduce a new species is approved, the code calls for fish health management, monitoring and reporting (Box 1).

Box 1

Diagrammatic representation of a code of practice for the responsible use of introduced species. The process is interactive (indicated by curved arrows) in order to modify proposals and act on the advice given during the review process

- **PROPOSAL**
  - Planned use, location, passport, source
- **INDEPENDENT REVIEW**
  - Disease, ecology, genetics, socio-economics, local species impacted
- **ADVICE**
- **APPROVAL**
- **PROTOCOLS IF APPROVED:** quarantine and monitor

Further guidance can be found in the chapter on Dissemination of Genetically Improved Strains and Material Transfer Agreements[13] in the Technical Guidelines for Responsible Fisheries on genetic resource management in aquaculture.

Material Transfer Agreements (MTA)

If the request for introduction is approved, the transfer should be consistent with relevant international and national laws such as those related to access and benefit-sharing, property rights or biosecurity.

[13] FAO. 2008. Aquaculture development. 3. Genetic resource management. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 3. Rome. 125p (also available http://www.fao.org/3/a-i0283e.html)

The conditions to access and use such genetic material are normally set through a MTA.

The following example of a MTA is based on one currently used by WorldFish[14].

Request to be sent on company or official letterhead

To: The request for improved germplasm should be made to a competent authority that has legal and political authority to disseminate the material.

From: I/we order the following material:
A list of material being requested should be attached here including the detailed description of the material, its intended use and location of use as listed in the text.

I/we agree

- to abide by the provisions in the Convention on Biological Diversity;
- to preclude further distribution of germplasm to locations at which it could have adverse environmental impact;
- not to claim ownership over the material received, nor to seek intellectual property rights over that germplasm or related information;
- to ensure that any subsequent person or institution to whom I/we make samples of the germplasm available, is bound by the same provision;
- that the responsibility to comply with country's biosafety and import regulations and any of the recipient country's rules governing the release of genetic material, is entirely mine/ours;
- to follow the quarantine protocols suggested by the FAO Technical Guidelines on Health Management for Responsible Movement of Live Aquatic Animals and the WorldFish Center;
- that when germplasm is transferred beyond the boundaries of our country, we will abide by the relevant international codes and guidelines, e.g. the CCRF, ICES, and the OIE (World Organization for Animal Health).

Date:..

Name of person or institution requesting the germplasm:...........................

Address:..

Shipping address (if different from the above):...

Authorized signature:...

[14] FAO. 2008. CIFAA Occasional Paper No. 29 RAF/CIFAA/OP29 (Tri) Pioneering fish genetic resource management and seed dissemination programmes for Africa. Rome.

Precautionary Approach

FAO, the Convention on Biological Diversity (CBD)[15], the North Atlantic Salmon Conservation Organization (NASCO)[16] and others have adopted a precautionary approach to fishery management and aquaculture development. Such an approach allows for the precautious development of aquatic resources in the absence of complete information on the resource or ecosystem. In some international and national fora, the use of the phrase 'precautionary approach' or 'precautionary principle' is controversial and has developed strong connotations and blocked further discourse of how best to sustainably manage and conserve aquatic resources. In such cases it may be more effective to use the phrase 'Adaptive Management'.

The precautionary approach advocated by FAO, CBD and NASCO states that where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. In all cases the following should be considered:

- Development proposal: to be drafted by the entity (the proponent) proposing to develop or use (harvest or farm) an AqGR;
  - The proposal should contain information on species, stock or strain, any genetic technology used to create it; location of fishery or fish farm and any special considerations, e.g. threatened or endangered species, non-native species, special disease or parasite concerns, and expected benefits to be derived from the proposal.
- Creation of an independent review board: this body should have expertise from genetics, aquatic ecology, civil society and economics.
- The review board should

[15] Convention on Biological Diversity (CBD). 2018. CBD [online]. Montreal. [Cited 25 September 2018]. www.cbd.int/

[16] North Atlantic Salmon Conservation Organization (NASCO). 2018. NASCO [online]. [Cited 25 September 2018]. www.nasco.int/

  - advise the proponents on the suitability of their proposal taking into account risks to environment and society; and
  - advise resource managers on the suitability of the proposal, taking into account benefits and risks to the environment and society.
- The proponents should revise the proposal in accordance with the advice provided by the independent review board and resubmit the proposal.
- The competent authority should decide on whether to allow the development activity to proceed.
- If the decision is to proceed with the proposal, appropriate quarantine, biosecurity, monitoring and evaluation should be put in place.

In order to help proponents and government resource managers implement a precautionary approach, the following are suggested:

- **Reference points** should be established to help determine desirable situations and undesirable impacts, e.g. target and limit reference points. For example, Maximum Sustainable Yield could be considered a target reference point. An example of a limit reference point could be a specific number of escaped farmed fish. Some potential reference points are listed in the Table 9 below. Resource managers should develop quantitative values for the reference points of relevance for their specific situation.
- **Undesirable outcomes**, as well as **corrective or preventative measures**, should be identified, including the prohibition or enforced cessation of activities that carry unacceptable risks or have already had unacceptable adverse impacts. Pre-agreed actions or contingency plans should be implemented in a timely manner when limit reference points are approached, or when adverse impacts are apparent. Thus monitoring of aquaculture facilities, local species and the environment is necessary to know when reference points are reached. Such actions could include switching to sterile fish if breeding with local species is a problem or changing containment or location of facilities. Conversely, if good culture or fishing practices are used and no adverse

impacts are found, additional development following the same approach could be planned.

- **Priority should be given to maintaining the productive capacity of the resource** where there is uncertainty as to the impact of development. In capture fisheries, this means that priority is given to conservation of stocks over harvesting the stocks when there is uncertainty. This can be extended to aquaculture where the productivity of local stocks should be maintained when there is uncertainty as to the risk of genetically altered species adversely affecting them. This may require locating fish farms in areas away from valuable local resources.
- **The impacts should be reversible within the time frame of 2–3 decades** (~1 human generation). This element renders as non-precautionary the use of reproductively viable, genetically altered species in many situations, none the less a precautionary approach can be followed. Species introduced for aquaculture have naturalized and established self-sustaining populations in many instances; the eradication of such populations (i.e. the reversibility of the impact) is difficult or impossible, especially in marine areas, large inland water bodies and wetlands, and extensive river systems.

The burden of proof should be placed according to the above requirements and the standard of proof should be proportional to the risks/benefit (i.e. a higher standard of proof would be required when risks relative to benefits are high). The precautionary approach has often been taken to mean that the burden of proof rests with those proposing the use or development of a resource (i.e. the aquaculture facility must prove that a genetically altered species will have no adverse impact). This is the “guilty until proven otherwise” approach. The application of this, in real situations, is difficult. All cases for allowing or prohibiting aquaculture activities should be based, to the greatest extent possible, on sound scientific information and opinion.

Table 9: Some example reference points regarding AqGR
(T = Target and L = Limit reference points)

Number of broodstock for long term maintenance of genetic diversity	Effective population size = 500 (T)
Number of broodstock for short term maintenance of genetic diversity	Effective population size = 50 (T)
Levels of inbreeding (F) in the short term	F < .18 (L)
Levels of inbreeding (F) in the long term	F < .05 (L)
Percent sterile fish in production system	100% (T)
Level of gene flow between farmed type and wild relative	Less than 1 migrant/generation (L)
Fishing mortality	Fishing mortality < 20% of unfished biomass (L); Maximum Sustainable Yield (T)
Risk of extinction	Ne < 50 in the wild; order of magnitude decrease in population size

ANNEX 6 – CAPACITY BUILDING

Capacity building and extension are required on all of the components of the Framework, i.e. information generation and management, governance and policies, and infrastructure and equipment. Extension services are necessary to convey scientific and policy advice to the private industry. Capacity building can be facilitated or enhanced through Private Public Partnerships (PPP). Capacity development for the digitalization of information allows for more efficient capacity building through, for example, online courses and training, targeting students across nations and geographical distances.

The *Revised Draft Report on The State of the World's Aquatic Genetic Resources for Food and Agriculture*[17] indicated national capacity could be strengthened to:

- Establish/rehabilitate broodstock development facilities, and breeding and hatchery facilities to provide quality broodstock and seed stock;
- Seek public–private cooperation to achieve adequate supply of key farmed types; and
- Develop breeding programs directed at avoiding inbreeding and improving record keeping.

Additionally, capacity in policy development and in interdisciplinary approaches may be required.

Effective mechanisms for capacity building include:

- workshops on specific topics
- farmer field schools
- study tours
- exchange of scientific and technical personnel
- intern and apprentice programmes
- online courses and training
- universities or trade schools.

[17] FAO. 2018. Revised draft report on the State of the World's Aquatic Genetic Resources for Food and Agriculture [online]. [Cited 25 September 2018]. www.fao.org/fi/static-media/MeetingDocuments/AqGenRes/ITWG/2018/Inf2e.pdf

ANNEX 7 – WORKING WITH THE PRIVATE SECTOR

Olesen[18] *et al.* (2015) concluded that there were three key factors for increasing adoption of genetically improved farmed fish: (i) long-term public commitment needed for financial support of the breeding nucleus operation (at least during the first five to ten generations of selection); (ii) training at all levels (from government officers and university staff to breeding nucleus and hatchery operators, as well as farmers); and (iii) development of appropriate business models for benefit-sharing between the breeding, multiplier and grow-out operators (whether they be public, cooperative or private operations). The public support should be invested in selective breeding in the most important and highest volume species, which may not be a priority for investment by private breeders due to, for instance, long generation intervals and delays in return to investment.

