1. Summary of the workshop

The Workshop on Status and Trends in Aquatic Genetic Resources: a Basis for International Policy, was convened in Victoria, British Columbia, Canada, from 8 to 10 May 2006 and attended by a small group of internationally recognized experts in the fields of aquaculture, biotechnology, fishery genetics, international development and international policy. The experts contributed scholarly reviews on the status of aquatic genetic resources and trends in their conservation and use in capture fisheries and aquaculture, and identified key policy issues, priorities and implications for the international development community in general and for FAO and the FAO Commission on Genetic Resources for Food and Agriculture (CGRFA) in particular.

Fish genetic resources (FiGR) comprise all finfish and aquatic invertebrate genetic material that has actual or potential value for capture fisheries and aquaculture. In capture fisheries, both inland and marine, more species are becoming endangered and more stocks overexploited. Aquaculture is expanding rapidly and now accounts for about 50 percent of the aquatic foods that are directly consumed by humans. Although genetic resources and technologies are playing a part in this expansion, they have not yet been used to extents comparable to their use in agriculture.

There is an urgent need to develop international policies for FiGR, and the breadth and complexity of capture fisheries and aquaculture present significant challenges to this process. Policies will need to address the differences between FiGR and other genetic resources, notably those for plants and livestock. These differences are due not only to the relatively recent domestication of most farmed aquatic species, but also to the large numbers of fished and farmed aquatic species and to the diversities of their aquatic environments (from the deep sea to small mountain streams) and of the production systems in which they are captured or farmed.

Policies will need to address current market forces from an increasing human population, increased environmental concerns, and improved efficiency of production and harvest. Other issues include information, management, risks and benefits, investments and awareness. Many issues here are common to both capture fisheries and aquaculture, and addressing these would benefit FiGR use and conservation in both. For example, there is a tremendous lack of information on the status and function of much of the world's FiGR. There are also, however, significant issues that are unique to a given source of fish production; for example, the growing investment opportunities in aquaculture and the problems of governance of capture fisheries in areas beyond national jurisdiction, especially in the deep sea.

Information on FiGR was identified as a key issue. At present, it is incomplete, scattered and unstandardized. For wide use, information on FiGR should be global, authoritative, free and objective.

Although tremendous progress has been made in the genetic improvement, genetic stock identification and genomics of aquatic species, much further work is needed:

- to assess the status of FiGR in capture fisheries and aquaculture;
- to improve the capacities of scientists, technical persons, governments and industry;
- to improve facilities for characterizing FiGR;
- to develop genetically improved farmed types of aquatic species;
- to develop appropriate policy instruments on use and conservation of FiGR;
- to improve general awareness and levels of knowledge about FiGR; and
- to prioritize species, geographic areas, and production systems on which to expend resources for conservation and use of FiGR.

The workshop participants agreed that further prioritization of activities and species on which to work will be required. Nonetheless the following were judged to be of major importance:

- establishing and maintaining a directory of FiGR information sources and databases;
- compiling information on the status of FiGR for important exploited and potentially exploitable aquatic species;
- training in risk analysis with respect to FiGR conservation and use;
- identifying national and local gaps in capacity with respect to FiGR conservation and use, including special and urgent needs;
- creating Technical Guidelines for the Management of FiGR in support of the FAO Code of Conduct for Responsible Fisheries and other international instruments;
- linking existing national facilities with specific expertise in FiGR management at a regional level and creating a directory of these facilities and other service providers for conservation, characterization, genetic analysis and genetic improvement;
- reviewing existing international, regional, and national policy documents concerning FiGR;
- increasing general awareness of FiGR among the general public, resource managers and policy makers; and
- developing case studies of successful genetic improvement programmes and fisheries management that have incorporated genetic principles.

2. Background of the workshop

In 1995, the twenty-eighth session of the FAO Conference[1] decided to extend the mandate of its Commission on Plant Genetic Resources to cover all components of biodiversity of relevance to food and agriculture. The result was the FAO Commission on Genetic Resources for Food and Agriculture (CGRFA), an intergovernmental body advising FAO on relevant policies and programmes. The FAO Conference recognized that approaches to plant, forestry, animal and fisheries genetic resources are different and require specialized expertise in each field, and that the implementation of the broadened mandate of the Commission should be step by step. The time has now come for the CGRFA to implement coverage of fish genetic resources (FiGR).