PPP have become a valuable tool through which governments attract and mobilize investments to serve the interests of the public and private sectors. Although there is no standard definition of a PPP, the Canadian Council for Public-Private Partnerships defines a PPP as "a cooperative venture between the public and private sectors, built on the expertise of each partner that best meets clearly defined public needs for services or infrastructure through the transfer between partners of resources, risks and rewards." Werowski and Hall (2008)[19] list two essential elements to this definition:

1. that the arrangement is to provide public services; and
2. that partners share risk.

The aim of PPPs is to structure the relationship between the public and private sectors to serve these two purposes: to allocate the risks to those best able to manage them and to add value to public services by using private sector skills and competencies.

[18] Olesen, I., Bentsen, H.B. Phillips, M. & Ponzoni, R.W. 2015. *Journal of Marine Science and Engineering*, 3: 240–266. (also available at www.mdpi.com/2077-1312/3/2/240/pdf)

[19] Weirowski, F. & Hall, S.J. 2008. Public-private partnerships for fisheries and aquaculture: Getting started. WorldFish Center Manual number 1875. The WorldFish Center, Penang, Malaysia.

Such partnerships have many potential benefits such as better allocating risks among the parties involved, decreasing governments' capital costs, accelerating project implementation and infrastructure provision. Depending on the agreed goals, many PPP arrangements can be established for the aquaculture sector and the development of AqGR. However, this definition refers to a country that has a developed private aquaculture sector with established expertise. Often, the expertise for breeding and managing AqGR does not exist in the private sector and governments would need to help establish such expertise. In the Werowski and Hall publication, "*PPPs are not incentives or subsidies given by the public sector to attract private investments*". Whether public incentives or subsidies are considered a PPP or not, the same principles would apply, that is the public and industry would benefit and risks would be shared based on the group most able to handle them. We propose a more general definition of PPP that would include these public subsidies.

Several Country Reports submitted for the preparation of the first report on the State of the World's Aquatic Genetic Resources for Food and Agriculture (SoW AqGR)[20] listed numerous public and public private partnerships that have been used to establish breeding centres and to genetically improve farmed aquatic species. China is the leader in aquaculture production and has cited numerous examples of public funding and partnerships to help the industry develop improved strains.

[20] http://www.fao.org/aquatic-genetic-resources/background/sow/en/

CASE STUDIES

Case study	Title	Author
Case study 1	AqGR information management: German database on AqGR	Clemens Fieseler
Case study 2	Genetic improvement of tilapia in the Volta Basin	Devin M. Bartley
Case study 3	Selective breeding and dissemination of farmed aquaculture strains: the GIFT project and the INGA network	Hans B. Bentsen
Case study 4	Impact of aquatic exotic species in the Pacific	Pacific Community (SPC)
Case study 5	Developing and distribution of the Jian Carp (*Cyprinus carpio* var. *jian*) in China	Freshwater Fisheries Research Center (FFRC) of the Chinese Academy of Fisheries
Case study 6	Enabling the private sector: The Chile Foundation	Marcela P. Astorga
Case study 7	Genetic resources management policy in Iran (Islamic Republic of)	Mohammad Pourkazemi

CASE STUDY 1. AQGR INFORMATION MANAGEMENT: GERMAN DATABASE ON AQGR

1.1 BACKGROUND

In 2000, the German Federal Ministry of Food, Agriculture and Consumer Protection, published the "*Conception for the conservation and sustainable use of genetic resources for food, agriculture and forestry*". It forms the basis for specialized National Programs in various sectors, *inter alia* for AqGR. This includes measures to support the efficient conservation and sustainable use of agrobiodiversity, which can only be implemented with the participation of a wide range of experts and institutions representing different stakeholders. This requires comprehensive information, consultation and coordination mechanisms.

Those are the tasks of the Information and Coordination Centre for Biological Diversity (IBV) at the Federal Agency for Agriculture and Food (BLE). As the central authority responsible for information and coordination in the field of agrobiodiversity, the IBV facilitates the use of synergies and improves the efficiency of interested parties. The IBV is responsible for the collection, documentation and user-oriented dissemination of data related to agrobiodiversity in Germany. According to increasing demands for an efficient monitoring of status and trends of genetic resources the IBV is further developing the National Inventory for Aquatic Genetic Resources (AGRDEU).

1.2 THE EXISTING PUBLICALLY AVAILABLE AGRDEU DATABASE

The AGRDEU database has the objective to document the most important AqGR in Germany as a national species inventory both for farmed species and wild relatives. It is maintained by the IBV of the Federal Agency for Agriculture and Food (BLE). It serves as an instrument for the implementation of the National Technical Program for the Conservation and Sustainable use of Aquatic Genetic Resources. The AGRDEU database is developed as a tool for the conservation and sustainable use of AqGR. Within the database AqGR are documented separately in freshwater, marine and aquaculture subsystems. A selection of species used in German marine and inland fisheries is listed. For each listed species taxonomic, occurrence and risk level information is recorded.

In the aquaculture area of the database, key findings of an inventory project are available. These key findings are focusing on the major German aquaculture species. Quantitative and qualitative data of broodstock from AqGR farmed in Germany can be retrieved. Broodstock are searchable by species, specific rearing conditions, morphometric and genetic criteria.

Because the demand for an efficient monitoring of status and trends of AqGR is increasing and the currently publically available AGRDEU database is very limited in its information, the IBV has made a fundamental revision of the existing database.

1.3 THE NEW REVISED AGRDEU DATABASE

The new database (not yet publically available) intends to provide comprehensive information from species to strain/stock level of both farmed types and wild relatives. This database consists in principle of three interconnected levels:

1. dataset with German AqGR species – covers information at species level;
2. dataset with publications on genetic characterization of German AqGR; and
3. dataset of all genetically characterized strains and stocks mentioned at point 2. This dataset contains information below the species level.

1. List of species

The database founded upon a list of species in which all AqGR, relevant to the areas of marine capture fisheries, inland fisheries, aquaculture and recreational fishing in Germany are defined, in accordance with the following FAO definition:

"Aquatic genetic resources for food and agriculture comprise all genetic material of actual or potential value for the productivity and sustainability of capture fisheries, aquaculture and culture-based fisheries, including finfish, crustaceans, molluscs and other aquatic invertebrates, aquatic microorganisms, plants, amphibians, reptiles and mammals."

The list of AqGR includes fish, crustaceans and molluscs, which in Germany are subjected (in some cases only potentially) to farming and fishing purposes in the marine and limnic areas. Reptiles, amphibians and mammals can be neglected in this context in Germany. In the case of aquatic micro- and macrophytes, there is only a marginal production for the pharmaceutical sector in Germany. Therefore, aquatic micro- and macrophytes are not listed in the database, so far.

Currently there are 144 species in the list of German AqGR (118 fish species, 11 mussel species, 9 crustacean species and 6 cephalopod species). The dataset in the species list contains for each listed species the following information:

- codes of the FAO ASFIS list (ISSAAP, TAXOCODE, 3A_Code);
- scientific and common name (German and English);
- taxonomic information (phylum, class, order, family, genus, species);
- habitat (marine, brackish and freshwater);
- utilization information (inland or marine capture fisheries, recreational fisheries, aquaculture);
- general species information (link to FishBase, and where available to FAO Species Factsheet and/or FAO Aquaculture Fact Sheets);
- for non-native species: link to DAISIE Alien-Factsheet; and
- Red List classification according to German Red Lists for freshwater and marine organisms.

2. List of publications

The publication list currently contains a collection of 34 publications that have generated genetic data of aquaculture breeding strains and wild stocks of AqGR in Germany. For every publication, the source citation and the e-mail contact of the lead author are provided. Where available the Digital Object Identifier (DOI) and/or the Uniform Resource Locator (URL) for downloading the relevant publication are provided.

Key publications in this list are the publications of special survey projects advised by the German technical committee of AqGR for the monitoring on genetic biodiversity of German AqGR. The monitoring and documentation of the biological diversity of AqGR is a defined goal in the National Technical Program for the Conservation and Sustainable use of Aquatic Genetic Resources. To the implementation of this goal, the German Federal Ministry for Agriculture and Food commissions these survey projects. The findings of these projects are essential for a proper management of AqGR.

3. List of breeding strains and wild stocks of AqGR

The list of breeding strains and wild stocks examined in the above-mentioned publications, currently covers information on 494 breeding strains and 644 wild stocks of AqGR. The dataset in this list gives *inter alia* the following information for each listed strain or stock:

- Publication Code;
- Species information (common name, scientific name);
- Conservation categories (on farm, *in-situ, ex-situ*);
- Origin of samples (rivers' names or name of fish farm, river basin, federal state, district, community, geographical coordinates);
- Management of the river or lake (recreational fisheries, capture fisheries, no management);
- Framework parameters (sample size, average overall length and mass, average condition factor);
- Genetic parameters (number of individuals with analysis of mitochondrial DNA, haplotype diversity, nucleotide diversity, GenBank accession numbers, number of individuals with analysis of microsatellite markers, maximum number of alleles per locus, mean number of alleles per locus, allelic richness, private alleles, H_e, H_0, F_{IS}, maximum F_{IS}, minimum F_{IS});
- Molecular genetic/biochemical/morphometric methods used;
- Proposed management unit (only wild relatives);
- Name of identified strain or stock; and
- Comments.

Currently information on farmed types and wild relatives are treated separately, because the information needs are slightly different. A combination of the data with appropriate filter options is also conceivable.

1.4 STATUS AND FUTURE CHALLENGES

The new German AGRDEU Database takes a simple approach for incorporating genetic diversity as information base for national and global reporting requirements on AqGR.

The species list on German AqGR acts as a national species inventory and documents the most important AqGR in Germany on species level. It provides for each species associated information on taxonomy, use and conservation. It is an open list to which additional species can be added at any time, depending on the requirements. It is a tool for fulfilling the commitments to the Ministry for agriculture and food and for implementing the National Technical Program for the Conservation and Sustainable use of Aquatic Genetic Resources.

At present, the database is still like a "living document" and in constant development. Many things can still be improved and upgraded. A comparison with the recommendations of the FAO document Incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives[21] can help to optimize the AGRDEU database and to meet future German international reporting requirements on AqGR.

The revised AGRDEU database is not publicly available yet and exists as ACCESS database only. It is planned to convert this database into another format, which is searchable online and provides publicly available information on German AqGR. Once it is publicly available for farmers, fishers and resource managers, the new AGRDEU database could positively affect aquaculture and fisheries resources management in Germany.

[21] FAO. 2017. Incorporating genetic diversity and indicators into statistics and monitoring of farmed aquatic species and their wild relatives [online]. [25 September 2018]. http://www.fao.org/3/a-bt492e.pdf

CASE STUDY 2. GENETIC IMPROVEMENT OF TILAPIA IN THE VOLTA BASIN

2.1 BACKGROUND

Nile tilapia is an important farmed fish with global production estimated at 4 million tons in 2016. However, only a small proportion of this production, about a million tons, and subsequent benefits, are in Africa. The majority of production and of the genetic improvement of this species has come from Asia. Recognizing the potential to increase production of Nile tilapia in Africa, the countries of the Volta Basin, in collaboration with FAO, the government of Spain and WorldFish, developed the three-year project (2008–2011) *Aquaculture investments for poverty reduction in the Volta Basin: creating opportunities for low-income African fish farmers through improved management of tilapia genetic resources* (TIVO). The project's overall goal was to contribute to the development of the Volta Basin's capacity for the conservation, sustainable use and development of its AqGR. In light of financial constraints, the project only included Ghana rather than the entire basin.

2.2 THE TIVO PROJECT

The TIVO project's objectives were to survey the strains and native populations of Nile tilapia to identify valuable genetic resources for potential use in a breeding program, and for protection. The project developed a strain of genetically improved Nile tilapia, named the Akosombo strain that would be well suited for the Volta Basin. In light of the popularity of another strain of Nile tilapia known as the Genetically Improved Farmed Tilapia (GIFT), the project also planned to test the performance of the Akosombo strain compared to the GIFT. The project was also to help develop a dissemination system and appropriate policies for use and dissemination of the improved strain, including conservation measures to protect native tilapia genetic resources.

In order to achieve TIVO's objectives, specific infrastructure and equipment were needed. For the genetic improvement of tilapia the following were required at facilities near Lake Volta, Ghana:

- sufficient ponds and hatchery facilities to raise numerous families of Nile tilapia;
- hapas (small net enclosures) for selective breeding and maintaining selectively bred strains of tilapia;
- tagging equipment to identify families and individuals for breeding; and
- training facilities for hatchery personnel.

To compare the performance of the Akosombo strain with the GIFT (imported from WorldFish, Malaysia) a quarantine receiving facility and bio-secure grow-out and testing facilities were required. For the dissemination of genetically improved Akosombo strain, the quarantine facility would ensure healthy strains would be distributed and in addition, multiplication hatcheries are required to breed the genetically improved strain in sufficient numbers to supply the aquaculture industry.

Although multiplication hatcheries are the ideal solution to supply large numbers of genetically improved tilapia, most of the production of the Akosombo strain is being done and disseminated by the Aquaculture Research and Development Centre in Ghana (ARDEC).

To characterize the genetic resources of local tilapia populations and the genetically improved strains of Nile tilapia, DNA was extracted by a partner institution in Burkina Faso and then sent to Wageningen University in Holland for high resolution genetic analysis. As noted in the Framework, partnerships can facilitate the use and development of AqGR; in this instance appropriate infrastructure and expertise were not available in Ghana but were available elsewhere and accessed with good results. The identification of valuable native tilapia AqGR, as well as the quarantine and biosecure facilities, were key elements that convinced an originally reluctant environmental group to allow the TIVO project to proceed.

TIVO achieved many of its objectives; the Akosombo strain was reported to grow 25 percent faster than the wild-type and the ARDEC has been reported to be supplying most of the hatcheries in the vicinity of Ghana's Lake Volta with the Akosombo strain. The quarantine and biosecure facilities are functioning and following the conclusion of the project genetic characterization of the Akosombo strain has been made (Van Bers *et al.,* 2012). However, comparisons between the GIFT and Akosombo strains were not done because the biosecure farming system in which the comparisons were to be conducted, i.e. ponds and raceways, was not the actual farming system being used by Ghanaian aquaculturists, that consists of cages in lakes. Coordinated policies on the risk and use of genetically improved tilapia and the conservation of native tilapia resources are still needed (Ansah *et al.*, 2014).

The TIVO project taught several valuable lessons:

- Genetic resource management can increase production from aquaculture.
- Sufficient infrastructure will be required to ensure biosecurity and proper genetic improvement.
- Partnerships can help provide valuable expertise that may not be readily available in country.
- Risk assessment and biosecure facilities should be based on the actual type of aquaculture farming system(s) to be used.
- Twinning aquaculture conservation, sustainable use and development of AqGR will help increase uptake of genetic improvement programs.
- In conclusion, the TIVO project has helped increase aquaculture production through development of infrastructure and partnerships for genetic resource management in Ghana.

REFERENCES

Ansah, Y.B., Frimpong, E.A., & Hallerman, E.M. 2014. Genetically-Improved Tilapia Strains in Africa: *Potential Benefits and Negative Impacts. Sustainability*, 6: 3697–3721 [online]. [Cited 27 March 2018]. doi: 10.3390/su6063697.

Van Bers, N.E., Crooijmans, R.P., Groenen, M.A., Dibbits, B.W. & Komen, J. 2012. SNP marker detection and genotyping in tilapia. *Molecular Ecology Resources,* 12(5): 932–41 [online]. [Cited 27 March 2018]. doi: 10.1111/j.1755-0998.2012.03144.x.

CASE STUDY 3. SELECTIVE BREEDING AND DISSEMINATION OF FARMED AQUACULTURE STRAINS: THE GIFT PROJECT AND THE INGA NETWORK

3.1 BACKGROUND

Most aquaculture species have not been through a planned process of genetic domestication and selective breeding as has occurred with terrestrial farm animal species. Less than 10 percent of the global aquaculture production is based on genetically improved material from selective breeding programs (Gjedrem *et al.*, 2012). As a result, the majority of aquaculture production is still based on wild type animals that are poorly adapted to life in captivity. This often implies poor growth rate and poor animal welfare, high mortality, inefficient use of resources such as feeds, water and energy, and higher cost per kilogram of fish produced. Farming of aquatic organisms from selectively bred populations has the potential to contribute significantly to increased supply of fisheries commodities, including in those regions and countries with significant food security and nutrition challenges. Increased aquaculture production may also reduce the (over)exploitation of wild fisheries stocks.

The feed conversion efficiency of many farmed fish species is higher than that of domesticated terrestrial farm animals (Gjedrem *et al.*, 2012), partly because of lower energy requirements for body thermoregulation. Furthermore, an increasing amount of studies show considerable genetic variation and significant heritability for a wide range of performance traits in aquaculture species under farming conditions (Gjedrem and Olesen, 2005), laying the foundation for rapid domestication and performance improvement of specialized aquaculture stocks through modern selection programs (Gjedrem, 1985; Bentsen, 1990). Highly favourable benefit/cost ratios ranging from 8 to 400 are reported for investments in fish breeding programs (Gjedrem, 1997; Ponzoni, 2007 and 2008). Consequently, the prospects are good for developing high performing and resource efficient domesticated populations and strains of aquaculture organisms that may secure the future supply of aquatic animal products and even outperform traditional farm animals in terms of feed conversion efficiency.

3.2 THE GIFT PROJECT

Nile tilapia is one of the aquaculture species that have been subjected to domestication and selection for improved performance in recent decades. The global production of Nile tilapia has increased rapidly from 0.4 million metric tons in 1980 to 4.2 million metric tons in 2016 (FAO, 2018) and is now a major aquaculture species. A contributor to this increase is the achievements from the GIFT project. The GIFT project was an international collaborative project to improve the genetic performance of farmed Nile tilapia that was carried out over 10 years from 1988 at the BFAR/FAC facilities in Muñoz, Philippines in collaboration with Akvaforsk (now Nofima) on the initiative of Dr. Roger S.V. Pullin and Dr. Trygve Gjedrem (Pullin *et al.*, 1991; Gjedrem, 2012). The project was implemented and coordinated by ICLARM (now WorldFish) with funding from the United Nations Development Program (UNDP) and the Asian Development Bank (ADB). The objective of the project was to apply updated farm animal breeding and selection technology to improve the performance of tropical farmed finfish. Nile tilapia was chosen as a test-case because of the short generation interval of the species, and for its significance for a wide range of fish farming operations, including small-scale and backyard farmers.