At its tenth session, the CGRFA agreed that its Secretariat, in cooperation with FAO's relevant services, should submit a Multi-Year Programme of Work (MYPOW) to its eleventh session so that the Commission could implement its full mandate in the medium and longer term, including work related to fisheries. The Secretariat was asked to prepare a document on the status of the resources and needs of the various sectors, including fisheries. In response, the Fishery Resources Division (now Fisheries and Aquaculture Management Division) of the FAO Fisheries and Aquaculture Department and the CGRFA, in collaboration with the World Fisheries Trust (WFT), convened this workshop of internationally recognized experts in the fields of aquaculture, capture fisheries, molecular genetics and genomics, the deep sea, international development and aquatic conservation in order to:

- review the status of trends of aquatic genetic resources and biodiversity in capture fisheries and aquaculture (see contributed papers section); and
- identify policy issues, priorities and implications for the international development community, and specifically for FAO and the CGRFA, with regard to aquatic genetic resources and biodiversity.

[1] ftp://ftp.fao.org/ag/cgrfa/Res/C3-95E.pdf

3. Report of the workshop

The term fish genetic resources (FiGR) means all finfish and aquatic invertebrate genetic material that has actual or potential value for fisheries and aquaculture, including culture-based fisheries that rely on release of hatchery-bred seed to the wild. FiGR thus include DNA, genes, gametes, individual organisms, wild, farmed and research populations, species and organisms that have been genetically altered by selective breeding, hybridization, chromosome manipulation and gene transfer. The value of such genetic diversity in food production systems and in ensuring the existence and evolution of natural populations has been well established. However, policies for managing these resources at the global level are generally lacking[2]. The report concerns almost exclusively FiGR, but farmed aquatic plant genetic resources such as seaweeds are mentioned where appropriate.

Although the CGRFA expanded its mandate to cover aquatic species in 1995, it has taken over a decade to begin to address relevant issues.[3] Workshop participants expressed a sense of urgency for the development of adequate policies for the sustainable use and conservation of FiGR. In both inland and marine capture fisheries, more species are becoming endangered and more stocks over-exploited.[4] Currently, about 50 percent of the aquatic foods consumed by humans come from aquaculture.[5]

FiGR are valuable not only because of their importance in aquaculture and the need to accelerate genetic improvement of farmed aquatic populations, but also because wild stocks are under threat and declining, and wild gene pools represent and ensure the continued survival of populations and species.

Although there are international and regional institutions and organizations that are contributing to addressing these problems (Table 1), there is no global strategy for the management — i.e. the conservation and use — of FiGR. Specific strategies are required for *in situ* conservation of FiGR on farms and in natural ecosystems, and for *ex situ* conservation of FiGR and as cryopreserved gametes or embryos.[6]

3.1 SPECIAL CHARACTERISTICS OF FiGR AND THE AQUATIC ENVIRONMENT

In 1995, the twenty-eighth FAO Conference recognized that different approaches are needed for managing plant, forestry, animal and fisheries genetic resources. The domestication of most of the aquatic species used in aquaculture has a much shorter history than the domestication of plant and livestock species in agriculture and there are many other unique features of the aquaculture and fisheries sectors with respect to conservation and use of genetic resources. The workshop identified the following special features of aquatic species and FiGR that should be considered in policy development:

- Most species of farmed fish have a relatively short history of domestication and genetic improvement.
- Some species of farmed fish have reproductive characteristics (very high fecundity and short generation times) that can facilitate rapid genetic improvement.

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[2] Pullin *et al.*, 1999.

[3] Bartley and Toledo, this volume; Pullin, this volume.

[4] Grant, this volume; Smith, this volume; FAO, 2004, http://www.fao.org/DOCREP/007/y5600e/y5600e00.htm

[5] FAO, 2006. State of World Aquaculture. FAO Fishery Technical Paper No. 500. FAO, Rome.

[6] Pullin, this volume.

TABLE 1
Some international and regional initiatives that address aquatic genetic resources in capture fisheries and aquaculture