The GIFT project was started by collecting and testing genetic material from four wild strains from Africa (Egypt, Ghana, Kenya, Senegal) and four farmed strains already presented in the Philippines (locally named as Israel, Singapore, Taiwan and Thailand) (Eknath *et al.*, 1993). The growth performance of the eight purebred strains (Eknath *et al.*, 1993; Bentsen *et al.*, 2012) and all possible crosses between them (Bentsen *et al.*, 1998) was tested in a wide range of farming environments. The ranking of the purebred strains was quite consistent across test environments, with three of the wild strains among the fastest growing. The general heterosis effect was low (on average crossbreds were 4.3 percent heavier than the mean of the parent strains, a maximum 14 percent heavier). The additive genetic variation across strains and crosses was then estimated within and across environments, showing an overall heritability for body weight of 0.16 (Eknath *et al.*, 2007; Bentsen *et al.*, 2012). It was concluded that the gain from a crossbreeding program involving the tested populations would be insignificant compared to long term selection for improved additive genetic performance in a mixed, synthetic population including all eight strains (Eknath *et al.*, 2007), and that this population would perform well in a wide range of extensive to semi-intensive farming systems. Five generations of selection for improved growth performance were then carried out, resulting in a realized accumulated increase in body weight at harvest of 88 percent, or 13.6 percent per generation, quite similar to a number of later tilapia selection studies (Bentsen *et al.*, 2017). Reports from several descendant populations also show continued selection response during more than 10-15 additional recorded generations (Ponzoni *et al.*, 2005; Luan, 2010; Hussain *et al.*, 2011; Thodesen *et al.*, 2011; Gjerde *et al.*, 2012). Significant additive genetic variation and prospects for broader selection goals for a range of traits other than harvest body weight has also been reported both in the original GIFT population. These traits include for serum lysozyme activity, Chiayvareesajja *et al.*, 1999; for frequency of early maturing females, Longalong *et al.*, 1999; and for male proportion among progeny, Lonzano *et al.*, 2013 in the original GIFT population. In descendant populations prospects for broader selection goals include for fillet yield, Nguyen *et al.*, 2010; Gjerde *et al.*, 2012; Thodesen *et al.*, 2012; for body shape, Trong *et al.*, 2013b; for survival in freshwater and brackish water; for cold tolerance, Luan, 2010; and for female reproductive traits, Trong *et al.*, 2013a; 2013c.

The funding from UNDP was granted through the Division for Global and Interregional Programs. Accordingly, several international meetings were organized by ICLARM from the very start of the GIFT project to discuss the plans and the progress of the project and its relevance for selective breeding of tropical farmed fish. In 1993, the International Network for Genetics in Aquaculture (INGA) was established to promote the exchange of research methodologies and results between member institutions, to organize training courses in quantitative genetics and selection theory, and to propose exchange of genetic material. In 1999, INGA had a membership of 13 countries in Asia, the Pacific and Africa (Bangladesh, China, Côte d'Ivoire, Egypt, Fiji, Ghana, India, Indonesia, Malawi, Malaysia, Philippines, Thailand and Viet Nam) and 12 advanced scientific institutions (Gupta and Acosta, 2001). The first in a series of international INGA training courses in quantitative genetics was organized in 1995 with participants from all Member Countries, and continued until the turn of the century. Several of the participants in the INGA courses have since then taken lead roles in establishing national aquaculture breeding programs for tilapias as well as a of other species (e.g. Rohu carp, Common carp, Silver Barb, River catfish) (Gupta and Acosta, 2001; Ponzoni *et al.*, 2010a).

Genetic material from the GIFT project was disseminated by ICLARM through INGA for on-farm testing from the very early generations in 1994, both within the Philippines and through public institutions in Bangladesh, China, Thailand and Vietnam (Dey *et al.*, 2000) and in Fiji (Mather and Nandlal, 2000). After the termination of the GIFT project in the Philippines, the dissemination of GIFT genetic material and selection methodology continued through INGA contacts and other partners (Ponzoni *et al.*, 2010a; Bentsen *et al.*, 2017). A tagged and pedigreed set of progeny families after the fifth selected GIFT generation was transferred in 2000-2001 from the GIFT facilities in the Philippines to the new headquarter of WorldFish (ICLARM) in Malaysia (Ponzoni *et al.*, 2005; 2010a). The GIFT population was then re-established in 2002 in Malaysia, and a further pedigree based selection program for improved growth performance with one-year generation interval was initiated in collaboration with Department of Fisheries, Malaysia at the Aquaculture Extension Centre in Jitra, Kedah State (Ponzoni *et al.*, 2005). Furthermore, a tagged and pedigreed set of families from the same generation was supplied to Research Institute for Aquaculture No. 1 (RIA1) Hanoi, Vietnam in 1997 to found a further selection program there (Luan, 2010; Ponzoni *et al.*, 2010a). A third set of families was granted to a private Norwegian company (GenoMar, then BioSoft) in 1999 as a part of an agreement to secure funding to maintain the GIFT population during a critical period after the termination of the GIFT project (Eknath and Hulata, 2009; Ponzoni *et al.*, 2010a).

In addition to the breeding program that supplies tilapia farmers in Malaysia with continuously upgraded seed, WorldFish has also been collaborating with public and semi-public institutions in other countries to transfer the most recent GIFT material and to initiate further local selection and/or dissemination programs in the recipient institutions. Both pedigree based selection and modified mass selection with rotational cohort mating have been applied (Ponzoni *et al.*, 2010a). This involves transfers to Bangladesh (Bangladesh Fisheries Research Institute, Mymensingh, 1994-2005, BRAC Centre, Magura, 2008), Brazil (Universidade Estadual de Maringá, 2005), China (Shanghai Ocean University, 1994, Freshwater Fisheries Research Center, Wuxi, 2006), Philippines (TGA Farms Incorporated, Pampanga, 2006), Sri Lanka (Aquaculture Development Center, Dambulla, 2007), Thailand (Pathumthani Fisheries Test and Research Center, 1994-2007) and Vietnam (RIA1, Hanoi, see above, RIA2, Ho Chi Minh City, 2006) (Ponzoni *et al.*, 2010a). It has been suggested to form a network of GIFT breeding populations to increase the effective population size by exchange of broodstock, similar to breed associations of terrestrial farm animal species (Ponzoni *et al.*, 2010b). Unfortunately the INGA folded after donor funding dried up, but nevertheless distribution of GIFT material has continued.

Genetic material and technology from the GIFT project has also been a source for private breeding operations. GenoMar used the material acquired in 1999 (see above) to establish a breeding nucleus in Luzon, Philippines and has since then carried out a pedigree based selection program. The seed is marketed under the brand GenoMar Supreme Tilapia (GST) in the Philippines and through multiplier operations in China and Malaysia (Jamtøy, 2013). RIA1 in Vietnam used the material acquired in 1997 to establish a population based on GIFT broodstock (Ponzoni *et al.*, 2010a) under the brand NOVIT, that has been selected based on pedigree records since then for growth rate and cold tolerance and marketed in Vietnam and abroad. In 2004, NOVIT family material was exported to China to establish a private pedigree based selection and multiplier program for improved growth rate and fillet yield in Hainan, China under the brand Progift (Thodesen *et al.*, 2011; 2012). The same year, a similar material of NOVIT families was also exported to Nicaragua, and served as a base population for an in-house selection program operated by the company Nicanor S.A. (Gjerde *et al.*, 2012). Material from the Nicaraguan program was then transferred to Florida, USA, in 2010, and used to establish a private pedigree based selection and multiplier program under the brand Spring Genetics. Spring Genetics seed is currently marketed in USA and worldwide, and through multiplier operations in Mexico and Brazil (Spring Genetics, 2016). The mentioned pedigree based selection programs in China, Nicaragua (now terminated) and United States of America were all designed and supervised by AFGC (now Akvaforsk Genetics), a Norwegian based provider of genetic improvement services to aquaculture industries. Furthermore, since GIFT-derived genetic material has been available on the open market over many years, it is not unlikely that unrecorded use of the material and technology has contributed to the establishment of other commercial breeding populations as well.

So far, the GIFT project has had limited impact in Africa. From the early years of the project, there was international concern about possible environmental impacts on native stocks of introductions of systematically selected, genetically mixed tilapia populations for general farming purposes. Consequently, caution was recommended regarding introductions of GIFT genetic material to Africa. As an alternative, it was recommended to prioritize the transfer of GIFT technology to develop farmed populations in Africa based on local tilapia stocks. Several such projects have been initiated in INGA Member Countries by WorldFish in Africa since then, e.g. in Egypt (Rezk *et al.*, 2009), in Ghana (Lind *et al.*, 2012; Ponzoni *et al.*, 2010a; Tran *et al.*, 2012), and in Malawi for *Oreochromis shiranus* (Maluwa and Gjerde, 2007). Meanwhile, selection programs outside Africa have accumulated genetic progress and competitive advantage during more than 15-20 generations of selection, potentially encouraging further unauthorized introductions to Africa. Since 2007, WorldFish has recommended to support authorized, risk assessed and monitored re-introductions of GIFT material to Africa (WorldFish, 2007). The first case study was implemented in Ghana (Rosendal *et al.*, 2012; Tran *et al.*, 2012).

REFERENCES

Bentsen, H.B. 1990. Application of breeding and selection theory on farmed fish. Proc. 4th World Congress on Genetics Applied to Livestock Production, Edinburgh, Scotland, 16: 149–158.

Bentsen, H.B., Eknath, A.E., Palada-de Vera, M.S., Danting, J.C., Bolivar, H.L., Reyes, R.A., Dionisio, E.E., Longalong, F.M., Circa, A.V., Tayamen, M.M. & Gjerde, B. 1998. Genetic improvement of farmed tilapias: growth performance in a complete diallel cross experiment with eight strains of *Oreochromis niloticus. Aquaculture*, 160: 145–173. https://doi.org/10.1016/S0044-8486(97)00230-5

Bentsen, H.B., Gjerde, B., Nguyen, N.H., Rye, M., W. Ponzoni, R.W., Palada de Vera, M.S., Bolivar, H.L., Velasco, R.R., Danting, J.C., Dionisio, E.E., Longalong, F.M., Reyes, R.A., Abella, T.A., Tayamen, M.M. & Eknath, A.E. 2012. Genetic improvement of farmed tilapias: Genetic parameters for body weight at harvest in *Oreochromis niloticus* during five generations of testing in multiple environments. *Aquaculture*, 338-341: 56–65. https://doi.org/10.1016/j.aquaculture.2012.01.027

Bentsen, H.B., Gjerde, B., Eknath, A.E., Palada de Vera, M.S., Velasco, R.R., Danting, J.C., Dionisio, E.E., Longalong, Reyes, R.A., Abella, T.A., Tayamen, M.M., Ponzoni, R.W. 2017. Genetic improvement of farmed tilapias: Response to five generations of selection for increased body weight at harvest in *Oreochromis niloticus* and the further impact of the project. Aquaculture, 468, 206–217. https://doi.org/10.1016/j.aquaculture.2012.01.027

Chiayvareesajja, J., Røed, K.H., Eknath, A.E., Danting, J.C., deVera M.P. & Bentsen, H.B. 1999. Genetic variation in lytic activities of blood serum from Nile tilapia and genetic associations to survival and body weight. *Aquaculture* 175: 49–62. https://doi.org/10.1016/S0044-8486(99)00034-4

Dey, M.M., Eknath, A.E., Sifa, L., Hussain, M.G., Tran, M.T., Nguyen, V.H., Aypa, S. & Pongthana, N. 2000. Performance and nature of genetically improved farmed tilapia: a bioeconomic analysis. *Aquaculture Economics and Management*, 4: 83–106.

Eknath, A.E., Tayamen, M.M., Palada-de Vera, M.S., Danting, J.C., Reyes, R.A., Dionisio, E.E., Capili, J.B., Bolivar, H.L., Abella, T.A., Circa, A.V. Bentsen, H.B., Gjerde, B., Gjedrem, T. & Pullin, R.S.V. 1993. Genetic improvement of farmed tilapias: the growth performance of eight strains of *Oreochromis niloticus* tested in different farm environments. *Aquaculture*, 111: 171–188.

Eknath A.E., Bentsen, H.B., Ponzoni, R.W., Rye, M., Nguyen, N.H., Thodesen J. & Gjerde, B. (2007). Genetic improvement of farmed tilapias: Composition and genetic parameters of a synthetic base population of *Oreochromis niloticus* for selective breeding. *Aquaculture*, 273:1–14. https://doi.org/10.1016/j.aquaculture.2007.09.015

Eknath, A.E. & Hulata, G. 2009. Use and exchange of genetic resources of Nile tilapia (*Oreochromis niloticus*). *Reviews in Aquaculture*, 1: 197–213. https://doi.org/10.1111/j.1753-5131.2009.01017.x

FAO, 2016. Global Aquaculture Production 1950–2016 [online]. Rome. http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en.

Gjedrem, T. 1985. Improvement of productivity through breeding schemes. GeoJournal 10 (3), 233–241.

Gjedrem, T. 1997. Selective breeding to improve aquaculture production. World Aquaculture, pp. 33–45.

Gjedrem, T. 2012. Genetic improvement for the development of efficient global aquaculture: A personal opinion review. *Aquaculture*, 344–349: 12–22. https://doi.org/10.1016/j.aquaculture.2012.03.003

Gjedrem, T. & Olesen, I. 2005. Basic statistical parameters. In: Gjedrem, T. (Ed.), Selection and Breeding Programs in Aquaculture. Springer, pp. 45–72.

Gjedrem, T., Robinson, N., Rye, M. 2012. The importance of selective breeding in aquaculture to meet future demand for animal protein: A review. *Aquaculture*, 350–353: 117–129.

Gjerde, B., Mengistu, S.B., Ødegård, J., Johansen, H. & Altamirano, D.S. 2012. Quantitative genetics of body weight, fillet weight and fillet yield in Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 242–243: 117–124.

Gupta, M.V. & Acosta, B.O. 2001. Networking in aquaculture genetics research. In: Gupta, M.V. & Acosta, B.O. Fish Genetics research in Member Countries and institutions of the International Network for Genetics in Aquaculture. ICLARM Conference Proceedings 64, ICLARM Contribution, 1614: 1–5.

Hussain, M.G., Kohinoor, A.H.M., Nguyen, N.H. & Ponzoni, R.W. 2011. Genetic stock improvement of the GIFT strain in Bangladesh. In Liu, L.P. & Fitzsimmons, K. Proceedings of the 9th International Symposium on Tilapia in Aquaculture, 22-24 April 2011, Shanghai.

Jamtøy, O. 2013. In: Aquaculture and development cooperation. NORAD seminar, 17 January 2013, Bangkok. Presentation no. 18, 25 pp. (also available at http://www.norad.no/en/about-norad/news/fiskeoppdrett(1).

Lind, C.E., Brummett, R.E. & Ponzoni,R.W. 2012. Exploitation and conservation of fish genetic resources in Africa: issues and priorities for aquaculture development and research. *Reviews in Aquaculture*, 4: 125–141.

Longalong, F.M., Eknath, A.E. & Bentsen, H.B. 1999. Response to bi-directional selection for frequency of early maturing females in Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 178: 13–25.

Lozano, C.A., Gjerde, B., Ødegård, J. & Bentsen, H.B. 2013. Heritability estimates for male proportion in the GIFT Nile tilapia (*Oreochromis niloticus L.*). *Aquaculture*, 372–375: 137–148.

Luan, T.D. 2010. Genetic studies of Nile tilapia (*Oreochromis niloticus*) for farming in Northern Vietnam: Growth, survival and cold tolerance in different farm environments. Norwegian University of Life Sciences (PhD thesis).

Maluwa, A.O. & Gjerde, B. 2007. Response to selection for harvest body weight of *Oreochromis shiranus*. Aquaculture, 273: 33–41.

Mather, P.B. & Nandlal, S. 2000. Progress towards providing Fijian farmers with a better tilapia strain: Evaluation of the GIFT fish in Fiji. Naga: *The ICLARM Quarterly*, 23: 46–49.

Nguyen, N.H., Ponzoni, R.W., Abu-Bakar, K.R., Hamzah, A., Khaw, H.L. & Yee, H.Y. 2010. Correlated response in fillet weight and yield to selection for increased harvest weight in genetically improved farmed tilapia (GIFT strain), *Oreochromis niloticus. Aquaculture*, 305: 1–5.

Ponzoni, R.W., Hamzah, A., Tan, S. & Kamaruzzaman, N. 2005. Genetic parameters and response to selection for live weight in the GIFT strain of Nile Tilapia (*Oreochromis niloticus*). *Aquaculture*, 247: 203–210.

Ponzoni, R.W., Nguyen, N.H. & Khaw, H.L. 2007. Investment appraisal of genetic improvement programs in Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 269:187–199.

Ponzoni, R.W., Nguyen, N.H. Khaw, H.L. & Ninh, N.H. 2008. Accounting for genotype by environment interaction in economic appraisal of genetic improvement programs in common carp *Cyprinus carpio*. *Aquaculture*, 285:47–55.

Ponzoni, R.W., Khaw, H.L. & Yee, H.Y. 2010a. GIFT: The story since leaving ICLARM (now known as The WorldFish Center). Socioeconomic, access and benefit sharing and dissemination aspects. Fridjof Nansen Institute Report 14.

Ponzoni, R.W., Khaw, H.L., Nguyen, N.H. & Hamzah, A. 2010b. Inbreeding and effective population size in the Malaysian nucleus of the GIFT strain of Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 302: 42–48.

Pullin, R.S.V., Eknath, A.E., Gjedrem, T., Tayamen, M.M., Macaranas, J.M. & Abella, T.A. 1991. The Genetic Improvement of Farmed Tilapias (GIFT) Project: the Story so Far. *Naga: The ICLARM Quarterly*, 14: 3-6.

Rezk, M.A., Ponzoni, R.W., Khaw, H.L., Kamel, E., Dawood, T. & John, J. 2009. Selective breeding for increased body weight in a synthetic breed of Egyptian Nile tilapia, *Oreochromis niloticus*: Response to selection and genetic parameters. *Aquaculture*, 293: 187–194.

Rosendal, G.K., Olesen, I. & Tvedt. M.W. 2012. Access to, equity and protection of genetic resources in Ghana: The case of tilapia (*O. niloticus*). Fridjof Nansen Institute Report 15.