Activity	Theme	Results
1985 International Association for Genetics in Aquaculture[1]	Genetic improvement in aquaculture	Numerous peer-reviewed publications and network of geneticists
1992 United Nations Conference on Environment and Development[2]	Sustainable use and conservation of FiGR, plus fair and equitable sharing of benefits	Legally binding International Convention on Biological Diversity; Agenda 21; Jakarta Mandate on Marine and Coastal Biodiversity; Cartagena Biosafety protocols
Development of Genetically Improved Farmed Tilapia (GIFT)	Use of traditional animal breeding and selection from a diverse gene pool to create faster growing and hardier fish for developing-country aquaculture	Successful, public-funded projects that produced GIFT and disseminated them in Asia and the Pacific to become the basis of national tilapia breeding programmes; the projects also developed capacity for national breeding programmes in Asia and Africa[3]
1993 International Network for Genetics in Aquaculture[4]	Enhancing research and developing collaborative linkages that could help establish national breeding programs	Facilitated development of fish breeding programmes, exchange of information, assessment of genetic improvement programmes and capacity building
1995 FAO Code of Conduct for Responsible Fisheries	Sustainable fisheries and aquaculture in an environmentally and socially acceptable manner	Soft law code used by FAO member States *et al.* for fisheries development and management; Technical Guidelines in support of the Code have been produced for many areas of capture fisheries and aquaculture - none yet for FiGR
1995 FAO Commission on Genetic Resources for Food and Agriculture	Inter-governmental body to formulate policies on genetic resources in, inter alia, capture fisheries and aquaculture	The Commission has not yet addressed FiGR
2001 FAO Committee on Fisheries Sub-Committee on Aquaculture[5]	Inter-governmental forum to address all issues relevant to aquaculture development and management; its parent body is the Committee on Fisheries	Provides advice to FAO Fisheries and Aquaculture Department, but has addressed FiGR so far only in general terms of sustainable use
2001 European Community Directives on GMO's[6]	Strengthening the legislative framework and risk assessment on the deliberate release of GMOs into the environment and the placing of GMOs on the market	Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms
2004 ICES Code of Practice on the Introductions and Transfers of Marine Organisms	Code on procedures and risk assessment for the introduction of alien species that also includes genetically altered organisms	Code of practice that has been adopted in principle by FAO and FAO Regional Bodies

[1] http://www.mediaqua.fr/IAGA/web/general_information/index.htm
[2] http://www.ciesin.columbia.edu/TG/PI/TREATY/unced.html
[3] ADB. 2005. An impact evaluation of the development of genetically improved farmed tilapia and their dissemination in selected countries. Asian Development Bank, Manila, Philippines. 124p.
[4] http://www.worldfishcenter.org/inga/network.htm
[5] http://www.fao.org/fi/body/cofi/cofiaq/cofiaq.asp
[6] http://europa.eu/scadplus/leg/en/lvb/l28130.htm

- The variety of aquatic species that are fished and farmed is very high.
- Fished and farmed aquatic species have very diverse life histories including, for example, short- and long-lived species.
- The wild relatives of farmed aquatic species are also important for future breeding programs in aquaculture.
- Some farmed aquatic species that escape from captivity can readily establish feral populations.

The workshop also noted that aquatic production systems, species and environments have the following special features:

- Production systems include not only conventional capture fisheries that target wild stocks and aquaculture that is based on farming captive-bred fish, but

also culture-based fisheries that are stocked from hatcheries and capture-based aquaculture in which wild-caught fish are fattened.
- Some aquatic species that are fished or farmed are used in recreational and ornamental fisheries.
- Some aquatic species and their wild populations are seriously threatened with genetic change or extinction.
- Distinct types of farmed aquatic species are generally less threatened, but become so as farmers choose to retain only the most recently developed and profitable.
- Some threatened and endangered fish species are being targeted by capture fisheries or taken as bycatch.
- The numbers of farmed aquatic breeds/strains/varieties and other types are increasing.
- Almost all aquatic species that are hunted and trapped in capture fisheries are wildlife, and are often regarded as common property resources.
- Capture fisheries may take place in open access environments or in areas not under national or international jurisdiction, e.g. high seas.
- Capture fisheries and aquaculture often impact and are themselves impacted by other users of natural resources, especially inland waters (irrigated agriculture/ domestic and industrial use), forestry, human settlements, tourism, and waste disposal.
- *Ex situ* and *in situ* conservation of FiGR are important, but can be difficult and costly.
- Aquatic environments in capture fisheries are extremely diverse, from the deep sea to mountain streams, and are also typically difficult to monitor.
- Aquatic environments in aquaculture range from highly controlled intensive recirculation systems to open water cage, pen, pond and raceway systems in fresh, brackish and marine waters and in most temperature zones.
- Aquatic environments in capture fisheries and aquaculture are often interconnected. in particular some capture fisheries take place in waters that are transboundary, international, and sometimes beyond the scope of any effective jurisdiction.

3.2 *DRIVERS* INFLUENCING MANAGEMENT OF FiGR

In order to develop appropriate policies on FiGR, key drivers influencing their management need to be identified. "Drivers" refers to trends that influence the conservation and sustainable use of FiGR. The workshop identified the following key drivers.

Driver 1: *Market forces*
- increased demand for food fish due to human population growth, increased affluence and the many health benefits of fish will increase pressure on farmed and wild populations;
- globalization and competition for markets within and among food production sectors will stimulate competition for aquatic resources and necessitate good marketing;
- competition for inputs, resources and space will force fish production to be more cost-effective and efficient; and
- consumer attitudes to some aquatic food production systems and to some new technologies (for example, genetically improved farmed fish and farming systems that are perceived as environmentally and/or ethically unsound) will constrain their adoption.