Spring Genetics. 2016. Homepage. [Cited January 2016]. http://spring-genetics.com

Thodesen J. (Ma, D.Y.), Rye, M., Wang, Y.X., Yang, K.S., Bentsen, H.B. & Gjedrem, T. 2011. Genetic improvement of tilapias in China: Genetic parameters and selection responses in growth of Nile tilapia (*Oreochromis niloticus*) after six generations of multi-trait selection. Aquaculture, 322–323: 51–64. https://doi.org/10.1016/j.aquaculture.2013.02.010

Thodesen, J. (Ma, D.Y.), Rye, M., Wang, Y.X., Bentsen, H.B. & Gjedrem, T. 2012. Genetic improvement of tilapias in China: Genetic parameters and selection responses in fillet traits of Nile tilapia (*Oreochromis niloticus*) after six generations of multi-trait selection for growth and fillet yield. *Aquaculture*, 366–367: 67–75.

Tran, N., Amevenku, F., Crissman, C., Badjeck, M. & Delaporte, A. 2012. Ex-ante social and economic impacts of improved Nile tilapia *Oreochromis Niloticus* (Akosombo strain) in Ghana: an initial trade-off (TOA-MD) analysis and moving the impact assessment forward. Technical Report, WorldFish Center, Penang, Malaysia.

Trọng, T.Q., van Arendonk, J.A.M. & Komen, H. 2013a. Genetic parameters for reproductive traits in Nile tilapia (*Oreochromis niloticus*): I. Spawning success and time to spawn. *Aquaculture*, 416–417: 57–64.

Trọng, T.Q., Mulder, H.A., van Arendonk, J.A.M. & Komen, H. 2013b. Heritability and genotype by environment interaction estimates for harvest weight, growth rate, and shape of Nile tilapia (Oreochromis niloticus) grown in river cage and VAC in Vietnam. *Aquaculture*, 384–387: 119–127.

Trọng, T.Q., van Arendonk, J.A.M. & Komen, H. 2013c. Genetic parameters for reproductive traits in Nile tilapia (*Oreochromis niloticus*): II. Fecundity and fertility. *Aquaculture*, 416–417: 72–77.

WorldFish Center. 2007. Policy on the transfer of Genetically Improved Farmed Tilapia (GIFT) from Asia to Africa by the WorldFish Center. WorldFish Center, Penang, Malaysia.

CASE STUDY 4. IMPACT OF AQUATIC EXOTIC SPECIES IN THE PACIFIC

4.1 BACKGROUND

Numerous aquatic species have been introduced into the Pacific Island Countries and Territories (PICTs) for several reasons (both accidentally and deliberately). Some of the main reasons for the deliberate introduction of exotic aquatic species are:

- recreational fishing (e.g., rainbow trout into Papua New Guinea)
- biological control of certain pests (e.g., *Oreochromis mossambicus* into most PICTs)
- aquaculture (e.g., white-leg shrimp into most PICTs)
- ornamental/aquarium trade
- research purposes (e.g., various species of groupers into Palau).

Additionally, numerous species have been introduced accidentally, through ballast water, biofouling or as hitchhikers accompanying other introduced species.

The introduction of exotic species, including aquatic species, to new environments by human activities, both intentionally and accidentally, has been identified by scientists, environmentalists, governments and industry as a major and increasing concern. Marine bioinvasions, including via vessel-related vectors such as ballast water and hull fouling, have been identified as one of the four greatest threats to global marine biodiversity and ecosystems, and are a significant threat to coastal economies and even public health.

The potentially serious threats posed by introduced marine pests (IMPs), combined with the extremely high value and significance of coastal and marine resources to Pacific islands peoples, highlights the importance of vigilance regarding future aquatic introductions.

However, when it comes to the aquaculture sector, the contribution of exotic aquatic species has been of vital importance. More than 90 percent of the aquatic production of the Pacific region, both in volume (metric tons) and in value (USD) comes from exotic species, which were introduced for the development of the aquaculture sector in the region.

Four of the six main aquaculture species in the Pacific region have been introduced, by order of production in volume:

- Blue shrimp (*Penaeus stylyrostris*)
- Nile tilapia (*Oreochromis niloticus*)
- Red cottonnii algae (*Kappaphycus alvarezii*)
- Freshwater prawn (*Macrobrachium rosenbergii*)

Species were introduced in the past with very little precaution with regard to biosecurity. However, the current trend in most PICTs, is towards the strengthening of biosecurity legislation and policies in order to deal with animal health related issues, food safety standards and species introductions (export and import standards). Due to the relevance of the fisheries and aquaculture sectors in the region, the aquatic component is relatively strong in most of these regulatory frameworks.

Additionally, the following countries have developed and are beginning to implement national strategies on aquatic biosecurity: Papua New Guinea (PNG), Cook Islands, Solomon Islands, Tonga, Samoa and Fiji. These national strategies aim to standardize protocols for the deliberate introduction of aquatic species, and the measures in place to minimize accidental releases of aquatic species, including exotic aquatic pathogens.

Without any doubts, the region is and will continue to introduce exotic species for further development of the aquaculture sector. This will include, not only new species, but also new/improved strains and varieties of existing exotic species. For instance, several countries currently farming Nile tilapia, such as Fiji, Vanuatu, Samoa, Solomon Islands and PNG are considering the introduction of an improved strain of Nile tilapia (GIFT tilapia) from Malaysia. In line with new national biosecurity strategies, these introductions will be conducted based on researched and country specific import risk analysis.

Governments of PICTs have the responsibility of assessing benefits versus risks of aquatic species introductions. Management of introduced species must balance both costs and benefits with due consideration for the precautionary approach given at times the paucity of information on the topic.

This case study is focused on marine shrimp, Nile tilapia and red seaweeds, in order to illustrate impacts of exotic species in the Pacific aquaculture sector.

4.2 SEAWEEDS

Successful commercial production of seaweed in the Pacific region is presently based on one single species of red algae, the species *Kappaphycus alvarezii*, being cultured in the Solomon Islands, Fiji, Kiribati and PNG, the 4 main producer countries, with a total production for the region of around 20 000 tonnes (wet weight) and there are more than 10 000 families involved in the sector. This species was introduced from the Philippines and Indonesia to most PICTs during the 1980’s and 1990’s.

Other seaweed species that have been or are being evaluated within the region include the brown seaweed *Cladosiphon* sp., which is known to occur naturally in Tonga and New Caledonia. This seaweed was cultured quite successfully in Tonga for many years, but farming ceased in 2007 due to market difficulties. Other edible species, such as *Cladosiphon* sp., *Caulerpa* sp., *Codium* sp. and *Gracilaria* sp. are currently being grown in several Pacific Island countries in very low volumes (we could say almost anecdotally in most cases). Sea grapes (commonly known as sea caviar), such as the species *Caulerpa racemosa*, have been cultured in Samoa and French Polynesia since 2011 with promising results in terms of growth and survival rate.

Three principal farming methods have been tried in the Pacific Islands region: 1) off-bottom (fixed monofilament lines between posts driven into the substratum); 2) floating rafts (bamboo floating structure); and 3) floating long-lines (rope-made floating structure).

Commercial cultivation in Fiji, Kiribati, PNG and Solomon Islands consists almost entirely of off-bottom farming.

The Pacific Island region is environmentally ideal for seaweed aquaculture. Seaweed farming from this region is currently making a useful contribution to supplement other world sources. It is an important economic boost for the less-developed outer islands, where few alternative income-generating opportunities exist.

Moreover, there is a wide range of suitable habitats for seaweed farming in the region, but a number of limitations constrain production and export, including isolation and distance from markets, small volume of production, vulnerability to world price fluctuations, socioeconomic issues, and limited skills and capacities for culturing seaweed.

Seaweed production in Pacific Island countries, however, continues to contribute to income and provides employment for some people in isolated coastal areas, and there are plans to expand seaweed production to new countries such as the Federated States of Micronesia and Samoa.

4.3 MARINE SHRIMP

The introduction of marine shrimp for aquaculture into PICTs dates back to the 1970s and 1980s. In places like French Polynesia where aquaculture development efforts were the most intense and sustained during that period, there has been up to 13 species of marine shrimp introduced and a total of 26 introductions recorded. PICTs who have introduced marine shrimp and continue producing shrimp as a result include Fiji, French Polynesia, Guam, Hawaii, New Caledonia and Vanuatu. The two main species of shrimp currently cultured are *Penaeus stylirostris* and *P. vannamei*.

Production volumes are small by world standards with, in the last 10 years, the leading countries for volume and consistency being New Caledonia (1500–2000 metric tonnes per annum) and French Polynesia (40–120 metric tonnes per annum). Production in the remaining countries is only small (10–30 metric tonnes per annum) and limited by several constraints including: high production cost, competition from imported products, shortage of post-larvae supply, limited access to land, lack of technical capacity and insufficient private investment.

Given the scale of production, shrimp farming has limited direct environmental impact in the region except for some isolated cases associated with farm design. The record of *Farfantepenaeus merguiensis* in Fiji is the only known report of an introduced non-native marine shrimp becoming established in the importing country. The impact of *F. merguiensis* in Fiji is not known. There has been several cases of infectious hypodermal and hematopoietic necrosis (IHHN) being imported with introduced stock of *P. stylirostris* (Commonwealth of the Northern Mariana Islands, French Polynesia, Guam, New Caledonia) but these have had no lasting impact on the farming of this species which is naturally resistant to IHHN.

Even though the spread and scale of marine shrimp farming remains limited in the Pacific region, the sector plays important roles for food security, job creation and aquaculture advancement. With all PICTs importing shrimp from outside the region, there is an existing market and opportunities for domestic production to grow. Two main challenges exist for the expansion of shrimp farming in PICTs: increasing hatchery output and the development of a profitable technologies and techniques adapted to the constraints of the region.

4.4 TILAPIA

Freshwater aquaculture of tilapia has been prioritized by some Pacific island governments in response to pressing needs to produce more fish for food security. This is particularly so in the high-island countries of Melanesia and Polynesia with relatively large and growing human populations, that have sufficient land and surface water resources for pond aquaculture.

Tilapia was introduced over 50 years ago and is widely distributed in the Pacific region. Nile tilapia has biological traits that make it the best option for freshwater pond aquaculture in the Pacific, when compared with indigenous candidates like mullet or milkfish.

PNG is the leading Pacific country for tilapia farming with an estimated 60 000 tilapia farms in operation, mostly small-scale at household-level for food security. Fiji is next with around 500 farms, Samoa has 60 and Vanuatu around 30. Production of tilapia in the Pacific is difficult to estimate, due to the remote locations of many farms and the subsistence nature of operations with little incentive for record-keeping by farmers. A trend in recent years is emergence of a small but growing commercialized tilapia production sector at small-to-medium-enterprise level in peri-urban areas of Port Moresby, Goroka, Lae, Suva, and Apia.

There is no explicit evidence, or objective synthesis of information, to show that tilapias have brought about negative ecological impacts including loss of biodiversity in the Pacific region. Public perceptions about tilapia are generally positive. However the possibility of environmental consequences in the Pacific, including effects upon indigenous fish stocks, from introduced species such as tilapia, has received much less scientific attention than in Asia. Any concerns that are expressed about tilapia as an introduced exotic species in the Pacific mainly relate to knowledge gaps and application of the precautionary principle.

Tilapia will play an increasingly prominent role in the delivery of food and livelihoods in the Pacific, in a future where over-fishing, environmental degradation, and the projected impacts of climate change will continue to deplete an already depauperate indigenous freshwater fish fauna. Pond aquaculture of tilapia will become increasingly important due to the twin drivers of population growth and declines in coastal fisheries. This activity will be a beneficiary of the projected impacts of climate change so is one strategy for climate change adaptation. It is already playing a role in disaster resilience, such as in the aftermath of tropical cyclone Winston in 2016.

CASE STUDY 5. DEVELOPING AND DISTRIBUTION OF THE JIAN CARP (*CYPRINUS CARPIO* VAR. *JIAN*) IN CHINA

5.1 BACKGROUND

The Jian carp, *Cyprinus carpio* var. *jian*, was artificially bred in 1988 by the Freshwater Fisheries Research Centre of Chinese Academy of Fishery Sciences (FFRC) using integrated genetic breeding technologies.

The strain was officially approved in January 1990. On 30 October 1996, it was proclaimed as one of the first batch good strain with the serial number of GS01-004, with the announcement of the Ministry of Agriculture (No. 57). The strain has been therefore extended to 27 provinces, municipalities or autonomous region in China, providing considerable social and economic benefits (Zhang and Sun, 1996). The Jian carp is also one of the aquatic species included in the 11th Five Year Plan of China (2006-2010). In the ABS regime, the research institute developed the strain with support from the government. Indeed, Jian carp was included in extension plans of a number of provincial, municipal and county governments, following the national extension projects of “Eighth Five-Year Plan”. Two key elements have been essential to facilitate the access of the aquaculture farmers to the Jian carp strain: 1) information availability on the improved strain; 2) training programs for breeding farmers.

In a nutshell, the Jian carp was developed through a six-generation combined breeding program involving family selection, inter-lines crossing and gynogenesis. The breeding program started with individuals belonging to two distinct lines of *C. carpio* separated by high genetic differentiation. In detail, the Hebao red common carp (*C. carpio var. wuyuanensis*) was used as a maternal line whereas the Yuanjiang common carp (*C. carpio yuanjiang*) as a paternal line. The Hebao red common carp is original of the Wuyuan Jiangxi Province and characterized by orange color, short type, tender meat and small size. The Yuanjiang common carp is original of the Yuanjiang Yunnan Province and more similar to the wild species, showing black color, long spindle type, large size, tough meat. Four females of Hebao red common carp and four males of Yuanjiang common carp were initially identified to start the genetic improvement program.

5.2 INFORMATION SHARING AND DISSEMINATION

Jian carp was promoted by media, exhibition, international workshop, journals, television and radio programs, and regular training programs in the country. Among these initiatives, the publication of a cover advertisement on Scientific Fish Farming (the most popular magazine on aquaculture in China) in 1980 was particularly significant.

Jian carp breeding technology was also the object of many international academic exchanges between the FFRC and other institutions, laying the ground for the establishment of networks focused on genetic improvement.

5.3 TECHNICAL TRAINING, KNOW-HOW AND MARKET DEVELOPMENT

In the 1990s, the FFRC held more than 20 training courses to more than 4 000 people in Jiangsu, Liaoning, Gansu, Shandong, Anhui, Tianjin, Hebei, Guizhou and Ningxia. Through the training programs, the national Jian carp extension network was set up and included, among its main activities, the monthly publication of networking newsletters and the provision of consultation to the network members. This led to the establishment of a platform for expert advice, communication at network level and seed extension.

The extension of Jian carp has significantly contributed to the development of freshwater aquaculture in China and to reform the farming models. Jian carp became the major cultured aquatic resource in ponds, cages and paddy fields. The pond culture, for example, being characterized by two harvest period per year, improved significantly farm productivity and helping the majority of fishermen to get out of poverty.

The China Fishery Technology Extension Center and the provincial Fishery Technology Extension Station supported the introduction of Jian carp brooders from the FFRC to local hatcheries as well as the expansion of seed production and supply to farmers. The improved strain has been rapidly promoted throughout the whole country with the establishment of several breeding farms for seed production in the major producing provinces.

5.4 SCIENTIFIC RESEARCH

The contribution of scientific research to the improvement of germplasm quality was crucial. In terms of genetics, trait performance is the result of the interactions between the genotype and the environment. Therefore, maintaining the stability of certain desirable traits in successfully-bred strains is difficult without well-developed aquaculture bases and facilities.

In order to solve various possible problems in germplasm conservation and technical extension of Jian carp, scientists conducted research programs and formulated corresponding management specifications. In particular, targets of the scientific research have been genetic characterization, germplasm quality, development of standardized protocol for germplasm conservation and selective breeding of new strains.

Scientists conducted germplasm conservation at three different levels: 1) parental strains used for the development of the Jian carp, 2) improved strains and 3) fish seed. Among the three levels, the highest conservation priority was given to the parental strains.

Investments and efforts in scientific research resulted in the stability of Jian carp through generations.

5.5 PROMOTION OF SUSTAINABLE DEVELOPMENT

The Chinese government recognized great importance to the production of original and improved strains and to the protection of aquatic germplasm resources. Thus the National Committee for the

Approval of Original and Improved Varieties of Aquatic Animals was established with the aim of formulating regulations of responsible management if these resources. It further provided supports to the establishment of fish farms of original and improved varieties and organized some groundbreaking works in fish germplasm conservation. The sustainability of the research was achieved through joint efforts and close partnership between scientists and farmers. Supports from farmers included advices on best farming practices or provision of ponds and facilities for experiments and germplasm conservation. At the same time, the researchers assisted farmers towards the improvement of Jian carp quality and a good management of problems in farming practices. The close relationship between scientists and farmers has been crucial for the sustainable development of the Jian carp industry.

REFERENCES

Zhang, J. & Xiaoyi, S. 1996. Common carp hybrid and Jian carp culture, a textbook of Central Broadcast/TV University and Freshwater Fisheries Research Center.

CASE STUDY 6. ENABLING THE PRIVATE SECTOR: THE CHILE FOUNDATION

The Chile Foundation (FCh) is a private non-profit organization whose mission is to increase Chile competitiveness through the development of high-impact innovations and investment on human capital in order to promote and subsidize national economy. To this aim its work is focused on the development of local and international networks as well as on the delivering of high impact solutions in areas such as sustainability, human capital development, education, aquaculture, entrepreneurship, and foods.

Partners of the FCh are the State of Chile and BHP-Billiton-Minera Escondida.

Throughout its existence the foundation has become a “do tank”, fostering the creation of more than 65 companies in diverse productive areas at national level and promoting new industries and innovative products. The foundation has adopted the common national goal of delivering high-impact technological solutions through transference, research and development. This demanding task requires a joint-management with, among others, more than 160 international organizations, companies, governments and technological centres across 35 countries.

The FCh have been playing a leading role in aquaculture for 36 years. It has been a pioneer in the creation of the salmon industry, with the first salmon plant built in the country. In general, FCh has strongly contributed to the diversification of aquaculture in Chile and the development of technologies for aquaculture production of new native species with high commercial value.

The foundation has two experimental centres, in Quillaipe and Tongoy, which actively work on innovative development through the introduction of new species and the transfer of technologies and knowledge for the industry.

6.1 QUILLAIPE AQUACULTURE CENTER

The centre develops R&D projects and bioassays for the pharmaceutical, food, and aquaculture industry in general.