Driver 2: *Environmental issues*

- stagnation and decline of capture fisheries due to overexploitation and habitat degradation will force improved management in some cases and increase reliance on aquaculture or alternative foods in others;
- increased environmental awareness on the part of policy makers and the public will result in increased demand for sustainable use of fishery products;
- availability of fresh water will change in response to climate change and the needs of human population growth and development; and
- climate change will alter the potentials for capture fisheries and aquaculture in some areas and FiGR are the basis for sustaining the ability of aquatic species to adapt to changed environments, in nature and in farming systems.

Driver 3: *Production and management forces*

- alien aquatic species and genotypes will present opportunities (increased production and value) and problems (loss of wild biodiversity and habitat);
- because most capture fishery resources have been fully explored and there are few new species or areas available, better management of existing stocks or increased reliance on other food sources will be required;
- improved methods for fishing and farming will enable the sectors to expand;
- issues of sustainability have arisen in both capture fisheries and aquaculture and improved methods of fishing and farming are needed to sustain or expand production;
- scientific advances, particularly in the application of genetic technologies, including genomics, to capture fisheries and aquaculture, will provide opportunities for improved fish production;
- intensification of farmed fish production and harvest systems will produce more food per unit area and require improved breeds and management;
- access to FiGR, benefit sharing and intellectual property rights will influence use and policies; and
- increasing consolidation of farmed fish production systems with feed and seed suppliers is likely to have different effects on large- and small-scale producers.

3.3 *ISSUES* INFLUENCING MANAGEMENT OF FiGR

The breadth and complexity of the fishery and aquaculture sectors present significant challenges to the development of international policies on FiGR. Addressing the wide range of issues and special features of FiGR will take time and substantial human and financial resources. The mandate of this workshop was to present an unprioritized range of issues to the CGRFA. Prioritization of species on which to work, geographic areas, and production systems etc. Will be the work of future *fora* convened to develop specific details of the MYPOW or other programmes of work.

The issues presented below concern information, management, risks and benefits, investments, awareness, and policy. Some FiGR issues here are common to capture fisheries and aquaculture; for example, some wild FiGR of importance for both capture fisheries and aquaculture are being overfished. There are also important FiGR issues that are specific to either capture fisheries or aquaculture; for example, the difficulties of capture fisheries governance in high seas and areas beyond national jurisdiction, and the growing investment opportunities in aquaculture.

Issue 1*: Information (see also section 3.4)*

For both capture fisheries and aquaculture, there are gaps in information on the status of FiGR and on trends in their conservation and use. Information is often scattered, incomplete and not easily accessible. Genetic information about fish populations is often limited. Where population genetic data do not exist or are too expensive or difficult to

collect, especially in some developing countries, surrogate criteria and indicators can sometimes be developed to predict genetic stock structure or to identify genetically unique populations or strains. For example, within a given species, populations that exhibit different life histories, have different migration times, or inhabit different river basins can be expected to be genetically different.

In capture fisheries, lack of information about fish stocks leads to a lack of regulation and to illegal, unreported and unregulated (IUU) fishing. Information is increasing for a change to ecosystem-based management of capture fisheries, but the importance of FiGR and other genetic resources in ecosystem function are yet not well understood. Most important, existing genetic information on fish stocks is often simply not used in fishery management.

Issue 2: *Management of FiGR*
Capture fisheries and aquaculture share several FiGR management issues. Because of a lack of consensus on global priorities, fisheries development and conservation programmes remain largely divorced from FiGR management concerns. Ownership of and access to FiGR, and sharing the costs of FiGR conservation and the benefits from FiGR use, are also issues for both capture fisheries and aquaculture.

Management – i.e., conservation and sustainable use – of FiGR is often ignored in capture fisheries. This applies not only to the target species but also to key species for ecosystem function and to bycatch species, which are often more vulnerable to extinction than the target species. Capture fisheries can damage habitats, thereby endangering biodiversity, including marine mammals and seabirds. Capture fisheries can have particularly severe impacts on populations of slow growing or late maturing species.

In aquaculture, objectives of development or of assistance are often not clearly defined, resulting in confusion between farming for local food security and farming for export. The wild relatives of farmed fish have actual or potential value, and are often important as food sources in developing countries, so their stewardship must be adequately compensated. There are at present few international efforts to conserve the wild relatives of farmed aquatic species.

Issue 3: *Genetic risks and benefits*
Capture fisheries confront basic conceptual problems such as the definitions of "population" and "stock" – key concepts in the analysis of genetic risk. In aquaculture, there is a need for cost/benefit analysis of breeding programmes and genetic resources management. The use of alien species and alien genotypes in aquaculture and stocking programmes is unevenly regulated in developed and developing countries alike, and the consequent risks to wild and farmed populations are not quantified. Movement of stocks, introductions and transfers, and interactions between hatchery and wild stocks as a result of escapes or deliberate release have yet to be well analysed in terms of their risks to wild and farmed FiGR. To deal with biosafety issues, genetic risk assessment based on genetic stock identification, especially for culture-based fisheries and capture-based aquaculture, was identified as a high priority. Guidelines or codes of conduct on genetic resource management would be useful in addressing many of the management and risk/benefit concerns.

Issue 4: *Investments and applications*
FiGR conservation and use in aquaculture presents significant investment opportunities. However, genetic improvement strategies in aquaculture, from domestication and selective breeding to hybridization and other forms of genetic alteration, can be applied only where there are adequate resources, in terms of human and institutional capacities and prioritized funding. As aquaculture produces more of world's fish supply, the

value of FiGR for farmed and potentially farmable fish is increasing, but this has not yet been recognized in terms of increased investment in their management.

Issue 5: *Education and awareness*
In capture fisheries and aquaculture, decision makers often fail to appreciate the urgency to act before species or valuable stocks/strains go extinct. There is also widespread consumer ignorance of how food fish are produced, and most of the general public have no concept of FiGR.

Many capture fisheries professionals are also unaware of the importance of FiGR. In developed and developing counties, many fisheries policymakers and managers either do not know how to use genetic information when it does exist, or are unaware of its existence.

In aquaculture, professional awareness of the importance of FiGR is relatively high in the developed world and increasing in developing countries, but everywhere there is little public awareness about how farmed fish are bred and sometimes misinformation about the actual and potential applications of genetics in aquaculture (Liu, 2007).

Issue 6: *Policy instruments and mechanisms*
While policies on FiGR are lacking or inadequate for most capture fisheries, the problem is especially acute with deep sea fisheries. In aquaculture, advances in molecular biology and genetics are outpacing policy formulation for their application and regulation. Policies regulating use of FiGR and alien species/genotypes, when they exist, are often difficult to enforce. The genetic resources of farmed aquatic plants are a special case, as they are not yet adequately covered by existing instruments for plant genetic resources or as FiGR.

Capture fisheries and aquaculture in general lack adequate FiGR policy instruments, at international, regional, national and local levels. This reflects the ongoing inadequacies of efforts to document and to monitor FiGR and to provide for the sharing of costs for their conservation and of benefits from their use, especially for poor people. In developing countries, inadequate human capacity and infrastructure, including low capacity for risk assessment and management when using genetically altered forms, are especially acute. In general, policy formulation will need to balance a cross-sectoral, multidisciplinary approach (that addresses poverty alleviation and FiGR conservation) with more focussed approach to address specific topics, such as genetic improvement in aquaculture.

3.4 FiGR INFORMATION SOURCES AND NEEDS

FiGR information refers broadly to genetic characterization (e.g. genetic sequences and other measures of genetic diversity at individual and group levels), breeding histories, performance data, and behavioural and life cycle characteristics. Categories of FiGR information include: DNA; genes; gametes; individual organisms; wild, farmed and research populations; species; forms that have been genetically altered by selective breeding, hybridization, chromosome manipulation and gene transfer; and methods for genetic characterization, FiGR conservation, and genetic improvement.

For wide use by the Members of FAO and others, FiGR information should be global, authoritative, free and objective. At present, much FiGR information is incomplete, scattered and held in diverse formats. No existing databases give adequate coverage to FiGR or consolidate existing information, although there are some excellent information sources for specific topics; for example, FishBase[7] has good coverage of cytogenetics and some population genetics. The National Institutes of

[7] www.fishbase.org

Health of the United States of America maintains genomic databases on molecular genetics and bioinformatics.[8]

Current FAO datasets on capture fisheries and aquaculture, include very little information on FiGR. The FAO *Species Fact Sheets* on farmed aquatic species contain good information on taxonomic features and natural history, but coverage on their genetics is uneven and often lacking. As the number of farmed fish strains, hybrids, and other genetically altered forms increases in aquaculture, aquaculture statistics will need to capture their relative contributions to farmed fish production and value, as is done for livestock.[9] This would assist both conservation and use of FiGR. Similarly, fuller information on the genetics of wild fish populations would improve their conservation and use as FiGR for capture fisheries and aquaculture.