Located in the Quillaipe Experimental Centre, Aquadvise is the service provider offering bioassays services and consulting to over 30 national and international aquaculture supply companies operating in the pharmaceutical, food, and aquaculture industry. It counts on a qualified multidisciplinary staff trained in engineering, marine biology, veterinary medicine, aquaculture, economics, environment and nutrition.

6.2 TONGOY AQUACULTURE CENTER

The Tongoy Aquaculture Centre counts on modern infrastructures as well as R&D capacities oriented towards the commercial production of sea Bass (*Cilus gilberti*), sole (*Paralichthys adspersus*), hirame/olive flounder (*Paralichthys olivaceus*), yellowtail amberjack (*Seriola lalandi*) and razor clams (*Ensis macha*) in the northern part of the country.

The centre is also responsible for repopulation programs aimed at increasing the amount of resource available for catching. Additionally, the centre provides technical assistance to the industry in the following areas: massive production of warm water species; sale of certified Japanese oyster and northern scallop seed; creation of alliances for the development of qualification and post-graduate programs; and technological transfer.

Aquaculture Diversification program in Chile

The “Aquaculture of Sea Bass” project is a programme aimed at diversify Chilean aquaculture production through the farming of the native *Cilus gilberti*, the sea bass, a species with a high-demand on the global market.

In this view, FCh has leaded the establishment of a partnership between several stakeholders including universities, private companies and technology centres in order to support the development of a sustainable cultivation of this species.

The experimental activities finalized to the development of juvenile production technologies and subsequent fattening are carried out at the FCh Aquaculture Centre, based in the Tongoy Bay and in experimental farming centres owned by the Arturo Prat University and the Development Corporation of the Arturo Prat University, in Iquique.

The sea bass, in addition to a recognized high quality meat, has proved relatively easy to domesticate. The technological standards achieved are expected to further allow a sustainable production of this species in a large area of northern Chile.

Cultimar

Cultimar is a commercial hatchery located in Tongoy and belonging to FCh. It is dedicated to large-scale sustainable production of diploid and triploid Japanese oyster (*Crassostrea gigas*) larvae and seed. Also, Cultimar produces diploid and triploid scallop (*Pecten maximus*) seeds, molluscs seeds and microalgae.

The hatchery also offers technical assistance in mollusks and microalgae farming as well as technology training for bivalve mollusks production.

CASE STUDY 7. GENETIC RESOURCES MANAGEMENT POLICY IN IRAN (ISLAMIC REPUBLIC OF)

Iran (Islamic Republic of) is the second largest country in the Middle East and the seventeenth in the world. It is a land of diverse geological formations, climates, and soils, and a home to ancient civilizations, as well as being the origin of many agricultural genetic resources. Mountains and deserts cover more than half of the country's area. Iran (Islamic Republic of) has a 2 000 km southern coastline along the Persian Gulf and Oman Sea, and 700 km northern coastline along the southern shore of the Caspian Sea. The variation in precipitation and evaporation indicates a wide variety of climates within the country. Temperature can vary between –20 °C and +50 °C, while precipitation fluctuates from less than 50 mm to more than 1 200 mm/year. Overall, Iran (Islamic Republic of) is generally categorized as having arid and semi-arid climates.

7.1 BIODIVERSITY OF IRAN (ISLAMIC REPUBLIC OF)

From a biodiversity perspective, the country is located in the Palearctic realm at the crossroads of four biogeographical regions: the Euro–Siberian, the Irano–Touranian, the Nubo–Sindian, and the Saharo–Arabian regions. The variety of landscapes resulting both from a unique biogeography and from the physical and evolutionary processes operating across ecosystems and organisms, has produced a diverse selection of flora and fauna, including more than 1 300 species of fishes living in diverse freshwater, brackish water, marine, cave and qanat (man-made underground water channel) ecosystems and several other endemic and exclusive aquatic creatures. The north and west of the country, with many unique indigenous species of plants and vertebrates, are part of the Irano–Anatolian Biodiversity Hotspot, one of only thirty-five such areas recognized on earth. Moreover, recent molecular biology investigations have revealed that the biodiversity of Iran (Islamic Republic of) may even be significantly underestimated. Many of these genetic resources, because of their adaptation to an often harsh environment, may contain desirable characteristics such as tolerance to drought, salinity, heat or other biotic and abiotic stresses.

7.2 CONSERVATION OF BIODIVERSITY: A NECESSARY PRACTICE

With the current population growth rate and the demands on the utilization of the natural resources, there is increasing pressure on these resources. Several other factors contribute to the process of resource erosion, including long periods of drought, high pressure of grazing, urbanization, land degradation, etc. According to the estimations, 6 percent of the Caspian Sea fishes are critically endangered and 21 percent require immediate protection. All five Caspian sturgeon species, Caspian seal and several other aquatic species from Iran (Islamic Republic of) are in the red list of IUCN (International Union for Conservation of Nature); and many more are yet to be evaluated. Recent biodiversity loss in agricultural sector (plants, animals and macro-organisms) in Iran (Islamic Republic of) is largely related to the long-lasting dry seasons and human population growth, and the resulting increase in human activities. There is no doubt that Iran (Islamic Republic of) needs a new pathways to conserve its biodiversity and until recently there was no efficient strategy for conserving, assessing and utilizing the national genetic resources.

7.3 PROPOSED PLAN FOR GENETIC RESOURCES MANAGEMENT AND ITS OBJECTIVES:

Recently, through actions of the Agricultural Research, Education and Extension Organization (AREEO) a "National Law on Conservation and Use of Genetic Resources" has been ratified as a national framework for genetic resources management. The law is centered on the following objectives:

- to manage genetic resources;
- to conserve endangered species;
- to improve using capacities, facilities and technologies among stakeholders;

- to set regulations for access and benefit sharing, intellectual property rights and commercialization of genetic resources; and
- to establish national gene banks, both *in situ* and *ex situ.*

To this end, the Iranian Ministry of Jehad-e-Agriculture, Ministry of Health and Medical Education as well as the Department of Environment appointed a high level position to cover Conservation of Genetic Resources with related budget allocations. In terms of AqGR, a senior official within the Ministry of Agriculture is now responsible for identifying and gathering a “Board of Advisors” which is composed of representative high-level officials, private sectors, universities, researchers and research managers who provide professional advice in areas of policy, infrastructure and technical requirements. In addition, the Board will integrate and develop strategic approaches within their domains, in close collaboration with national authorities and international networks. Moreover, the Board may boost public knowledge using public media to identify the value of aquatic genetic diversity as a heritage of generations. Furthermore, it is expected that local communities, particularly fisheries cooperatives and societies, will provide support towards sustainable conservation, sustainable use and development of AqGR.

7.4 CREATING A FRAMEWORK FOR AQGR

Whilst the Iranian Fisheries Science Research Institute (IFSRI) is the main institution responsible for conducting research on country-wide aquatic systems and resources, it does not have legal authority to implement required actions to protect these systems and resources. Nevertheless, the current and forthcoming legislation has given and will grant an effective role to IFSRI to characterize and assess the natural stocks, and provide guidelines for sustainable utilization of the country’s aquatic resources and their rehabilitation. Recently, IFSRI has taken a crucial role as the main partner of a National Genetic Resources Protection Project to identify, prioritize and protect aquatic resources across country. In line with such initiatives, the first national live gene bank was established in 2011 for five species of surgeon at the Caspian Sea Sturgeon Research Institute in Rasht, in the north of Iran (Islamic Republic of). In addition to live specimens of different ages, sperm of several fish species are cryopreserved in a gene bank and some work has also cloned the growth hormone gene of Beluga in a molecular bank. Following successful establishment of sturgeon gene banks, IFSRI is planning to establish 14 gene banks for endangered and economic species over a five years period. As gene banks are highly dependent on financial support, the Advisory Board for AqGR is expected to provide sources, in addition to official support, to implement high priority actions in conservation, sustainable use and development of AqGR.

7.5 CONCLUSION

Iran (Islamic Republic of) is considered as a mega-diverse country. Recently, the Iranian parliament put a “National Law on Conservation and use of Genetic Resources” in its agenda to establish a national structure for genetic resources management. Under this law the Ministry of Jehad-e-Agriculture has to define appropriate directorial positions for conservation of genetic resources which receive specific budget allocations. An Advisory Board has been created with responsibility for managing AqGr and to set up regulations for access and benefit sharing, intellectual property rights and commercialization of genetic resources. The IFSRI has already established *in vivo* and *in vitro* gene banks of sturgeon in North and plans to establish 14 aquatic gene banks by 2023.

Aquatic genetic resources for food and agriculture play a vital role in contributing to global food security and nutrition, as well as sustainable livelihoods. FAO, in consultation with the Committee on Fisheries Advisory Working Group on Aquatic Genetic Resources and Technologies agreed on the need to develop this Framework to support countries in assessing their national capacities to conserve, sustainably use and develop their aquatic genetic resources of relevance for the aquaculture sector. The guidance within the Framework covers five main components: information and databases; governance, policy and planning; infrastructure and equipment; capacity building and training; and enabling the private sector. Each component contains a set of essential requirements that would need to be created or better developed. A number of annexes and case studies on specific topics are also included to provide further guidance on implementing the essential requirements under the different components.

ISBN 978-92-5-131093-9 ISSN 1020-5292

9 789251 310939

CA2296EN/1/11.18