In order to initiate and develop its coverage of FiGR, the CGRFA can draw upon its long experience with plant, and to a lesser extent livestock genetic resources information that is of importance to FAO Member States for policy-making and management. FiGR information is held by diverse groups in the public and private sectors. The CGRFA will have to consider to what extent it might need to become itself a centre for FiGR information that FAO will collect and hold, as well as offering linkages with and portals into FiGR information sources collected and held by others. The latter, decentralized system already exists to a limited extent, but much existing FiGR information has limited accessibility because of non-standardized formats and terminology and its reliability and provenance are rarely well checked.

FAO fish production statistics, from capture fisheries and aquaculture, are standardized and represent official government information, but have almost no information regarding FiGR. For CGRFA coverage of FiGR, the use of other sources of FiGR information that are not the official reports of its Members should not be a problem, provided that information meets the criteria of authoritativeness and objectivity stated above.

The workshop appreciated that gathering, compiling and disseminating information on FiGR will require human and financial resources. Therefore, it will be necessary to convince the collectors and holders of FiGR information such as international, regional, national and local organizations, that their FiGR information is useful and that making it more widely available as part of FAO's global coverage of FiGR will be of mutual benefit. Provision of FiGR information and facilitating linkages to FiGR information sources will help the Members and partners of FAO to:

- fulfil obligations under international conventions such as Convention on Biological Diversity, FAO Code of Conduct for Responsible Fisheries (see previous footnotes), and the Convention on International Trade in Endangered Species of Fauna and Flora (CITES);[10]
- facilitate better management of their FiGR through shared information and experiences;
- improve the identification and traceability of aquatic produce;
- assist risk assessment associated with the movement of aquatic species and the use of genetically altered species;[11]
- secure funding and cooperation from donors and partners; and
- seek compensation for adverse impacts on FiGR.

[8] http://discover.nci.nih.gov/
[9] http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGA/AGA4.htm
[10] http://www.cites.org/
[11] Genetic alteration may be the result of a number of genetic technologies, including hybridization, selective breeding, chromosome set manipulation, genetic engineering and gene transfer.

4. Conclusions and recommendations of the workshop

Tremendous progress has been made in the fields of fish genetic improvement (Liu, 2007; Pullin, 2007), genetic stock identification (Grant, 2007; Smith, 2007) and genomics (Liu, 2007). The stage is clearly set for the creation of policies on FiGR that reflect this body of experience and anticipate future global needs, especially in view of the expansion of aquaculture and the decline in many wild aquatic populations. The FAO Fisheries and Aquaculture Department, CGRFA and partners will be expected to play major roles in this area over the next several years.

The material presented in this summary and in the following review papers represents scientific analyses of extremely diverse, complex and sometimes controversial topics. Policies for the management of the world's FiGR will depend on a variety of factors. Work plans of the CGRFA will need to reflect that variety. It is the workshop participants' hope and recommendation that other *fora*, including those organized by the CGRFA, will find this material useful for prioritizing areas for future work, in order to meet global development and conservation objectives. Prioritization will need to consider, *inter alia,* species, production systems, geographic coverage, risks and benefits associated with different technologies, consumer perspectives and ethics.

Pending this prioritization, the workshop participants recommended the following next steps toward developing policy instruments on the use and conservation of FiGR:

- assess the status of FiGR in fisheries and aquaculture;
- identify and fill regional capacity needs for scientists, technical persons, government and industry;
- improve facilities for characterizing FiGR;
- continue genetic improvement of farmed aquatic species;
- improve general awareness and knowledge of FiGR;
- assess existing FiGR policy instruments; and
- explore the twinning (i.e. co-planning, co-financing, co-governance) of aquaculture operations with conservation of wild aquatic genetic resources and related habitats.

These recommendations are elaborated upon below.

4.1 ASSESS THE STATUS OF FiGR

FiGR exist "*in situ* and *in vivo*" (as free-living, wild and feral populations, and as captive populations on-farm), "*ex situ* and *in vitro*" (as collections of cryopreserved sperm, embryos and other tissues/DNA), and "*ex situ* and *in vivo*" (as aquarium and research populations). Increasing the amount and quality of information on the status of FiGR could use updatable geographic information systems that incorporate genetic information, including diversity and abundance measures. A consultation on existing databases could be convened in order to assess their ability to incorporate this extraordinary diversity. Several good general information sources exist (Pullin, 2007; Liu, 2007; Smith, 2007), as well as specialized databases on key species, e.g. common carp, or groups of species such as Pacific salmon and tilapia. A directory of information sources and databases is needed, and establishing and maintaining such a directory could be suitable roles for the CGFRA and the FAO Fisheries and Aquaculture Department.

The status of important farmed aquatic species groups (including tilapias, carps, catfishes, penaeid shrimps, bivalves, abalones, seaweeds, and freshwater macrophytes) could be compiled, reviewed and synthesised. For marine capture fisheries, the most important groups include small pelagics, reef fishes, elasmobranches, large pelagics, demersals, and diadromous fishes. Important inland capture fisheries groups include those for many of the farmed species (such as carps, catfishes, characins, cichlids and salmonids), as well as many others described under the International Statistical Standard Classification of Aquatic Animals and Plants (ISSCAAP) scheme. With such a large array of species to study, clear prioritization and working through partnerships will be necessary. Documentation of the status of FiGR for these groups can link to other information sources such as FishBase,[12] the FAO cultured species fact sheets[13] and the FAO Species Identification Programme.[14] Work has already begun on summarizing the information available on salmon and trout genetic resources.[15]

4.2 IDENTIFY AND FILL REGIONAL CAPACITY NEEDS

Capacity building should be increased to include FiGR characterization and management, breed improvement, analysis of genetic data and training in risk analysis. Well-trained persons are already engaged in characterizing FiGR in fisheries and aquaculture (see, for example, the publications of the International Association on Genetics in Aquaculture (IAGA)[16] but they and their organizations merit more support to expand training activities. For example, training in risk analysis techniques would help those developing fish breeding programmes to making good choices of broodstock and genetic improvement techniques to meet their objectives surely and safely.

Regional networks can also play an important role in building and maintaining capacity and communication, e.g. Network of Aquaculture Centres in Asia and the Pacific (NACA),[17] and the International Network for Genetics in Aquaculture (INGA). The Southern African Botanical Diversity Network, funded by the Global Environmental Facility (GEF) to improve information and capacity on plants, could be a useful model for regions and organizations requesting support for FiGR. The Network of Aquaculture Centres in Eastern Europe (NACEE)[18] has recently been set up with support from FAO and could be expected to help address capacity building on FiGR, especially as capacity to improve and manage FiGR in carp and other freshwater species of commercial importance is well advanced in several member countries. Gaps in capacity should be examined on a geographic scale to identify any special regional and national needs.

FAO could consider creating Technical Guidelines for the Management of FiGR in support of the CCRF. Semi-technical manuals and scientific publications reviewing basic methods of breed improvement and methods of characterization and management of natural fish populations already exist and could be useful models.[19]

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[12] http://www.fishbase.org

[13] http://www.fao.org/figis/servlet/static?dom=root&xml=aquaculture/cultured_search.xml

[14] http://www.fao.org/figis/servlet/static?dom=org&xml=sidp.xml&xp_lang=en&xp_banner=fi

[15] Harvey, Brian in press FAO website.

[16] www.mediaqua.fr/IAGA/web/general_information/index.htm

[17] www.enaca.org

[18] http://www.agrowebcee.net/subnetwork/nacee/

[19] See for example Hallerman, E. 2003. Population genetics : principles and applications for fisheries scientists. American Fisheries Society, Bethesda, Md.

4.3 IMPROVE FACILITIES FOR CHARACTERIZING FiGR

New facilities in support of use and conservation of FiGR will not be necessary in all countries. Economies of scale are such that numerous small facilities analyzing small amounts of genetic material may not be economically justifiable. Improvements in transportation and communication are making collaboration among organizations cheaper and easier. Some existing facilities, together with the expertise of their staff, could be linked at the regional level. A directory of service providers for breed improvement, genetic characterization and genetic conservation could be created to facilitate access to expertise and technology and to prevent unnecessary duplication of efforts.

4.4 IMPROVE AWARENESS OF FiGR

Awareness of the importance of FiGR remains extremely poor and extends from the general public, to resource managers and through to policy makers. This is not altogether surprising, given the rapid developing state of development of genetics and its poor coverage in some school curricula, but it must be remedied as soon as possible. The first steps are to compile a list of target audiences that need specific information, then to identify appropriate channels and formats.

Part of the problem is the inability of many geneticists to communicate clearly about FiGR to the public and to professionals who are not geneticists. It was suggested that a workshop be convened to identify target audiences for learning about FiGR and to explore how best to reach them. This workshop could include participants from FAO, donors, government resource officers, Non-Governmental Organizations (NGOs), and other development groups. The International Development Research Centre of Canada has agreed to provide funding for such a workshop.[20]

FAO should consider including an article to increase awareness of the value of FiGR and specifically to discuss the necessity of reporting on breeds/strains/stocks/hybrids in the 2008 edition of the FAO flagship publication, *State of World Fisheries and Aquaculture* (SOFIA). If information on genetic resources is to be provided to FAO, then the FAO Fisheries and Aquaculture Department, with assistance from partners, will need to provide some standardization and guidance on appropriate terminology and reporting. The reviews listed under Status above can also be included in SOFIA and used to improve awareness of policy makers, various commissions, fishery managers, hatchery managers, farm managers, industry associations, NGOs, researchers and teachers.[21]

Case studies were proposed as a way of demonstrating the value of FiGR in fisheries and aquaculture. The Network of Aquaculture Centres in Eastern Europe (see footnote 18), the long-standing work on genetic improvement of common carp at the Fish Culture Research Institute in Szarvas, Hungary, and the well-established development, use, dissemination and management of common carp genetic resources in eastern Europe were suggested mechanisms and material for a case study. The history of the development and impact of the Genetic Improvement of Farmed Tilapia (GIFT)[22] was also suggested. Compilation of those fisheries that are managed at the genetic stock or strain level, and those farms or areas that report production by breed, would be useful in order to better understand the practicalities, costs and benefits of collecting information on FiGR.

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[20] The International Development Research Centre of Canada in collaboration with the World Fisheries Trust (Canada) subsequently convened a workshop, *Sink or Swim: Roundtable on Aquatic Genetic Resources,* Victoria, B.C. September 26/27, 2006. www.worldfish.org

[21] The United Nations General Assembly recently made a similar request that FAO should look a means to revise marine capture fishery statistics based on stock structure http://daccessdds.un.org/doc/UNDOC/GEN/N04/477/70/PDF/N0447770.pdf?OpenElement

[22] http://www.worldfishcenter.org/reshigh01_3.htm

4.5 ASSESS EXISTING POLICY INSTRUMENTS

Although FiGR are not well covered by most existing international, regional and national policies, any relevant policies that do exist should be appraised for their application to FiGR. Specific documents recommended for review were the FAO Code of Conduct for Responsible Fisheries (FAO, 1995)[23] the Cartagena Biosafety Protocols and their parent, the Convention on Biological Diversity (Secretariat CBD, 2000).[24] General documents on ownership, access and intellectual property rights should also be reviewed, especially the material transfer agreements and germplasm acquisition agreements currently used by INGA,[25] the Consultative Group on International Agriculture Research (CGIAR)[26] and others. Policy formulation will need to balance an holistic approach involving cross-sectoral and multidisciplinary policies on such issues as economic development, poverty alleviation and land use, with more specialized policies on FiGR that would address primarily fisheries and aquaculture, for example, public-private partnerships. The Convention on Biological Diversity develops work plans for types of ecosystems, e.g. inland waters, mountains, and deserts, whereas much of the work of FAO and the CGIAR centres is focused on geographic areas, climatic zones and specific commodity groups. The CGIAR centre with responsibility for capture fisheries and aquaculture is the WorldFish Center;[27] the CGIAR's Bioversity International[28] acts as a Member-Coordinator for a System-Wide Genetic Resources Programme, which includes some coverage of FiGR.

4.6 EXPLORE THE TWINNING OF AQUACULTURE OPERATIONS AND CONSERVATION

Aquaculture operations have usually had adversarial relationships with other uses of natural resources, especially nature conservation. This is to some extent unavoidable and it applies also in much of agriculture, forestry and other development. With aquaculture now in a rapid phase of growth, particularly in the developing world where most FiGR are also located, the time is ripe to explore to what extents aquaculture operations can be planned and conducted in harmony with nature conservation, including conservation of FiGR. Reconciliation between the needs of aquaculture operations and the needs of nature conservation is sorely needed. One approach could be to twin indefinitely the financing and conduct of aquaculture operations with those of nature conservation. This would mean setting aside conservation areas that are off-limits to aquaculture and to all contact with farmed fish and farm waters. Some potential sites for this already exist as nature reserves, sacred groves, etc. Similarly the practice of establishing aquatic protected areas is becoming a key part of capture fisheries management in many areas. For aquaculture production, the pay-offs would be not only the survival of threatened wild FiGR of present or likely future importance for breeding programmes, but also a platform from which to argue for permission to use, in designated farming areas, the most profitable species and genetically altered farm types available — as is the case for most of agriculture.

[23] http://www.fao.org/figis/servlet/static?xml=CCRF_prog.xml&dom=org
[24] http://www.biodiv.org/biosafety/default.aspx
[25] http://www.worldfishcenter.org/inga/
[26] see for example http://www.ciat.cgiar.org/improved_germplasm/mta_breeding.htm
[27] www.worldfishcenter.org
[28] www.bioversityinternational.org